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Morphological Variations in a *Plexaurella* species over a depth gradient.

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Excellent job

ABSTRACT:

At Discovery Bay, Jamaica gorgonians occur over a broad depth range. Variations in microhabitat over depth may influence the structural make-up of these colonies. This study examined morphological differences in the gorgonian *Plexaurella* (species unidentified) over a depth gradient of 20 to 50 feet. Current surge was estimated via the plastic bag method described in Cheston (1979). Height, width, and basal circumference of 31 colonies (16 at 20 feet, 15 at 50 feet) were measured in situ with a flexible measuring tape. Eleven samples (6 from 20 feet, 5 from 50 feet) were examined in the laboratory and polyp and spicule size and density were calculated. Height and width were significantly higher in the shallow water as were polyp density and spicule density (~~Mann-Whitney U~~ Students't test, $p < .001$, $p < .05$, $p < .1$, $p < .02$ respectively.) Circumference, polyp size, and spicule size distributions did not vary significantly between the 2 sites. We attribute the morphological differences to variations in current surge and, to a lesser degree, light intensity.

Interesting results

INTRODUCTION

"The gorgonians of the West Indian reefs comprise one of the most conspicuous and characteristic components of this shallow water community. The diversity and abundance of these forms in the tropical western Atlantic is unrivaled anywhere else in the world."

- Kinzie, 1970.

Discovery Bay on the northern coast of Jamaica offers a unique opportunity to examine gorgonian communities. These soft corals (Cnidaria, Octocorallia) are prevalent and abundant elements of the coral reef community. As studied by Kinzie (1970), gorgonians are found over a broad depth range [0 - 45 m]. Since the microhabitats vary considerably over this range, the morphology of gorgonians should reflect these variations in environmental stresses. In particular, Kinzie noted light, substratum, and current / surge strength influence structural parameters in the soft corals. Many of these adaptations are slight morphological changes.

The bulk of previous research has focused on sea fan orientation and growth forms (Grigg, 1972; Cheston, 1979; Russo, 1985). Grigg (1972) noted differences in branchlet diameter and spicule length related to the gorgonian's adaptations to shallow water motion. In Cheston's (1979) study, trends in greater spicule density at shallower depths were observed. Based upon

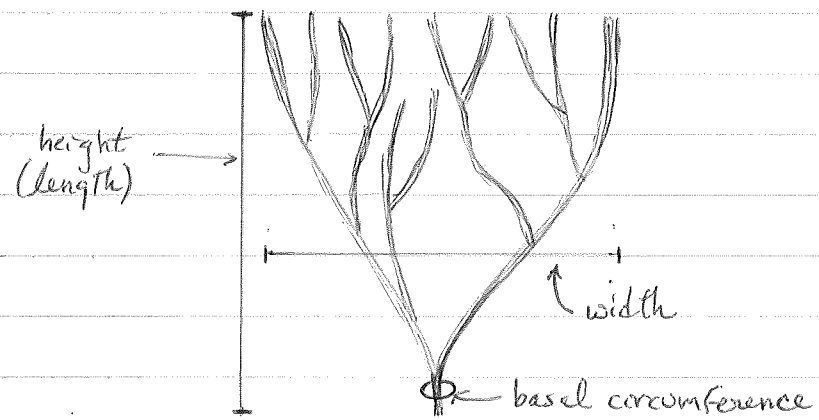
these previous observations and implications, we hypothesized that a "cousin" sea whip species would demonstrate similar morphological differences between shallow and deep water individuals of the same species.

For our study, we chose an unidentified <u>Plexaurella</u> species. The gorgonian was planar and branching with purplish pigmentation and a knobby polyp covering. Specifically, we investigated the colony orientation and dimensions (height, width, basal circumfence), spicule density, and polyp size and density at a shallow depth (20') and a deep depth (50').

Methods –

Measurements were carried out between March 3 and March 8, 1987 with the aid of SCUBA equipment. Fifteen colonies of an unidentified purple Plexaurella species were examined at the deep site and sixteen colonies at the shallow site. A flexible measuring tape was used to measure height, width, and basal circumference of each colony (Figure 1).

Figure 1: Representative colony of Plexaurella with measurement definitions.



General orientation to the current (perpendicular, parallel, or at a (±)45° angle) was also noted. Current direction for this purpose was determined from the prevailing motion of nearby gorgonians.

Five samples from the deep site and six from the shallow site were brought back to the laboratory to examine polyp size and density and spicule size and density. Only one branch from each colony was sampled (by cutting with a dive knife) to minimize disturbance to the gorgonian. Samples were maintained in the sea water table of the Discovery Bay Wet Laboratory to minimize deterioration.

Samples were analyzed within 12 hours since deterioration occurred beyond that point. Cheston (1979) reports similar time constraints.

Polyp density was quantified by counting the number of polyps on a 5 cm long segment of branch. The circumference of the segment was then measured, and the number of polyps per cm^2 was calculated. So as to minimize effects occuring at the growing tips, all polyp and spicule measurements were taken 2 cm from tips. (e.g. Polyp density was calculated over a 5 cm segment between 2 and 7 cm from the tip.) On each colony 20 polyps were measured by means of a micrometer mounted on a dissecting scope, 1 micrometer unit corresponding to 2.40 mm.

Wide polyps [illegible]

In order to quantify spicule size/density, we prepared a slide with a 1 cm x 1 cm sampling chamber. The walls of the chamber consisted of clay and were of sufficient height to contain several drops of Clorox. For each of the eleven samples, a $1 mm^3$ piece of the outer coenenchyme was placed within the chamber and the Clorox added. The sample then sat undisturbed for 30 minutes so that all of the non-calcifeous tissue dissolved. We stirred the sample gently in order to randomly distribute the spicules without breaking them. Using a compound microscope at 100x magnification, we then counted the number of spicules in 10 fields of view, dividing the spicules into size classes as follows: 0-1 micrometer units, 1-2 units, and 2+ units (1 micrometer unit = 0.60 mm).

Wave surge was estimated as described in

Cheston (1979). Twenty replicates were done at each site on March 7, 1987 using a water-filled plastic bag (22.5 cm by 17.5 cm) attached to a 50 cm string. We recorded the time required to extend the bag from a contracted position to the end of the string. The standard deviation of the 20 readings is taken as a measure of wave surge — a small standard deviation corresponding to unidirectional current flow with little surge, a large standard deviation corresponding to greater surge. The mean time to extend the bag is an indicator, although a very weak one (because it is related to surge), of unidirectional flow.

As a second indication of surge, we observed the motion of four individuals at each site and recorded the number of passes past vertical within 1 minute. Both procedures are described further in Cheston (1979).

Data was analyzed by means of t-tests and Mann-Whitney U tests between the 2 sites.

SITE DESCRIPTION —

Two sites within the typical depth range of our Plexaurella species were chosen along the East Fore Reef (EFR) of Discovery Bay, Jamaica. The deep site was located 50 m north of the EFR mooring at a depth of 50'. This area is characterized by distinct buttresses which are separated by 20 to 25 foot sand channels running east west. Along these buttresses, diversity of hard corals and gorgonians was much greater than within the sand channels themselves. The gorgonian samples were taken from the buttresses.

The shallow site, at a depth of 20 feet, was located

approximately 150 m south of the EFR mooring. This area is characterized by flatter buttresses than were found at the deep site. Sand channels generally run east west, but again are less distinct at this site. Finally, gorgonians seem to have a more patchy distribution here.

RESULTS

Current strength and wave surge differences between the deep and shallow sites were established to show environmental force differences. The standard deviations of the (plastic bag extension method) mean times of extension was much greater at the shallow site (16.90 ± 8.90s) than at the deep site (10.25 ± 1.71s). Also, the number of passes past vertical was significantly greater at the shallow site than at the deep one (student's t-test, $df = 6$, $p < .02$) (table four).

Mean height and mean width were both significantly higher at the deep site (Mann-Whitney U, $n_1 = 16$; $n_2 = 15$, $p < .05$ and $p < .05$, respectively). However, circumference did not vary significantly between the two sites (Mann Whitney U, $n_1 = 16$; $n_2 = 15$, student's t-test) (Table one). Mean length to width ratios were 1.69 ± .73 (20') and 2.57 ± 1.38 (50'). These values were not statistically different (Mann-Whitney U, $n_1 = 16$; $n_2 = 15$; student's t-test, $df = 29$).

Polyp density tended to be higher at the shallow depth, but was only marginally non-significant (Mann-Whitney U, $n_1 = 5$, $n_2 = 5$, $.05 < p < .1$ a value of .72 (p is p=.05)). Polyp size remained constant (Mann-Whitney U, $n_1 = 5$; $n_2 = 6$) (Table two).

We found a higher spicule density at the shallow site (Mann-Whitney U, $n_1 = 6$, $n_2 = 5$, $p < .02$), but there were no differences in size class distributions between the

two sites (G-test, df = 2, NS) (Table three).

As a general observation, we noticed that 10 of the 16 colonies sampled at 20' were perpendicular to the current whereas 13 out of 15 were perpendicular at 50'.

Was current direction constant at both depths?

Table one: COLONY DIMENSIONS

	SHALLOW (20') n=16	DEEP (50') n=15	p value
height*	24.7 ± 14.1 cm (7-63 cm)	56.4 ± 25.4 cm (30-121.5 cm)	$p < .001$
width*	16.4 cm ± 9.2 cm (2-35 cm)	26.7 ± 15.3 cm (9-59 cm)	$p < .05$
circumference	4.5 ± 1.0 cm (3-6.5 cm)	5.1 ± 1.6 cm (3-9 cm)	NS

Table Two: POLYP SIZE and DENSITY (1 unit = 2.4 mm)

	SHALLOW (20') n=6	DEEP (50') n=5	p value
density	34.7 polyps/cm² ± 9.0 (25.4-46.0)	24.2 polyps/cm² ± 9.0 (16.0-36.0)	marginally NS ($p < .1$)
size	1.80 units ± .310 (1.50-2.39)	1.87 units ± .204 (1.62-2.12)	NS

Table Three: SPICULE SIZE DISTRIBUTION (1 unit = .6 mm)

	Number of Spicules / 10 fields of view (21.12% of sampling chamber)		
size class	SHALLOW	DEEP	p value
0-1 units*	415 ± 73.4 (336-551)	304.4 ± 37.0 (251-324)	$p < .02$
1-2 units	16.7 ± 7.8 (8-30)	23.4 ± 8.2 (17-37)	NS
2+ units	11.2 ± 5.3 (1-10)	13.2 ± 5.1 (1-15)	NS
TOTAL*	443 ± 65.9 (376-568)	341 ± 35.6 (286-375)	$p < .02$

* denotes significance

Table Four: CURRENT MEASUREMENTS

	SHALLOW (20')	DEEP (50')	p value
"Plastic Bag" Method (mean time)	16.20 ± 8.90s n = 20	10.25 ± 1.71 s n = 20	$p < .01$
# Passes Vertical Method (mean #)	8.88 ± .63 n = 4	6.75 ± .5 n = 4	$p < .02$

DISCUSSION -

Our results indicate that there are indeed morphological differences over a depth gradient in the Plexaurella species we examined. This is expected as microhabitat varies considerably over depth with regard to wave surge and light intensity. Although general shape of the colony, indexed by mean height/width ratio, does not vary significantly, the size of the colony is significantly smaller ($p < .05$) in the shallow water. Russo (1985) reports a similar decrease in size with increasing depth in the sea fan Eunicella cavolinii. We attribute the change in colony size to the variations in water movement at the different depths. In our own surge measurements, both with the "plastic bag method" and with the "number of passes past vertical method," we demonstrated a greater surge at 20 feet than at 50 feet. Our measurements may seem somewhat crude; however, theory predicts and Russo's study (1985) has supported a similar, but exponential, decrease in wave oscillation with depth. Kinzie (1970) acknowledges the significance of oscillation on gorgonians in Discovery Bay especially at depths less than 10 m.

It seems intuitive that colony size may be somehow restricted in more turbulent water. The stress on a small colony should be less (than that on a larger colony) because of its smaller surface area. This difference in surface area may not be as important in deeper water where surge is low; however, in shallow water, which has high surge and is more prone to disturbance from storms, surface area may indeed be an important factor — a higher surface area perhaps resulting in a greater probability of mortality due to toppling. Wahle (1985) has demonstrated an increase in injury with gorgonian colony size on Jamaican coral reefs.

Kinzie (1970) reports stronger water movement to be the main cause of mortality among deep water species when they are transplanted to shallow water.

Since basal circumference remains constant and colony size (height and width) decrease between 50 feet and 20 feet, there is a lower size of colony/circumference ratio in shallow water. This suggests that similar amounts of support are necessary to maintain smaller colonies at shallower depths, and this may support the idea that surface area is an important factor in more turbulent habitats. Again, we attribute this morphological difference between the colonies at the two sites to differences in wave surge.

The proteinaceous core of Plexaurella is a further component of its support system. We were unable to compare core diameter, however, because we did not sample colonies at the bases. Variation in core diameter within an individual, even along 10 cm segments of branches, was quite high; therefore, we did not feel that core measurements at areas other than the colony base would allow us to draw any valid conclusions.

Since we performed no statistical tests on the orientations of the colonies, we are restricted to discussing general trends. Overall, our study supports the findings of numerous other (Russo, 1985; Wainwright and Dillon, 1969 cited in Kinzie, 1970; Riedl, 1972 cited in Russo, 1985) that the plane of the gorgonian colony is usually oriented normal to the wave surge. It is uncertain whether this orientation is related to hydromechanical properties of the colony which may enhance zooplankton capture or to waste removal from and nutrient availability to the polyps (Russo, 1985). Grigg (1972) provides other explanations involving the mechanical

stability of planar organisms and reduction in tissue damage due to twisting and/or abrasion.

Because our results indicate that an orientation normal to the current is more prevalent at 50 feet than at 20 feet, we suspect hydromechanical properties may be responsible. At 20 feet zooxanthellae may play a more important role (and zooplankton capture a lessen role) in gorgonian nourishment than at 50 feet; therefore, lowered filtering rates and the occurence of refiltration due to a less than optimal orientation would be of smaller consequence at 20 feet and may be found more often. Theoretically, any orientation would be appropriate for zooxanthellae photosynthesis. Location, in the sun versus the shade, would be more of a constraint.

However, if surge is not entirely bi-directional, but rather comes from many sides as may occur during storms, any of the above explanations may be responsible for the differences in orientation with depth. A more detailed study of wave oscillation in the 2 sites might provide some insight.

If current direction is variable at 20', then you might not expect all individuals of the gorgonian to orient the same way.

Transplant experiments of deep water gorgonians to shallow depths have demonstrated an increased composition / production of colored spicules (Kinzie, 1970). Within twelve days, the Gorgonia mariae colonies that were moved from 30 m to 1 m showed this adaptation to the change in light levels. Our observation of the Plexaurella species at the two depths did not reflect the same finding. There was no difference between the relative density of large pigmented spicules found at the shallow site compared to the deep site density. Since 70-80% of the incident light is attenuated in the first 10 m of water and only 30-40% of the remaining light is reduced between 10 m and 30 m, the pigmentation level and the colored spicule density at our shallow depth may not be readily distinguishable from the deeper depth data. More exact measures of spicule composition (ash weights) could not be determined in our study because of the lack of a working furnace at DBML.

Another aspect of Kinzies transplant experiments examined the changes in spicule form. Not only were the new spicules colored, but they also were non-typically shaped. He noted that the spicules resembled a closely related shallow water gorgonian's spicule shape. This result indicates a shallow water enviromental pressure to supplement the structure with specialized spicules. Grigg (1972)

also mentions a change in spicule length with varying depth in sea fans. Our observations show greater [~~numbers of~~ total] spicule density (all size classes) in the shallow water colonies. This difference arises from the number of smallest size class (0-1 units = 0-.6 mm) spicules. We surmise that the shallow depth gorgonians of our study use this particular type to fortify their structure. Pigmented spicules (uv protection) perhaps are not as important an energy investment as these smaller spicules.

unclear

There were three basic types of spicules observed in our study. The smallest ones ranged from 0~.6 mm and were stout. The intermediate size class consisted of rod-shaped (.6 mm - 1.2 mm) spicules with pointed projections. Both of these types were transparent. The largest spicules (1.2 mm plus) were opaque but of the same general shape as the intermediate class. Structural strength and pigmentation/protection of the gorgonian are derived from the combination of these components. Water-soluble pigments in the coenenchyme also probably afford the soft coral uv protection.

Related to the light and uv exposure are the gorgonians' polyps containing many of the symbiotic zooxanthellae. Kinzie (1970) suggests that

most gorgonians derive a large portion of nutrients from their zooxanthellae. Therefore, light exposure and polyp size and density are important to the colony's nutrition. Further study by Preston and Preston (1975) correlated polyp extension with light intensity and plankton availability. They also observed a variable dependence on zooxanthellae from species to species. Since dependence on zooxanthellae may change with depth and decreased light intensity, a change in polyp size and density may compensate for this change and/or reflect this variation. Our results do not demonstrate any significant differences in polyp size or density between the shallow and deep sites. However, there seems to be a trend toward greater polyp density at the shallow depth. Porter (1976 cited in Cheston, 1979) offers an explanation of greater polyp density and smaller polyp size at shallow depths relating the two parameters to zooxanthellae and light capture. No other litrature could be found relating polyp size and density in cnidarians to zooxanthellae.

In summary, colony size increases with depth and spicule density decreases while spicule size distribution and polyp

size remained relatively constant. Polyp density varied marginally. Orientation at both sites was generally normal to surge.

Obviously, our small sample sizes could contribute to large sources of experimental error and skew our observed results. Other problems with our project arose from difficulties identifying ~~speciating~~ our gorgonian to species both in the field and in the lab. (Spicule shape is the preferred method of determining species.) The limited resource material on gorgonian species also hindered our efforts.

An interesting offshoot to this study could examine the spicule composition of different parts of the colony. Literature suggests a higher density at the base area than at the branch ends or growing tips. Also deeper colonies could be included for greater variations in morphology. A very ambitious student may be interested in a similar study to Kinzie's zonation work. Community assemblages of gorgonians (species diversity, dominant morphs and species) at different depths and sites would be a great project. In general, the gorgonians are a relatively ~~scarcely~~ poorly studied organism with remarkable potential for investigation.

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