COSMOPOLITAN CHITONS

A Study of Movement Patterns in *Acanthopleura granulata* and Phototacticity in *Chiton tuberculatus*

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March 6, 1984
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Abstract:

Chitons, a primitive molluscs, are common in intertidal regions of Discovery Bay, Jamaica. This study involves following movements of individual marked chitons to determine movement patterns and homing behavior. *A. granulata* exhibits homing behavior; however its movement patterns with respect to time and tides cannot be conclusively determined. The response to light by another species, *C. tuberculatus*, is also studied and found to be negatively phototactic.

Introduction:

A skin dive in the lagoon on the west back reef of Discovery Bay, Jamaica will reveal many interesting marine organisms, not the least of which are the chitons. Though not brightly colored or quick moving as are the fish which share this environment, these members of the phylum Mollusca have a mysterious attraction all their own. Unnoticeable at first, it is necessary to swim very close to the rock walls in order to view the inconspicuous chitons which cling to the rocks near the surface. Although I had entered the lagoon to observe the abundant fish populations, I became more fascinated with the subtle intrigue of the chitons. I knew next to nothing about these creatures except that they seemed reminiscent of limpets which I had seen many times at the beach. A quick look into a marine life book revealed some interesting facts, however a lack of complete information was even more provoking.

Chitons, class Amphineura, sub class Polyplacophora, (which means bearer of many plates) are considered to be the most primitive of the molluscs. Most species live in intertidal and shallow water areas although some may be found at greater depths. Chitons feed on algae, scraping it from rock surfaces with their well developed radula. Generally, they may hide in rock crevices by day and feed at night however some feeding patterns have been correlated with tide schedules as well (George, D. & J. 1979). Another source indicated that most species are more active at night, motionless at low tide, and move to feed when the rock surface is submerged or splashed (Barnes, 1980).

Depending on the species, they may move according to time, tide or a combination of both. Aside from this certain schedule of movement, some species exhibit homing behavior, an amazing fact considering their primitiveness.

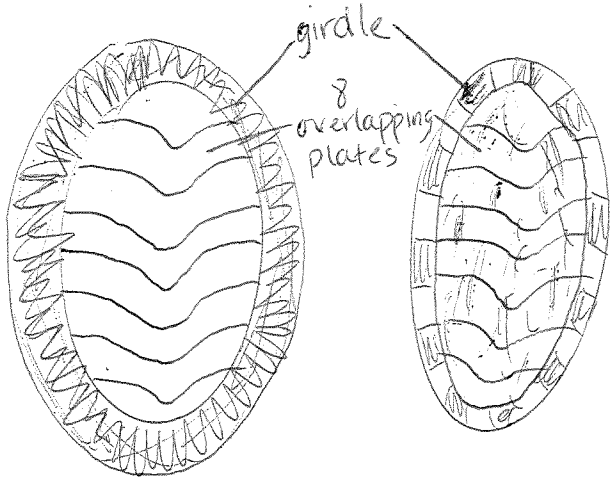
Since no study on chiton movement behavior had been done here at the marine laboratory, I thought it would be interesting to find out if the species here did indeed 'home'. Although chitons are sluggish and may remain in one area for a long period of time (in one reported case an individual remained in one place for three weeks!) I did not let this deter me as I had seen movement in a few preliminary observations. I decided to try to mark individual chitons and record their movement patterns over a certain period of time. In this way I could gather information concerning the presence of a homing pattern and perhaps diurnal or tidal cycles of movement.

In addition, during preliminary night observations of dock wall chitons, I noticed increased movement under direct light. They appeared to move down into the water when a flashlight was shone on them. Further research indicated that many are negatively phototactic and tend to locate themselves under rocks and ledges during the day. I therefore hypothesized that there would be fewer chitons appearing on the wall at night if lights were present than if no light was present.

Study Site:

I used two different study sites both located at the Discovery Bay Marine Laboratory in Discovery Bay, Jamaica. The first is a limestone rock island, approximately 10 m. slightly northwest of the laboratory dock. It has 5 faces, is about 1.5 m. across and is characterized by many sharp protrusions and hollowed-out crevices. (fig 2). This site was chosen due to its relatively easy-accessibility and isolated population of chitons (surrounded by water). The species at this site is *Acanthopleura granulata* (fig 1).

The second site is the cement wall of the dock extending from the east end, continuing for about 5 m. It is located next to a large group of limestone rocks and has a proliferating algal growth. *Chiton tuberculatus* is the species found at this site.



a. Acanthopleura granulata b. Chiton tuberculata

figure 1: Two species of chitons used in study - a. study part I b. study part II

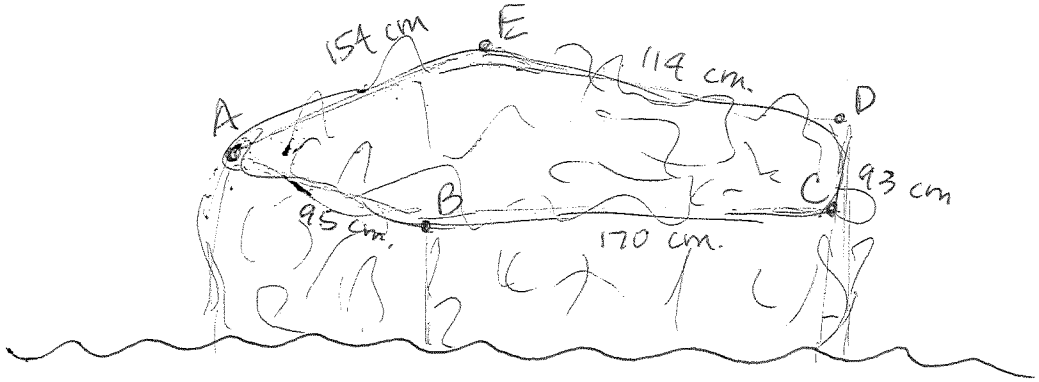


figure 2: Limestone rock island study site

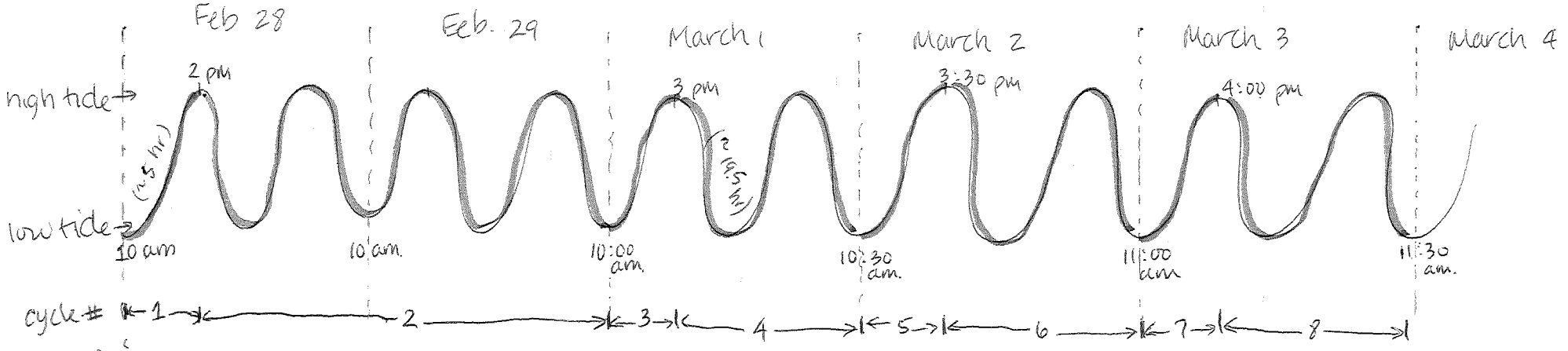


figure 3: Schedule of recorded cycle times

Methods:

For the first part of my study (movement patterns) I located 12 various sized A. granulata on the rock island and marked them. The method of marking included a symbol scratched into their shells with a sharp probe as well as brightly colored grease pencil markings for easier detection. In order to mark their location on the rock I attempted to outline them with the grease pencil but soon discovered this marking was easily washed off the rock. Rather than try to map the extremely rough surface of the rock, a series of 5, 3 m. ruled strings were tied to the top surface of the rock at the 5 corners (fig 2). Distances between strings were recorded. To measure the location of a chiton the two strings between which a chiton was located were used to obtain two different coordinates. Later, these 'points' could be plotted on graph paper to determine the relative distance the chiton moved between recordings. (Appendix I). The distance is by no means absolute, due to the very irregular surface of the rock and the fact that the strings were layed out in the shortest straight line to the chiton. This means that bumps and crevices could not be taken into account as part of the distance moved. The distance calculated was the gross distance moved during the time since the last recording.

I recorded coordinate locations and distance from the water line twice daily over a period of eight days. In a previous study comparing the movement patterns of two species of chitons in Somalia activity rhythms of both were already known (feed during nocturnal low tide, rest during

the rest of the time) so that the locations were measured only at low tides. (Chelazzi, et al 1983) Since I did not have any information on the behavior of these specific chitons I decided to make my recordings at both low and high tides. Due to time and snorkel-partner limitations I only made measurements during diurnal tides.

The first two days were spent devising an efficient method for location measurement. Also, due to bad weather, no data could be collected on the fourth day.

The calculated distances and the coordinate locations were used to detect homing and resting behavior and their relationship to time/tide cycles. A chiton classified as homing when it left a coordinate location for a period of time and then returned to that same location at another recording time. Resting behavior was described when an individual was recorded at the same coordinate at least twice in a row (gross distance = 0).

One recording time was in the morning at low tide and the other in the afternoon at high tide so the 2 daily cycle times are quite. Generally, the 'even' cycle times (longer, nocturnal) are about 19.5 hours long and the 'odd' cycle times are about 5 hours. (fig 3).

Mean rates of movement were calculated for each individual as well as for each cycle measured (including all individuals counted). I also tested to see if the sizes of the individuals were related to their mean rate of movement.

In the second part of my study I went out on two consecutive nights at about the same time (and tide cycle) to watch the Chiton tuberculatus which congregated on the dock wall. On the first night, when it was completely dark, I counted the number of chitons present; estimated their size class (small, medium or large) and their position in relation to the water line (above, below or at). On the second night, I turned on the overhead dock lights two hours before observation time and then made the same data measurements. I used these two nights' data to check for photoactic behavior in dark vs. light environment.

Results:

Eight out of twelve individual marked A. granulata exhibited the described homing behavior (66.67% of the sampled population). Almost all, 11 out of 12 chitons, or 91.67%, were found resting at some point during recording. Homing tended to occur at low tide (morning). Six of the eight homing individuals left their low tide 'home' location and then returned there on a following morning (again low tide).

Total gross distance moved by each individual chiton and its corresponding rate of movement were calculated (table 1). In addition, I compared mean rates of movement for shorter daytime cycles with those of the longer nocturnal cycles using the Mann-Whitney U

test for significant difference. I found the rate of movement during the short diurnal cycle was significantly greater than the rate during the longer cycle. ($R = 6$, $n_1 = 4$, $n_2 = 3$, $p = .05$).

In a linear regression test there proved to be no correlation between the rate of movement and chiton size.

The dock wall study revealed 51 individuals present on the first night (dark) and 23 individuals on the next night after the lights had been on for 2 hours. (Table 2) There were significantly more chitons present in the dark than in the light (Chi-square test, $\chi^2 = 5.49$, degrees of freedom = 1, $p < .025$). There were greater numbers of chitons in the dark under all the measured categories. However, chi-square analysis showed no significant difference in the positions with respect to the water line or in the sizes of the chitons between the dark and light times.

In addition to the collected data, I made several observations on A. granulata. Many more chitons were present above the water line at low tide while at high tide most were at or below the water line. At high tide I found many chitons were clumped in crevices and at low tide this 'group-hiding' seemed reduced. A scraping noise was heard at both low and high tides, presumably grazing on algae with the radula, however no levels of intensity were recorded.

Table 1 : gross distances moved and mean rates of movement for individual chitons and cycles

Individual	(cm) size	gross distance moved per cycle (cm) 1	2	3	4	5	6	7	8	$\bar{x}$ rate of movement $(\frac{cm}{hr})$
#1	4	58	11	8	0	0	0	0	0	0.63
#2	6	0	27	31	31			97	97	2.92
#3	4.5				16			0	28	1.0
#4	5.0	16	18	0	0			0	0	0.35
#5	5.5	12	70	18	26	0	0	45	45	1.78
#6	2.5	0			89	89	17	0		3.36
#7	4.5			33	33	19	176	11	0	3.7
#8	5.0	11	34	136	136				24	3.71
#9	4.5	9	81	22	80			0	6	2.04
#10	3.0	8	43	0	16			0		0.86
#11	4.0	17	31			0	14	0		0.8
#12	4.0	20	7	0	0	0	6	5	0	0.31
$\bar{x}$ rate of movement per cycle $(\frac{cm}{hr})$		3.78		5.51	1.99	3.6	1.82	2.87	4.14	

Table 2: Census of chitons on wall at night - one in darkness, the other lighted.

	Total #	# above H_2O line	# below H_2O line	# at H_2O line	# small	# medium	# large
Dark	51	25	8	18	16	8	27
Light	23	11	5	7	5	3	15

Discussion:

My study of A. granulata movement proves the existence of homing behavior in this species. Since this behavior occured mostly at low tide, the chitons probably rest in their homing position at this time, a behavior previously documented. They may move out to feed around high tide therefore accounting for the greater rate of movement during the shorter diurnal low to high tide cycle. Although I took this difference to be significant, p was actually equal to .05, I cannot conclusively say that this is the case. Since my measurements were not absolute but gross distances, the amount of movement over the longer nocturnal cycle may not be representative of the total movement during that cycle. It would be necessary to check the chiton location periodically during the night, perhaps at high and low tides to verify a pattern of movement. I did make one night observation at high tide. There seemed to be little overall change in numbers and location however no data were recorded.

My observations of chiton position relative to the water line suggest that there may be little vertical movement of the chitons on the rock. I can speculate that perhaps they rest at low tides and when water reaches them at high tides they move out to feed (somewhat horizontally). Some general observations may be contradictory to this theory. I noticed a greater tendancy for chitons to be grouped in crevices during high tide which does not seem to be indicative of feeding behavior. Perhaps this is a predator avoidance mechanism although a

specific predator at high tide is unknown.

The data indicates that there is a high variation in individual distances moved during any one cycle both between individuals and within an individuals cycle time recordings. The amount of movement and the distance from a "home" may be related to some unknown factor such as the amount of algae present at a given time.

The study of Chiton tuberculatus showed that this species is indeed negatively phototactic. Further research explained that this photosensitivity is caused by sensory cells unique to chitons. These mantle cells, called aesthetes, are present in the tegmentum (second layer) of the shell. In the family Chitonidae, of which C. tuberculatus is a member, the aesthetes are present as modified eyes and there may be thousands per individual. These cells may be inhibited by algal growth on the shell and it would be interesting to test if older chitons lose some of their photosensitivity due to increased algal cover on the shell. There are also many photoreceptors in the girdle which are not inhibited by algae (Barnes, 1980).

Although 23 individuals appeared on the wall even when the lights were on, they were located on a section of the dock wall which did not receive any light. Had this area been lighted, I predict that none of the chitons would have appeared.

I have evidenced homing behavior in Acanthopleura granulata and negative phototacticity in Chiton tuberculatus however I cannot make any conclusions about the feeding and resting cycle or movement patterns due to the methods used. It would be interesting to document these patterns for the species present at Discovery Bay and in order to do this, chiton location must be checked at every high and low tide and observations should be made within these tidal times.

Finally, for all chiton movement studies, a better method for marking individual chitons is needed. Sometimes it was difficult to locate some of my marked chitons since the scratched shells were not always fully in view (animals hiding in dark crevices). Because of this difficulty there is incomplete data for some individuals during certain cycle times. I suggest that a tiny piece of numbered paper glued to the shell with some type of water resistent glue or perhaps boat paint may be more effective marking methods. If the chitons can be successfully marked, I believe many more interesting studies concerning the behavior of these fascinating creatures could be performed.

Literature Cited:

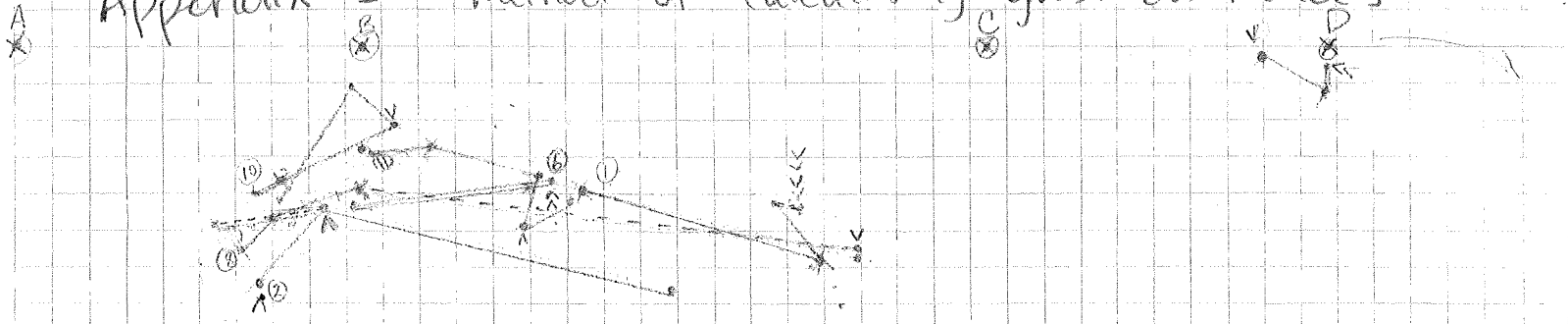
Barnes, Robert D. Invertebrate Zoology. Saunders College, Philadelphia. 1980. (pp. 383-6)

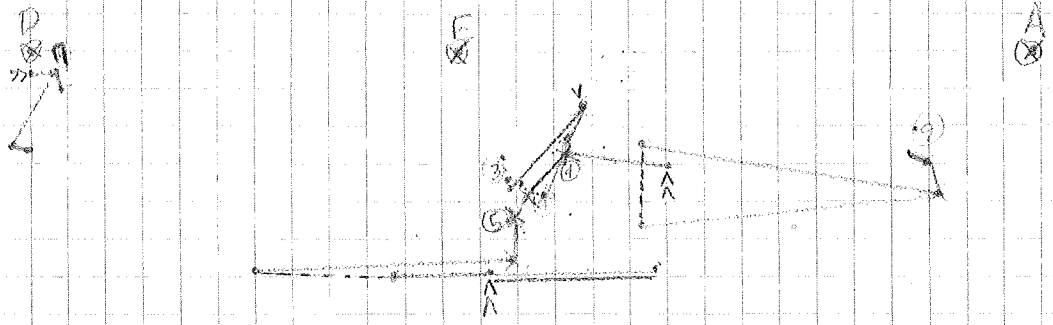
Chelazzi, H., G. Focardi, J.L. Deneubourg. "A Comparative Study on the Movement Patterns of Two Sympatric Tropical Chitons." Journal - Unavailable. 1981. ? 1983??

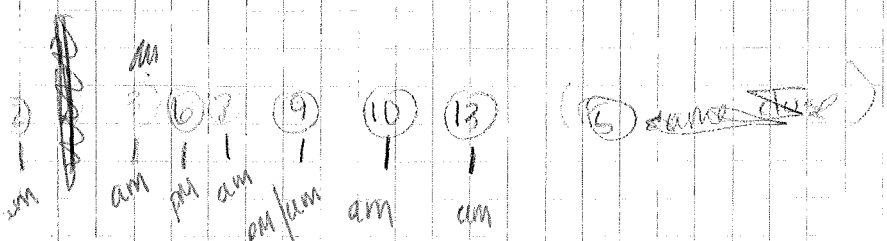
George, David and Jennifer. Marine Life. John Wiley & Sons, New York. 1979. (p. 86).

Very good discussion of your results and ideas for future projects.

Appendix I. Method of calculating gross distances







staying in homing position at least once after: 4 out of 7