# Aggregational Behavior of *Diadema antillarum*: A Sticky Business

"Even as I contemptate the ceiling is still above me. The purples and greens run together and separate in waves as the *Diadema* shimmer and dance along the tiles, piercing me with their every movement."

Library Blackboard
OMBL, 1981

Laura:
Some good observations, both in the field and the lab. Good, thoughtful discussion.
John

Laura Morell
Bio 52
3/4/81

# Aggregational Behavior of *Diadema antillarum*: A Sticky Business

Laura Ann Morell

Dept. of Biology, Dartmouth College, Hanover, N.H.

Study Site: Discovery Bay Marine Lab, Discovery Bay, Jamaica, W.I.

## Abstract

Aggregations of *Diadema antillarum* were studied on the east and west back reefs of Discovery Bay, Jamaica, W.I., and lab work was conducted at the Discovery Bay Marine Lab, U.W.I. located on the bay. Five tests were conducted to determine the aggregational behavior of *Diadema*, and to investigate factors or responses which may be influencing aggregation. A Morisita Index of Dispersion was employed to determine if the urchins were aggregated, and *Diadema* scototaxic, chemotaxic, and thigmotaxic responses were tested along with the effects of temporary environmental stress on aggregating behavior and the effects of local environmental stress on scototaxic responses. The results of these tests suggest that 1) *Diadema* have very well developed shadow responses, 2) scototaxic responses may be an important factor maintaining *Diadema* aggregations by day, 3) *Diadema*

scototactic

may not remain aggregated by night, 4) localized and temporary environmental stress such as wave surge and storm surge may intensify *Diadema* scototaxic responses and that this increased sensitivity to shadow may cause *Diadema* to appear more aggregated during rough weather, 5) thigmotaxic responses may only play a secondary role in the maintenance of aggregations, but may be an important form of urchin communication, and 6) scototaxic responses are primary factors determining the formation and maintenance of *Diadema antillarum* aggregations.

## Introduction to the Introduction

I think that I was first introduced to *Diadema antillarum* as a young adolescent when vacationing with my family in St. Lucia, a small island in the Lesser Antilles. I can remember snorkeling in a blue lagoon, staring in awe at their formidable spines, and hearing my mother sharply warning me to avoid them. But years later, while watching a movie of *Diadema* and SCUBA divers in Bio 21, I knew that I wanted to go on the Bio FSP, and it was inevitable that *Diadema* would become the focal point of my studies in Jamaica.

After reading an article by J. S. Pearse and S. W. Arch entitled "The Aggregational Behavior of *Diadema* (Echinodermata, Echinoidea), I became skeptical of their assumptions concerning *Diadema* behavior. On the basis of one night dive they reported that *Diadema*

remained fully aggregated at night. And while they postulated that "aggregations of *Diadema* were not stable in either size, shape, position, or individual composition", it seemed that any conclusion that they made could not be valid as they had never observed the movements of individual urchins within an aggregation.
I rashly vowed to disprove them. Imagine, *Diadema* remaining aggregated by night! Colin's *Caribbean Reef Invertebrates and Plants* said that *Diadema* migrate from the reef to forage at night, and I just couldn't see the whole gang of them going out to feed together. I would label all the individual urchins in an aggregation, follow their movements over several days and nights, and be able to make valid assumptions about the aggregating behavior of *Diadema antillarum*.

Perhaps I should have been suspicious of my plans when I read in S. Boyd's 1978 study of the homing behavior of *Diadema*, "all of the first four markers that I placed on *Diadema* spines were missing the next day". But I was determined to label *Diadema* and I stubbornly persisted in my attempts. After two days I was finally humbled; my fingers were sore and purple, my spirits were daunted, and not one label had stayed on. It was at this point that I began to contemplate *Diadema* aggregational behavior in a more scientific light...

# The Real Introduction

Diadema antillarum Phillipi, the long-spined sea urchin, is a common inhabitant of Caribbean coral reefs. According to Colin, in his Caribbean Invertebrates and Plants, Diadema hide within crevices or around sheltered locations of the reef by day and move into the open sandy areas adjacent to reefs at night where they graze on algae or sea grass. The urchin also grazes on macroalgae on the rocky surfaces of the reef.

In a study conducted in 1969, J. S. Pearse and S. W. Arch observed that aggregations of Diadema setosum on the reef flats of the Solomon Islands were persistent over a period of seven days, and on the basis of one night dive concluded that "the aggregations were fully formed even at night and not dispersed." Pearse and Arch feel that the aggregations are not simple responses to environmental factors but are a result of true social behavior. They suggest that "scototaxic responses may be important in the formation of the aggregations," but that the "maintenance of the aggregations depends on a thigmotaxic interplay of the spines between different individuals."

While unable to test Pearse's and Arch's conclusions by studying the movements of individual urchins within an aggregation, I proposed to study the aggregational behavior of Diadema antillarum by employing an index of dispersion. With this test I sought to determine if this species of Diadema also remained fully aggregated at night. And if this was found to be true I hoped to determine if aggregations remained on the reef to forage, or if they moved as a group from the reef onto an adjacent sandy area. I planned to supplement this study of day/night aggregating behavior with observations made in a lagoon where rocky substrate was limited.

I then sought to determine what factors cause, or what responses are responsible for Diadema aggregation. I investigated 1) the effects of temporary environmental stress, ie. storm surge, on aggregational behavior, 2) Diadema scototaxic responses, 3) the effects of localized environmental stress, ie. wave surge, on scototaxic responses, and 4) Diadema thigmotaxic and chemotaxic responses. My aposteriori hypotheses concerning these investigations will be presented in the Discussion.

## Methods

In order to study the aggregational behavior of Diadema antillarum on a reef, I constructed two 25m transects in the area of the East Back Reef, Discovery Bay, Jamaica. One transect was laid along the reef on a uniform coral/rock substrate, and the other was placed parallel to the reef on an adjacent sandy substrate (see Fig. 1).

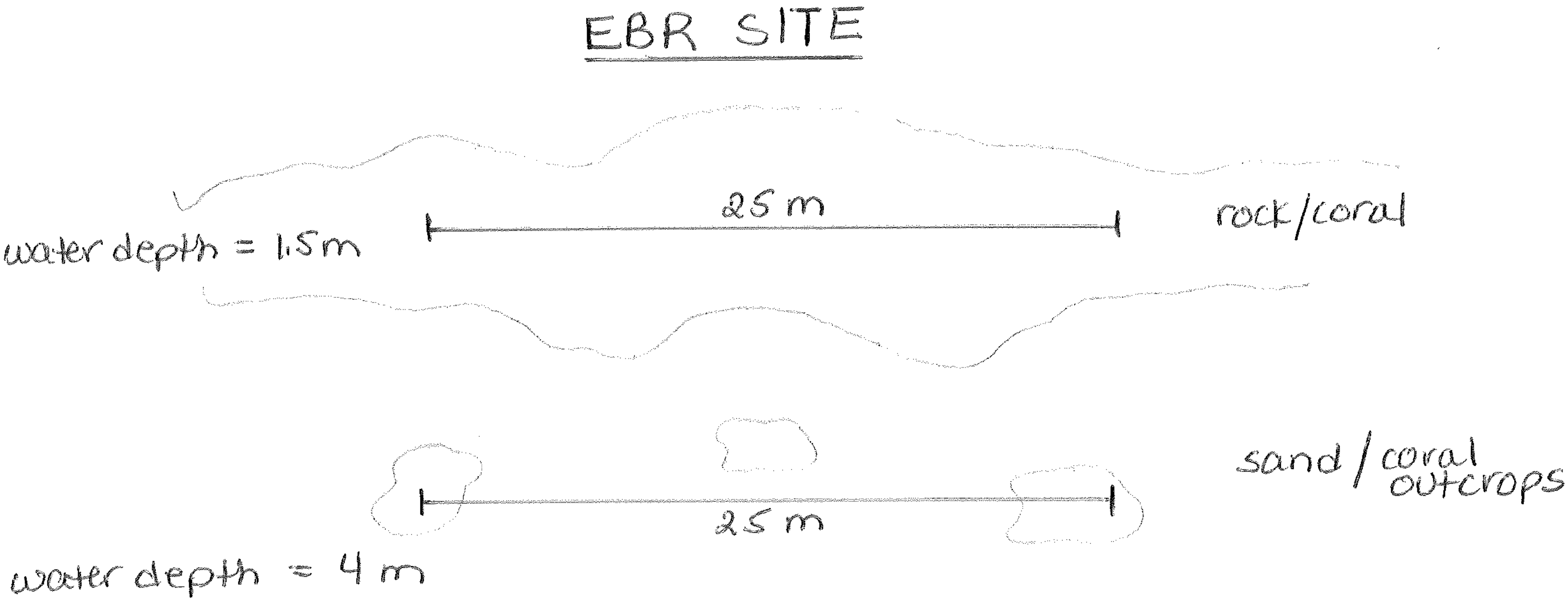


Fig. 1 - EBR study site

Unfortunately, this second transect was not uniform in substrate composition and could only be used for observational purposes (and as indicated in the Results, numerical data was not needed from this transect). All of the urchins in $1 m^2$ quadrats on both sides of the coral/rock transect were recorded at 9:00 am and again at 9:00 pm. A Morisita Index of Dispersion was applied to the data to determine if the urchins were randomly dispersed, uniformly dispersed, or aggregated. Observations of urchin behavior along the sandy substrate transect were also made at 9:00 am and 9:00 pm.

In order to study the aggregational behavior of *Diadema antillarum* in a lagoon area where rocky substitute is limited, I made several morning, afternoon, and evening observations of an aggregation located in the lagoon of the

West Back Reef (see Fig. 2). Diagrams of the aggregation were drawn at each observation.

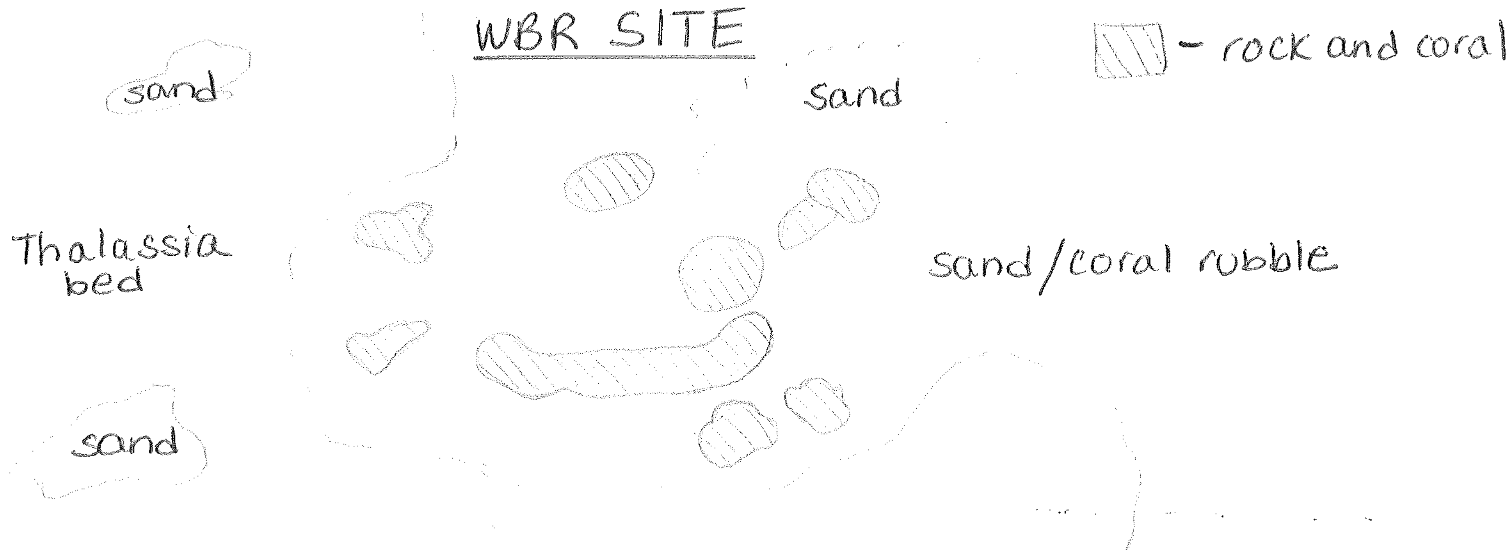


Fig. 2 – WBR study site

In order to investigate what factors may cause, or what responses may be responsible for *Diadema* aggregation, I conducted four tests:

1) Temporary Environmental Stress Test – In order to determine the effects of temporary environmental stress, such as the increased surge associated with a storm, on *Diadema* aggregational behavior, I compared the results of the Morisita Index of Dispersion of the EBR rock/coral transect on calm and rough days. I supplimented this test with rough and calm day observations made at the study site in the WBR lagoon.

2) Scototaxic Test – In order to observe *Diadema* sensitivity to dark areas, urchins were placed in inside and outside tanks where half of the tank

was shaded, and their movements within the tank were recorded over a two day period. Those placed in the inside tank were randomly selected, while half of the urchins in the outside tank were selected from a surge area (WBR canoe channel) and half from a calm area (WBR lagoon). The results of this test prompted me to design test number 3.

3) Localized Environmental Stress Test -
In order to determine if localized environmental stress, such as wave surge, affected *Diadema* scototaxic responses, I placed 8 urchins from a high surge area (WBR canoe channel) in an indoor tank that was half shaded, and 9 urchins from a low surge area (WBR lagoon) in a similar tank. Their movements within the tanks were recorded over a two day period. (Chuck collected the urchins from the calm area for me and I didn't realize that he had captured 9 untill the test was underway, and I didn't want to disturb them by removing one so I left the extra one in the tank).

4) Thigmotaxic and Chemotaxic Response Tests -
In order to determine if *Diadema* would be attracted to other urchins via thigmotatic or chemotatic cues, a 2 ft. square tank was constructed in the wet lab, and 4 "choices" were placed in each of the corners. These choices were a real urchin in a cage, a model urchin with wire spines,

a model urchin with real spines, and a model urchin with no spines. The model urchins were constructed with styrofoam, dark fuzzy cloth (ex-Palo Verde lizard skin), and weights. A test urchin was released in the center of the tank and after 30 min. its position in the tank was recorded. Twenty trials were conducted.

## Results

### Aggregational Behavior of Diadema antillarum

dispersion vs dispersal!

1) Transect Study - The results of the Morisita Index of Dispersion indicate that the urchins on the EBR rocky substrate remain aggregated both day and night. $I_\delta = 1.36$ by day and $I_\delta = 1.28$ by night where an $I_\delta > 1$ indicates clumped dispersal (see appendix for data and calculations). General observations revealed that more urchins were located in crevices during the day than at night. Many were in spine-touching distance of another urchin both day and night, but I observed that a large number of urchins were not in spine contact with another. During the evening I counted up to 40 urchins per $m^2$, an interesting observation as Colin writes that only 13 per $m^2$ have been recorded. No urchins were observed along the sandy substrate transect during the day or night.

Observations

2) <u>Lagoon Study</u> - Figures 3-5 illustrate the appearance of the WBR lagoon aggregation during the morning, afternoon, and night. The group appeared to be quite aggregated at 10:00 am, more dispersed at 4:00 pm, and spread out at 7:00 pm. By 7:00 pm many of the individuals were moving out into adjacent sand and sea grass patches. While several urchins appeared to be dispersing to forage in spine contact of one another, I also observed that many urchins were foraging beyond spine contact distance.

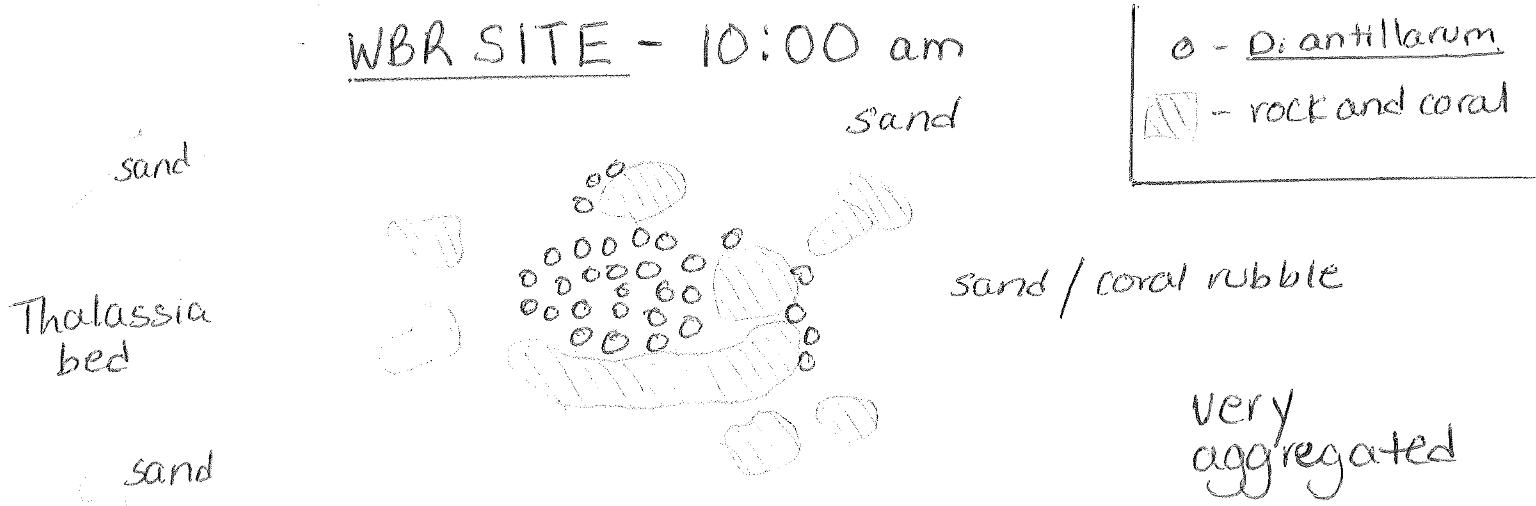


Fig. 3

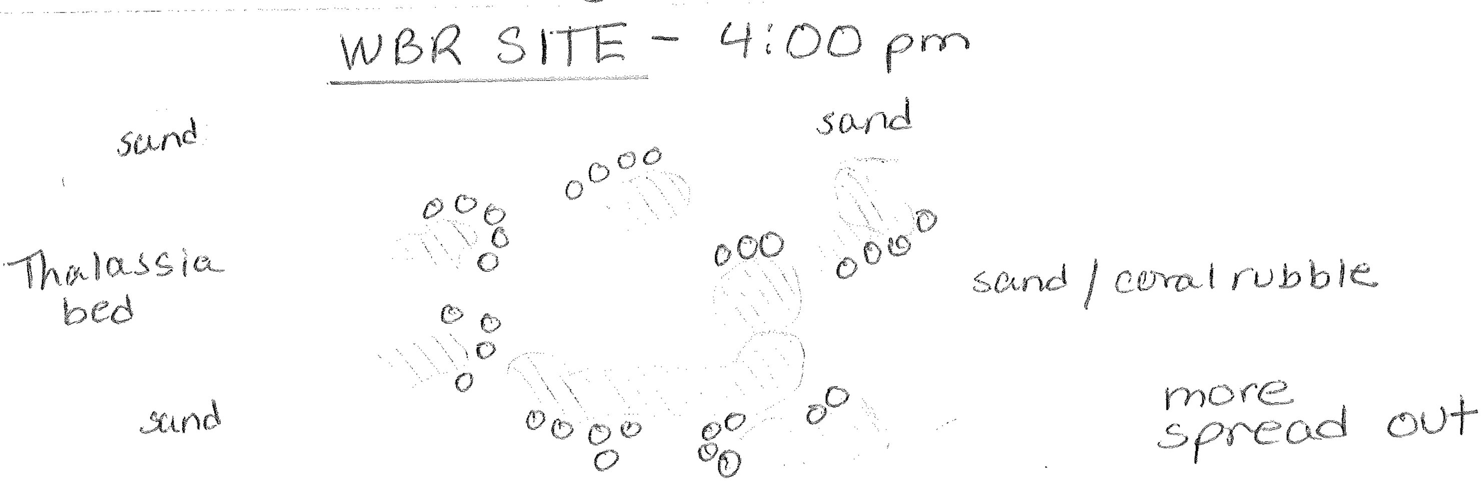


Fig. 4

<u>Fig. 3-4</u> - Diadema aggregations on WBR during day and afternoon

10 Squares to the Inch

## WBR SITE - 7:00 pm

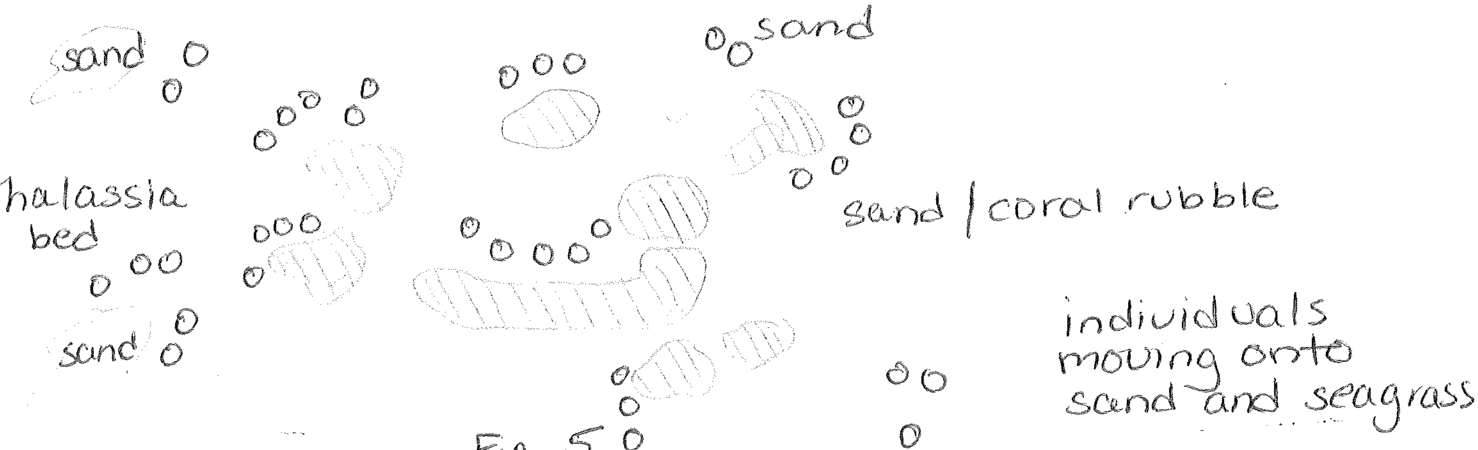


Fig. 5

Fig. 5 - Diadema aggregation on WBR during the night

## Factors and Responses Leading to Aggregation

1) Temporary Environmental Stress Test -

The results of the Morisita Index of Dispersion conducted along the EBR rock/coral transect during rough and calm seas indicate that urchins are aggregated during rough weather and dispersed during calm weather. $I_\delta = 1.36$ during rough seas and $I_\delta = .61$ during calm seas, where $I_\delta > 1$ indicates clumped dispersal and $I_\delta < 1$ indicates uniform dispersal (see appendix for data and calculations). Figures 6 and 7 diagram the aggregation located in the WBR lagoon on rough and calm mornings. These figures indicate that urchins located on a sand/coral rubble substrate with few rocky outcrops will also become aggregated during rough weather.

WBR SITE - ROUGH 10:00 am

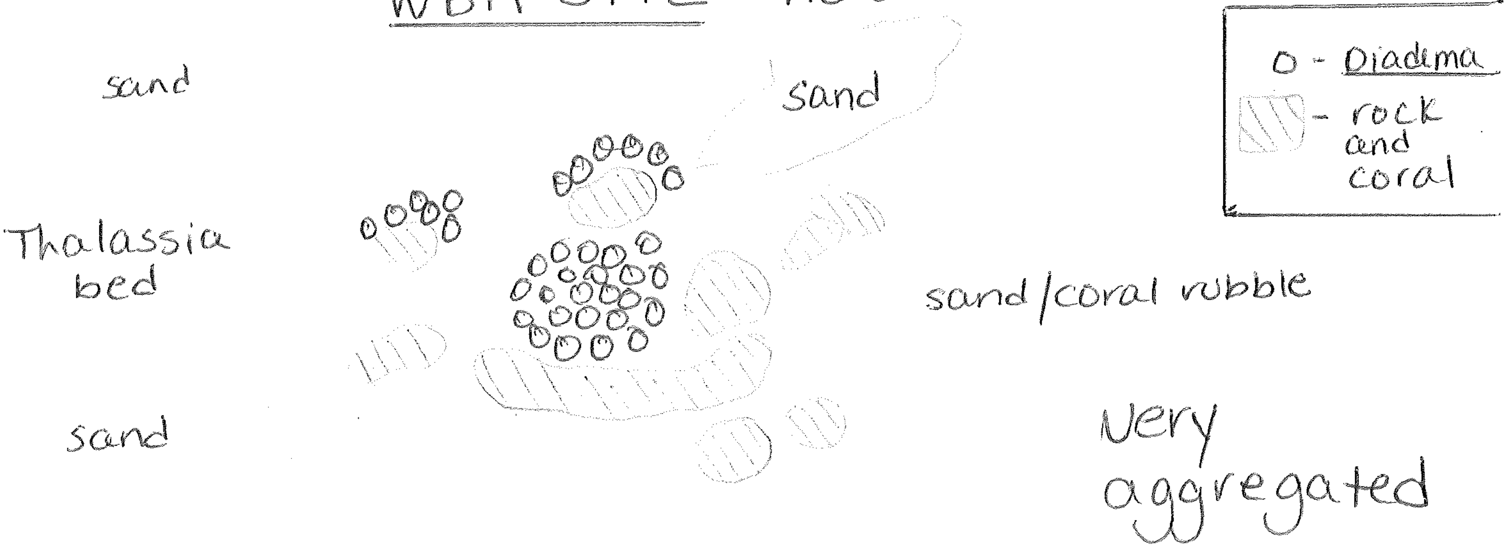


Fig. 6

WBR SITE - CALM 10:00 am

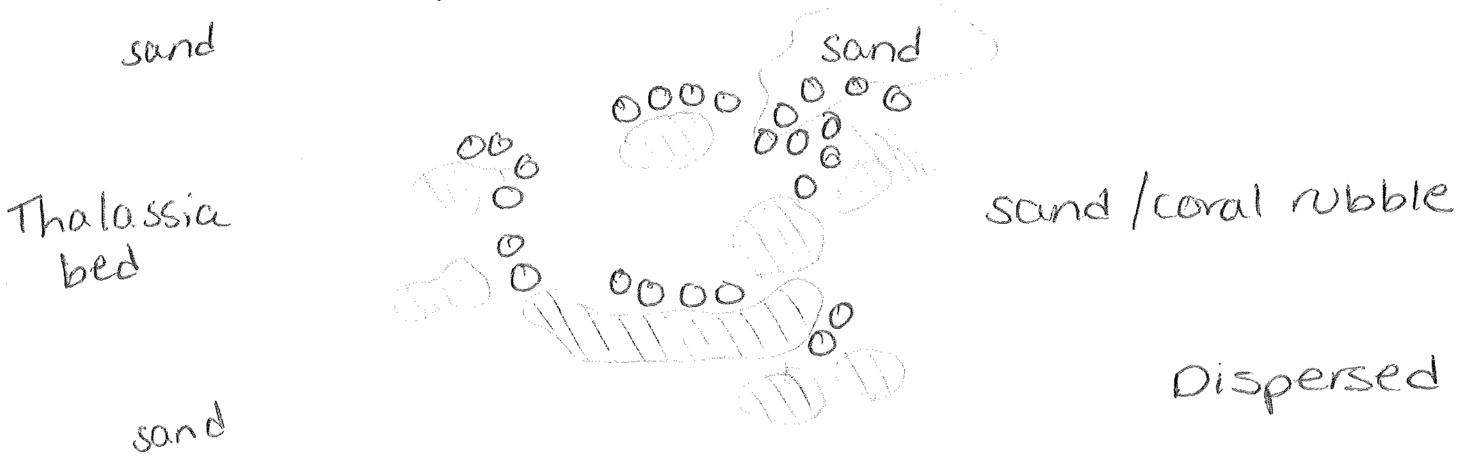


Fig. 7

2) Scototaxic Test - The randomly selected urchins placed in the inside tank showed a marked preference for the shaded side by day and the unshaded side by night. However, in the outside tank which contained urchins from a rough area and a calm area, two distinct aggregations formed. One appeared to prefer the shaded side and the other the unshaded area. This occurance led me to postulate that Diadema scototaxic

responses may be influenced by local environmental stress, and I therefore designed test three to examine this hypothesis.

3) Localized Environmental Stress/Scototaxic Test -

For the first three hours of observation the urchins from the rough zone showed a distinct preference for the shaded portion of the tank, and those from the calm zone showed a similar preference for the unshaded side. As evening approached all of the urchins moved to the unshaded area and remained there for the next 24 hours.

4) Thigmotaxic and Chemotaxic Tests -

The "choices" made by the urchins during 20 trials are summarized in Table 1.

Table 1. - Choices made by urchins in Thigmotaxic and Chemotaxic Tests in 20 trials

| real | model/ real spines | model/ wire spines | model/ no spines |
|---|---|---|---|
| 4 | 3 | 8 | 5 |

## Discussion

The results of my initial scototaxic tests suggest that *Diadema antillarum* do exhibit scototaxic responses. This supports observations made by Yoshida (1966) that *Diadema* have very well developed shadow responses.
In addition, my results enable me to hypothesize that scototaxic responses may be an important factor maintaining *Diadema* aggregations by day. This hypothesis would explain observations made during the day on the EBR and in the WBR lagoon. *Diadema* on the EBR were found to be aggregated by day, the majority of urchins being located in crevices along the reef. Urchins in the WBR lagoon were also observed to be more clumped by day, forming aggregations on the sand / coral rubble substrate. If *Diadema* do respond to scototaxic cues by day it would follow that they would be attracted to dark crevices along the reef or to each other if located on a sand / coral rubble substrate.

My results also suggest that scototaxic responses do not maintain *Diadema* aggregations by night. *Diadema* were observed to move away from each other in the WBR lagoon, and to come out of crevices on the EBR at night. These observations contradict Pearse's and Arch's postulation that aggregations remain "fully formed" even at night. (Although the results of my nighttime Morisita Index of Dispersion suggest that *Diadema* remain aggregated at night, I feel that their behavior was influenced by the presence of storm surge. My hypothesis concerning the effects of environmental stress on urchin aggregational behavior are presented below).

The results of my Localized Environmental Stress/Scototaxic test suggests that exposure to localized environmental stress, such as wave surge, may intensify scototaxic responses in *Diadema antillarum*. *Diadema* taken from a high surge area appear to show a more pronounced preference for shadow than do *Diadema* taken from a relatively calm area. This intensified scototaxic response would appear to be selected for in an area where pronounced sensitivity to dark crevices or each other would be beneficial for protection from surge. This proposal that scototaxic responses in *Diadema antillarum* may be intensified by environmental stress, enables me to theorize as to why *Diadema* were found to be more aggregated on both rock/coral

good

and sand/coral rubble substrates during rough weather than during calm weather. In contrast to Pearse's and Arch's supposition that aggregations are not simple responses to environmental factors, I hypothesize that increased surge caused by a storm might heighten *Diadema* scototaxic responses, causing them to fill availibe crevices or to cluster together, resulting in their appearence of being more aggregated.

I am also skeptical of Pearse's and Arch's proposal that the "maintenence of aggregations probably depends on a thigmotaxic interplay of spines between different individuals". My observations indicate that urchins may be considered aggregated without being in spine contact, and that urchins may forage beyond spine-contact distances. Unfortunately, I could not experimentally test the importance of thigmotaxic or chemotaxic responses in maintaining *Diadema* aggregations as I did not validly test *Diadema* behavior. The test I used was designed to determine if urchins would be attracted to a real urchin which they could not touch, indicating a chemotaxic response, or if they would be attracted to different fake urchins which they could touch, indicating thigmotaxic responses. Due to the set up of the tank, a pheromone that might be excreting from the real urchin could have dispersed randomly throughout the tank, and therefore, I must consider these results invalid. This fault in the experiment could be corrected for in the future by building a tank with a directional flow.

Thus, my findings support and heighten Pearse's and Arch's proposal that "scototaxic responses may be important in the formation of aggregations". And although I disagree with their proposal that thigmotaxic factors are the primary factors involved in maintaining Diadema aggregations, I do feel that they may be important secondary factors.

In conclusion, my findings 1) support Yoshida's observations that *Diadema* have very well developed shadow responses, 2) suggest that scototaxic responses may be an important factor maintaining *Diadema* aggregations by day, 3) suggest that *Diadema* may not remain aggregated by night as had been postulated by Pearse and Arch, 4) suggest that localized and temporary environmental stress such as wave surge and storm surge may intensify *Diadema* scototaxic responses, 5) disagree with Pearse's and Arch's proposal that aggregations are not simple responses to environmental factors by suggesting that increased sensitivity to light may cause *Diadema* to appear more aggregated during rough weather, 6) suggest that thigmotaxic responses may only play a secondary role in the maintenence of aggregations, and 7) suggest that scototaxic responses are primary factors in the formation and maintenence of *Diadema antillarum* aggregations.

# APPENDIX

Field observation   EBR - Rough/Day   2/26/81

- a 25 m transect was laid along the coral/rock substrate and 50, m² quadrats were designated along the two sides of the transect. All *Diadema* were counted in each quadrat.

coral/rock
9:00 am

| | | | | |
|---|---|---|---|---|
| 1 - 34 | 11 - 8 | 21 - 6 | 31 - 17 | 41 - 15 |
| 2 - 20 | 12 - 3 | 22 - 21 | 32 - 8 | 42 - 24 |
| 3 - 6 | 13 - 11 | 23 - 20 | 33 - 7 | 43 - 13 |
| 4 - 14 | 14 - 17 | 24 - 8 | 34 - 4 | 44 - 36 |
| 5 - 9 | 15 - 7 | 25 - 5 | 35 - 8 | 45 - 35 |
| 6 - 16 | 16 - 1 | 26 - 13 | 36 - 3 | 46 - 14 |
| 7 - 20 | 17 - 2 | 27 - 10 | 37 - 4 | 47 - 8 |
| 8 - 12 | 18 - 0 | 28 - 9 | 38 - 7 | 48 - 27 |
| 9 - 20 | 19 - 6 | 29 - 9 | 39 - 9 | 49 - 13 |
| 10 - 16 | 20 - 11 | 30 - 7 | 40 - 15 | 50 - 20 |

$$I_\delta = \frac{S \sum_i \left[ X_i (X_i - 1) \right]}{N(N-1)}$$

$S$ = # quadrats
$X_i$ = # individuals in ith quadrat
$N$ = total # of individuals in all quadrats

$$I_\delta = \frac{(50)(10764)}{(628)(627)} = 1.36$$

$I_\delta > 1$ indicates clumped dispersal

sand
4:00 pm

| | | | | |
|---|---|---|---|---|
| 1 - 7 | 11 - 7 | 21 - 6 | 31 - 2 | 41 - 8 |
| 2 - 0 | 12 - 5 | 22 - 0 | 32 - 0 | 42 - 2 |
| 3 - 0 | 13 - 3 | 23 - 0 | 33 - 0 | 43 - 1 |
| 4 - 5 | 14 - 3 | 24 - 3 | 34 - 0 | 44 - 12 |
| 5 - 3 | 15 - 0 | 25 - 6 | 35 - 8 | 45 - 0 |
| 6 - 0 | 16 - 0 | 26 - 2 | 36 - 7 | 46 - 0 |
| 7 - 1 | 17 - 0 | 27 - 1 | 37 - 3 | 47 - 0 |
| 8 - 0 | 18 - 0 | 28 - 3 | 38 - 4 | 48 - 0 |
| 9 - 0 | 19 - 0 | 29 - 7 | 39 - 8 | 49 - 0 |
| 10 - 0 | 20 - 0 | 30 - 11 | 40 - 7 | 50 - 0 |

$$I_\delta = \frac{(50)(786)}{(129)(128)} = 2.38$$

# Field Observation EBR Rough/night 2/26/81

sand 9:00 pm

| | | | | |
|---|---|---|---|---|
| 1 - 9 | 11 - 2 | 21 - 3 | 31 - 7 | 41 - 10 |
| 2 - 0 | 12 - 7 | 22 - 6 | 32 - 7 | 42 - 7 |
| 3 - 1 | 13 - 10 | 23 - 6 | 33 - 7 | 43 - 0 |
| 4 - 1 | 14 - 5 | 24 - 1 | 34 - 5 | 44 - 0 |
| 5 - 0 | 15 - 0 | 25 - 0 | 35 - 0 | 45 - 0 |
| 6 - 3 | 16 - 0 | 26 - 0 | 36 - 0 | 46 - 0 |
| 7 - 6 | 17 - 0 | 27 - 0 | 37 - 3 | 47 - 0 |
| 8 - 14 | 18 - 9 | 28 - 0 | 38 - 1 | 48 - 0 |
| 9 - 12 | 19 - 9 | 29 - 0 | 39 - 0 | 49 - 0 |
| 10 - 8 | 20 - 6 | 30 - 8 | 40 - 1 | 50 - 0 |

$$I_\delta = \frac{(50)(1228)}{(174)(173)} = 2.04$$

rock 9:00 pm

| | | | | |
|---|---|---|---|---|
| 1 - 11 | 11 - 7 | 21 - 15 | 31 - 14 | 41 - 9 |
| 2 - 6 | 12 - 18 | 22 - 15 | 32 - 40 | 42 - 3 |
| 3 - 14 | 13 - 20 | 23 - 6 | 33 - 22 | 43 - 9 |
| 4 - 21 | 14 - 9 | 24 - 23 | 34 - 8 | 44 - 18 |
| 5 - 10 | 15 - 8 | 25 - 30 | 35 - 11 | 45 - 7 |
| 6 - 6 | 16 - 7 | 26 - 14 | 36 - 7 | 46 - 7 |
| 7 - 2 | 17 - 17 | 27 - 22 | 37 - 13 | 47 - 6 |
| 8 - 2 | 18 - 6 | 28 - 13 | 38 - 10 | 48 - 8 |
| 9 - 5 | 19 - 7 | 29 - 22 | 39 - 13 | 49 - 9 |
| 10 - 7 | 20 - 18 | 30 - 12 | 40 - 4 | 50 - 10 |

$$I_\delta = \frac{(50)(9304)}{(601)(600)} = 1.28$$

general observations:

1) no urchins on sand

2) urchins not in crevices

3) some were touching spines, but the majority weren't

4) field guide states that "up to 13/m have been observed". I count 40/m.

Field Observations   ERR - Calm/Day   3/2/81

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 4 | 11 | 9 | 21 | 23 | 31 | 5 |
| 2 | 3 | 12 | 8 | 22 | 23 | 32 | 5 |
| 3 | 14 | 13 | 8 | 23 | 2 | 33 | 7 |
| 4 | 8 | 14 | 15 | 24 | 12 | 34 | 8 |
| 5 | 11 | 15 | 9 | 25 | 15 | 35 | 5 |
| 6 | 2 | 16 | 9 | 26 | 4 | 36 | 4 |
| 7 | 5 | 17 | 8 | 27 | 17 | 37 | 12 |
| 8 | 9 | 18 | 10 | 28 | 5 | 38 | 4 |
| 9 | 11 | 19 | 19 | 29 | 12 | | |
| 10 | 14 | 20 | 14 | 30 | 2 | | |

coral
1:00 am

general observations - today I did observe urchins out on the sand, they could be termed solitary as none were in spine contact of another.

## Literature Cited

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Yoshida, M. 1966. Photosensitivity. In Physiology of Echinodermata, p.p. 435-464 R.A. Boolootian, Ed., Interscience Publ., New York.

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Kristensen, I. 1964. The Effect of Raising Diadema at Different Levels of Light Intensity on Pigmentation and Preference for Darkness. Carib. J. Sci. 4(2+3) June + Sept.

I also used an article by Samarco, Copeland, and another on Echinometra but these articles were packed away before I formed my bibliography.