Some possible reasons for aggregating behavior in *Tripneustes ventricosus* (Lamarck)

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Biology FSP 1985
Discovery Bay, Jamaica
March 9, 1985

ABSTRACT:

This study looks at the changes in the densities of the sea urchin Tripneustes ventricosus (Lamarck) in three sites in Discovery Bay, Jamaica. Samples were collected at all sites on calm days, as well as two sites on rough days, and one site at night. The reproductive condition of urchins from low density and high density sites were compared. It was found that densities varied widely, even within a site. Urchins were found both clumped and alone in all samples taken. There were significantly more urchins in sea grass beds (Thalassia testudinum) than on rocks on calm days, though this was not true on rough days or at night. Differences in reproductive condition between individual urchins and ones in aggregates were found to be significant for one sample taken, though they were insignificant when all urchins tested were looked at.

INTRODUCTION:

Many echinoderms frequently form dense populations over large areas. Pearse and Arch (1969) suggest that "such aggregations [of Diadema spp.] do not seem to be simple passive responses to environmental limitations because adjacent areas of apparently identical substratum and feeding conditions are not occupied." Looking at the sea urchin Tripneustes ventricosus, Keller (1983) found that the densities of urchins

in a $1m^2$ cage would only stabalize at densities of 1 per m^2 even when food was not a limiting factor. What factors, then, cause the urchins to form aggregations of much higher densities?

There are several possible factors which may be influencing the formation of these aggregations. Sea urchins always release their eggs and sperm directly into the water where fertilization occurs immediately. Spawning in Tripneustes occurs primarily in March and April, so I tested the hypothesis that sexually ripe individuals would form aggregations to increase chances of fertilization. Warner (1979) says that although "common, nomadic species have little need for permanent, reproductive aggregation, a mechanism to promote clustering during spawning would still have a distinct survival value."

It has also been suggested that densities may increase during storms or rough weather (J. Gilbert, pers. comm.). It may be that the urchins aggregate in areas that offer more protection during rough weather. To test this, I studied changes in densities on calm and rough days at three sites, one of which was normally rougher than the other two. Urchins have also been seen rolling on the ocean floor when the currents are strong (R. Kimball, pers. observation; Recktenwald, 1984). I looked to see whether the urchins were found on rocks more often in rough weather, as they may be able to hold on better.

Another possible cause would be that the urchins aggregate in areas with an abundance of food. I did not have the time to address this question, but Recktenwald (1984) found that Tripneustes densities did not correlate

with densities of the sea grass Thalassia, which is the major daytime food (Todd and Kilmarx, 1983).

STUDY SITE and METHODS:

The work was all done in the West Back Reef and the East Back Reef in Discovery Bay, Jamaica, during early March, 1985. I chose the first three sites I found that had a large Thalassia bed, rocky or bare areas surrounding or within it, and was under 3m. deep. The West Back Reef was generally calmer than the East Back Reef, and the water depth varied from ½-1½m. Water depths at the East Back Reef were 2-3m.

Site 1 was in the West Back Reef, near the North-West shore. The Thalassia beds here were generally dense. Towards the southern end, the grass was approximately 20cm tall and had a lot of both filamentous brown algae and encrusting algae growing on and around it. As one went North, towards the reef crest, the water became shallower, and the grass attained a height of about 35 cm. There is little algae in this area. The rocky areas are flat with a few small rock promontories. The rocks and the ground were both covered with algae.

Also in the West Back Reef was site 2. It is away from the shore towards the East. A few patches of grass are dense here, but most of the area is sparser than Site 1, and the height of the grass is only about 15cm tall. Little algae was seen on the grass anywhere in the Site. The rocky areas here contained more and larger promontories, many of which were damselfish territories. Algae was growing on most of the exposed surfaces.

The last site was near the shore on the East Back Reef.

The Thalassia was consistently dense and long (25-30cm), and didn't have much algae. The rocky areas were more varied in topography than the other two sites, but otherwise they resembled those in Site 1.

To determine densities of Tripneustes, I sampled randomly at each site. A $(2m)^2$ quadrat (divided into four $1m^2$ quadrants) was taken to the study site. Within a site, I would swim 20 kicks with my eyes closed, and then release the quadrat which would drift to the bottom. Care was taken to avoid sampling an area twice. The number of Tripneustes found in each quadrant would be recorded, as well as the number of urchins that were touching each other. I only used a quadrat sample if it was either entirely over a grass bed or a rocky area in order to simplify categorizing substrate.

During each sampling period, 10-15 quadrats were taken in the grass beds, and 3-6 were taken on the rocks. Except for the night sample, Site 1 was always sampled at 8:30 EST, while Sites 2 and 3 were sampled at 14:30 EST. Each site was sampled on 2 calm days. Sites 1 and 2 were also sampled on one rough day, and Site 2 was sampled one night.

To test for reproductive condition, I collected specimens for dissection on two separate days. To be considered an individual, an urchin had to be 1-1½ m away from another urchin in all directions. The first day I collected five individuals from Site 1 (in the Thalassia beds), where the number of urchins was high enough to make finding individuals difficult. On the second day I collected twelve from a sandy area, covered with patches of algae, that was inshore from

Site 2. For collecting aggregating urchins, I would take three urchins that were next to each other (usually touching) from a clump. The first day I collected six from two small aggregations in the grass beds in Site 2. On the second day I found a very large dense aggregation, containing many smaller clumps, on an area of mixed Thalassia and Rocks in Site 2. I collected five groups of three urchins here.

The first five individuals were dissected the day after they were collected, but all others were dissected on the same day as collection. Gonad condition was grouped into one of five categories: immature; nearly ripe; ripe; partially spawned; or spawned. (For descriptions of these categories, see Appendix A).

A Student's t-test was used to check for differences within a site on calm days, while a Model II single-factor ANOVA was used to test for other differences in the densities. The frequency of distribution in the different reproductive categories were tested for with a G-test. Distributions were tested using all five categories, as well as by using only two categories: able to reproduce; and unable to reproduce.

RESULTS:

Differences were tested between the two calm samples at each site. There was no significant difference between the two samples at Site 1 ($t_{(134)} = 1.87$) or at Site 3 ($t_{(139)} = 1.28$). At Site 2, there was a significant difference within the site ($t_{(142)} = -5.33$, $P \ll .001$) (see Figure 1).

The overall densities between sites were compared for

FIGURE 1: Mean Densities and Standard Deviations of Tripneustes in Each Sample.

the calm days (I have assumed a calm day to represent the usual daytime situation). No significant difference was found between the sites in the West Back Reef (where it is calmer) and the East Back Reef (where it is rougher) ($ANOVA_{(1,418)}$, $F=1.48$). A significant difference was found between sites 1 and 2 ($ANOVA_{(1,279)}$, $F=15.15$).

Samples from Sites 1 and 2 were combined to test for differences between rough and calm days. There was no significant difference between overall densities on rough and calm days ($ANOVA_{(1,402)}$, $F=.66$). When densities of urchins on Thalassia and rocks are considered, one sees a significantly higher density of urchins on Thalassia ($P<.001$) instead of rocks, during a calm day ($ANOVA_{(1,415)}$, $F=25.08$). Whereas on a rough day, there is no significant difference in distribution on a substrate ($ANOVA_{(1,222)}$, $F=2.07$) (see Figure 2). It was observed in Site 1 that the density of urchins dropped to $\leq .20/m^2$ where the grass became taller and denser. This was found on both rough and calm days.

The one night sample from Site 2 was compared to the calm samples from this site. A significant difference was found between the densities during the night and day ($ANOVA_{(5,198)}$, $F=5.49$, $P<.025$). There were significantly more urchins on Thalassia during the day than at night ($ANOVA_{(1,198)}$, $F=5.32$, $P<.025$), but there were no differences in densities on the rocks ($ANOVA_{(1,66)}$, $F=.34$).

The total number of instances where individuals were touching at least one other was 18. Touching individuals were found in every sample except the one done at night. There do not appear to be any differences in the number of instances between sites, or between rough and calm days. Individuals were never found touching on rocks.

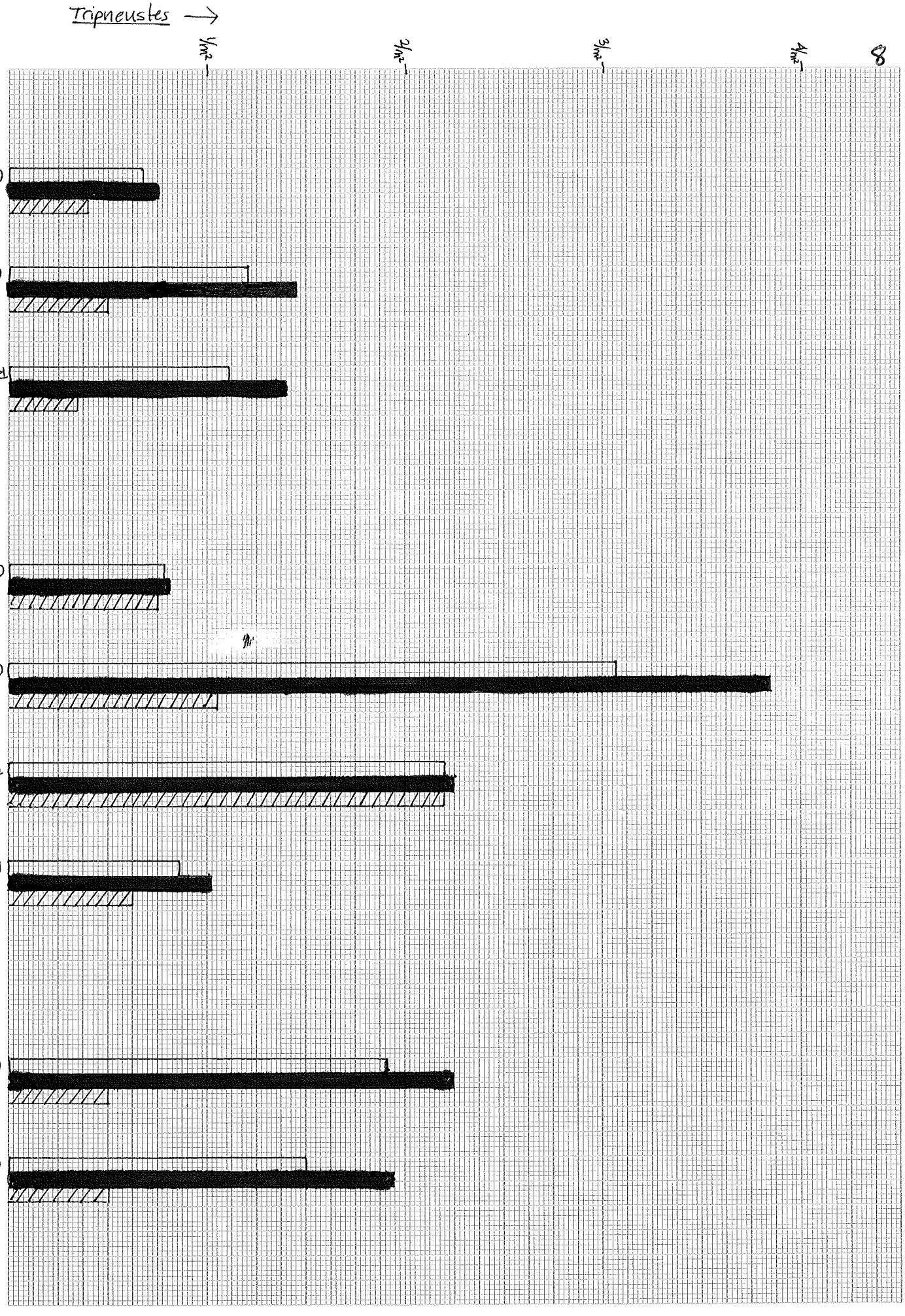

FIGURE 2: Mean Densities of Tripneustes overall ( ), in Thalassia ( ), and on Rocks ( ).

One can also find clumps of individuals within every sample, as well as bare patches where no urchins were in the quadrat. Although the number and size of clumps affects the overall density in a sample, there does not appear to be any relationship between the environmental factors tested and the number of clumps.

The data on reproductive condition were tested on both total specimens tested and on only those specimens which were collected on the second day (sample 2) (see METHODS for differences). When the total specimens are considered, there is no significant difference in the frequency of distributions among categories ($G_{(4)} = 5.88$) (see Table 1). When only sample 2 is considered, there is a significant difference between the five categories ($G_{(4)} = 10.68$, $P < .05$), and also when the individuals are put into two categories: able to reproduce; and unable to reproduce ($G_{(1)} = 6.50$, $P < .025$).

DISCUSSION:

As can be seen from the high standard deviations in the densities, there is a lot of variation in the distributions, and the urchins are not uniformly distributed over a habitat. High variation in aggregation size, shape, and distribution have also been found for Diadema (Pearse and Arch, 1969), and for Tripneustes (Recktenwald, 1984). The uneven distribution can also be seen because both low density and high density quadrats were found in each sample.

Because of these variations in distribution, I feel that the sampling method used was inappropriate for getting a good estimate of the density, or for giving a good determination

TABLE 1: Reproductive Condition of Individuals and Aggregates

	Individuals		Aggregates	
	Total	Sample 2	Total	Sample 2
Unable to Reproduce				
Immature	5	4	3	2
Spawned	6	5	4	2
Able to Reproduce				
Nearly Ripe	3	2	4	4
Ripe	1	0	7	6
Partially Spawned	6	5	4	2

Would be more informative to tabulate frequencies here.

How would you change sampling method?

of the distribution and size of aggregations. I would sometimes notice several dense clusters in an area as I was out sampling, but I would not necessarily sample one of these clusters. This would make my densities lower than they should have been, while at other times I would sample a lot of clusters although much of the area was bare. These possible biases must be kept in mind while looking at the data.

The higher densities of urchins found on sea grass during a calm day follows that found by other researchers (e.g. Shane and Zimmer, 1984). But on rough days, this difference is insignificant, meaning that a higher proportion of urchins are on rocks in the bad weather (though this is only true at Site 2). There are several reasons why urchins may be utilizing rocky substrates more on rough days. The rocks may provide more stability for the urchin when the currents are strong. Urchins may be able to grip better to rocks than to sand, and this may keep them from rolling around. Also, depending on how the urchin is positioned on the rock, the current may force him into the rock, which will prevent him from moving. Todd and Kilmarx (1983) hypothesized that, if urchins are able to take up nutrients through their body walls, they may move on rocks to take advantage of more of the water column. If this is true, it may be advantageous for the urchins to move up when the water is turbulent and more nutrients may be around. With the strong currents, high turbulence, and low visibility found during rough weather, predation on urchins may be lower, so that being exposed on the rocks is not as dangerous.

My results from the night sample are different from those found by other researchers, who found a significantly higher number of Tripneustes on the rocks at night (Shane and Zimmer, 1984; Todd and Kilmarx, 1983). I think this is primarily due to the sampling method used as I have noticed more urchins on rocks at night.

It is difficult to determine if there is a correlation between aggregations and reproductive condition. On the first day I sampled, my individual urchins were more densely populated, and the aggregates were from smaller aggregations than in the second sample. But the substrate and habitat were similar. In the second sample, there was a lot more difference between individuals and aggregates in spatial distribution, but the habitat differences (especially food availability) may have had some influence on the maturity of the individuals. However, I still do believe that urchins may aggregate when ready to spawn, but it is necessary to have a more definite and consistent definition of an aggregate and an individual.

It is also thought that spawning may be related to the lunar cycle, possibly because of the tidal cycle (Pearse, 1975). If one could watch the changes in number and size of aggregations just before, during, and after a full moon, a correlation may be found.

One of the main problems I had was in defining an aggregation. There are small localized clumps, as well as large aggregations which are mostly formed by many smaller clumps. This was part of the difficulty in determining where to collect specimens for dissection. A much better

method would have been to set up a large grid at each site. This would probably give more accurate densities. It would also allow someone to follow changes in the size and distribution of aggregations, with the possibility of mapping their movements. Changes in the population structure could then be looked at and correlated with different environmental factors.

It is easy to understand this aggregating behavior as a response to reproductive condition. Because of the potential for intraspecific competition, there must be other reasons that cause this aggregation behavior, if it does persist as a permanent element of the population structure. I could find no evidence on the densities of Tripneustes at times of the year other than the spawning season. Year-round aggregations have been noted in Diadema spp. (Pearse and Arch, 1969).

This study was unable to find any definite causes for aggregating behavior in Tripneustes. However, it has brought together some possible factors which influence this behavior. Maybe it can serve as a framework for a more complete study in the future.

ACKNOWLEDGEMENTS:

I would like to thank all of the people who agreed to be my snorkeling buddy when I was sampling: Pat Doak, Megan Haney, John Gilbert, Steve LaChance, Steve McLoed, and Chris Whelan.

APPENDIX A: Descriptions of Different Reproductive Conditions

Immature	Gonads pale, firm and flat against the test, no liquid present.
Nearly Ripe	Gonads small, but not flat, some liquid present.*
Ripe	Gonads large, readily fall apart and release liquid upon dissection.*
Partially Spawned	Gonads brownish, smaller, some liquid.*
Spawned	Gonads brown, flat, no liquid present.

* Females can be distinguished by orange gonads, releasing an orange liquid.
Males can be distinguished by pale olive-brown gonads releasing white sperm.

Descriptions were mainly taken from Keller (1983), and also from McPherson (1965).

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Good study and write-up of results. Project would have benefited from slightly more focused goals and methods. Good, critical discussion.