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THE INFLUENCE OF FISH PREDATORS
ON THE DISTRIBUTION AND ABUNDANCE
OF Diadema antillarum

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Introduction

Grazing by sea urchins has been demonstrated to affect the productivity and diversity of both temperate (Breen and Mann, 1976; Duggins, 1980; Ayling, 1981) and tropical (Sammarco et al., 1974; Sammarco, 1980, 1982; Carpenter, 1981) communities through reduction of available prey biomass. Overgrazing occurs when the local density of urchins is increased either through natural causes (Duggins, 1980) or by experimental manipulations (Sammarco, 1980; Carpenter, 1981). Reef or community growth (biomass) may be inhibited or species diversity decreased with potentially irreparable effects on community structure as a result. To accurately predict the potential impact of changes in urchin densities on community structure, it is necessary to understand the mechanisms which act on or within urchin populations to control or limit urchin distribution and abundance.

Predation is one mechanism whereby urchin abundance may be regulated and temporal-spatial distributions (activity patterns) maintained. Several predators on Diadema antillarum, the long spined urchin, have been identified and include at least 18 fish, two gastropod, and two decapod species (Randall et al., 1964; Randall, 1967). The nocturnal activity and diurnal quiescence of D. antillarum within reef crevices observed by numerous

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researchers (Thornton, 1956; Smith, 1969, 1973; Birkeland and Gregory, 1971; Ogden et al., 1973a) has been suggested to be a means whereby diurnal or crepuscular predators are avoided (Ogden et al., 1973a). Additionally, it has been indicated that several urchin predators, particularly fishes (grunts, queen triggerfish) and the King Helmet snail are severely overfished in the nearshore waters surrounding St. Croix (Ogden et al., 1973a). Consequently, the high urchin densities found on patch reefs in these areas may be due to overfishing of urchin predators and the observed activity pattern may remain as an evolutionary vestige to the once abundant predators (Ogden et al., 1973a, 1973b). However, several other studies have demonstrated that urchin activity patterns are not fixed and in the absence or declining abundance of predators activity patterns are subject to change (Fricke, 1974; Glynn et al., 1979; Bernstein et al., 1981).

Population control of prey species by predators may occur at several stages (larval, juvenile, adult) during the life history of the prey. Several studies suggest that certain size classes of urchins, especially juveniles, may be particularly vunerable to predators (Ogden et al., 1973a; Tegner and Dayton, 1977, 1981; Andrew and Choat, 1982). While overfishing at St. Croix may result in the removal or declining abundance of larger fish predators (Ogden et al., 1973b), smaller and/or less abundant predators may still have a significant effect on populations of D. antillarum.

Our objective was to access the importance of fish predators in regulating the abundance and activity patterns of the long-spined sea urchin, D. antillarum. We were especially concerned

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with determining whether or not fish predators were controlling the density of urchins through differential predation on the smaller size classes. To accomplish this objective it was necessary to: (1) establish the activity pattern, abundance and size-frequency distribution of D. antillarum; (2) establish the activity pattern and abundance of large and small potential fish predators; and (3) experimentally evaluate the effectiveness of the urchins' activity pattern in avoiding predators.

Materials and Methods

All data were collected from April 28 through May 4, 1983 within a permanent study area established south of the West Wall tank rack in Salt River Canyon, St. Croix. The study area measured 70 m long by 4 m wide and was subdivided into 5 m intervals. The upper bound of the area was the 15.2 m (50 ft.) contour line and the lower bound, depending upon downward slope, was at a maximum depth of 18.3 m (60 ft.).

Urchin Activity Patterns, Abundance, and Size Distributions

The activity pattern of D. antillarum in Salt River Canyon was determined by tagging urchin home-sites and scoring the presence or absence of urchins within the sites at various times during three consecutive days and nights. Urchins were considered to be active when not on or in the home-sites. On 29 and 30 April, 78 and 12 home-sites were tagged respectively. Of the 90 tagged sites, 23 were eliminated from consideration as urchins obviously had been disturbed by the tagging process and had abandoned their holes soon after (within 12 hours) tagging of home-sites occurred.

Abundance and size-frequency data of the deep water population of urchins in the Salt River Canyon were collected by counting and measuring test diameters *in situ*. Measurements were taken twice during the mission, once during the day and once at night.

Fish Activity Patterns and Abundance

Abundances and the activity patterns of both large and small potential fish predators of *D. antillarum* were also determined. Eighteen species of fishes have been identified as predators of juvenile and/or adult *Diadema* (Randall, 1967). The 18 species, with the exception of *Haemulon flavolineatum* and *Canthigaster rostrata* (Table 1), and an additional seven species (Table 2), were selected *a priori* as possible predators. Scarids (parrotfishes) were later added to the list based on the observation that they may incidentally consume juvenile urchins while feeding on coral.

Predator abundances were estimated by conducting replicated transects along the West Wall during predawn (0500-0600), dawn (0600-0630), postdawn (0630-0730), midday (1030-1330), predusk (1700-1800), dusk (1800-1830), postdusk (1830-1930) and night (0100-0215) periods from 28 April to 3 May 1983. Divers swam along the 70 m transect holding a thin wire frame which delineated a region two meters wide and one meter above the substratum. A "corridor" was formed by visually projecting the frame several meters ahead of the diver and fishes within the corridor were counted. Juveniles were distinquished from adults by size or age specific color patterns.

Effects of Predators

The activity patterns of urchins were experimentally disrupted to evaluate the affect of predators on controlling urchin abundances. Separate experimental methods were used to test for predation on adult and juvenile members of the population. Sixteen adult urchins which consistently re-occupied tagged home-sites were chosen for either enclosure (control treatment) or exclosure (experimental treatment) from their home-sites. Eight adults were enclosed within their home-sites by nailing plastic screen over the exit during the day (enclosure control treatment). The remaining eight urchins were identified by tying thread around the spines and noting any unique spine coloration patterns. The tagged urchins were then excluded from their home-sites by blocking the entrances with screening while they were foraging at night (exclosure experimental treatment). The home-sites and surrounding area of both the experimental and control treatments were examined the following morning for presence or absence of the resident urchins.

Juvenile urchins (<20 mm test diameter) were held singly in individual cages throughout the day. Circular cages measuring 13.5 cm in diameter with a height of 3.5 cm were constructed of 1/4 inch mesh galvanized hardware fabric. Two caging treatments were employed: (1) cages with tops which excluded fish predators (control treatment), and (2) cages without tops which restricted urchin movement but allowed access by fish predators (experimental treatment). A total of 14 cages, divided evenly between treatments, were placed within the study area on exposed coral surfaces. Four trials were run over two days.

Results

Urchin Activity Patterns, Abundance, and Size Distributions

Tagged home-sites were re-visited at various times of the day over three consecutive days and scored for the presence or absence of urchins (Table 3). Presence of a vacant home-site was considered as evidence of urchin activity (i.e. a high percentage of occupied holes would indicate a low degree of activity).

Diadema antillarum were observed to follow a diel activity pattern. Urchins began re-occupying home-sites prior to sunrise and remained inactive until just after sunset, after which they moved into more exposed positions on the reef surface (Figure 1). Over the course of the study, however, progressively fewer home-sites were re-occupied consistently. Thus the percentage of unoccupied holes increased especially during the postdawn period (Table 3). The lack of consistency or persistent use of the same hole suggests that some individuals may use more than one home-site.

Day and night estimates (Table 4) of the number of urchins within 20 m^2 quadrats were similar (Mann Whitney U-test, $U=13$, $p>0.05$). Although smaller urchins were counted more frequently during the night survey (Figure 2), a Kolmogorov-Smirnoff Test showed no significant differences in the size frequencies of urchins measured during the day and night ($Dcrit_{0.05}=0.1686$, $D=0.1086$).

Fish Activity Patterns and Abundance

Only three of the 18 fish species identified by Randall (1967) as predators of D. antillarum were present in the study area (Table 5). Juvenile Spanish hogfish (Bodianus rufus) occurred in low numbers and adults were rare. A few French grunts (Haemulon flavolineatum) and juvenile sharpnose puffers (Canthigaster rostrata) were observed in the area, but were inadvertently ignored during the census. Among the potential predators selected a priori, the bluehead wrasse (Thalassoma bifasciatum) was most abundant, followed by the yellowhead wrasse (Halichoeres garnoti), adult acanthurids, and scarids (Table 5). The greatest abundances of potential fish predators were recorded during the midday, predusk and dusk periods. Except for the few lobsters observed during the predawn period, invertebrate predators were not abundant.

Effects of Predators

If the observed activity pattern of Diadema antillarum is a mechanism whereby diurnally active predators are avoided, it was expected that experimental disruption of the urchins' pattern (such that they were exposed rather than protected during the day) should result in the loss of individuals from the experimental treatments but not from the controls. Of the eight adults prevented from returning to home-sites, three attempted to return and were found with their tests positioned against the screen barrier. Four urchins lacking tags but fitting spine coloration descriptions, were within 2 m of their home-sites and one urchin could not be found. The results of this experiment

were confounded due to the loss of some thread tags and escape of two urchins from control enclosures. Statistical analysis, therefore, was precluded.

Juvenile urchins were either enclosed in cages with tops (no predator access) or exposed in cages without tops (predator access). Although significantly more juvenile urchins disappeared from cages without tops (X^2=5.8, p<0.02), losses may be attributed to several factors besides predation, making the results of this experiment equivocal (Table 6). We observed the very smallest individuals (<4 mm) escaping through the mesh while some larger juveniles (<18 mm) crawled out of the cages without tops. Although we observed no act of fish predation, and fish in general showed little interest in the presence of the small urchins, we did observe one act of aggression. A small (10 cm total length) beau gregory, Pomacentrus leucostictus, entered an open top cage and repeatedly picked up and dropped a juvenile urchin. The urchin eventually was carried approximately 0.5 m from the cage before being ignored. Subsequent examination of the urchin revealed that a few spines had been removed from the aboral surface, but the urchin was alive and appeared to behave normally. The results of the predation experiments, although qualitative in nature, suggest that over the time span of our investigation, neither adult nor juvenile urchins were subjected to fish predation when urchin activity patterns were disrupted.

DISCUSSION

Diadema _antillarum_ occurring within the study site were
faithful to a diel activity pattern, similar to that observed by
Ogden et al. (1973a) on St. Croix patch reefs. Although the
exact time of the first movements of urchins from crevices at
night and the return of the last urchin into crevices at dawn was
not recorded, no activity was witnessed during the midday and the
entire population appeared to be active only at night (Figure 1).

The tagging of home-sites was assumed to have "disturbed"
some individuals as they failed to return to the sites after
tagging. These individuals were eliminated from the analysis
since inclusion would have indicated daytime activity, which was
never observed. While disturbance from tagging activities was
considered to be the likely cause of the individuals failure to
return to the tagged sites, the possibility also exists that not
every individual urchin returns to the same position every day
and that suitable refuges are not limited. Similarly, Birkeland
and Gregory (1971) observed a low incidence of homing (1 of 20
individuals) in _D._ _antillarum_. Ogden et al. (1973a) provide
further evidence of behavioral plasticity with respect to homing
by their observation that urchins found in crevices homed while
those lacking crevice sites did not. Both crevice and non-
crevice sites were tagged within our study site, however, and
there appeared to be no difference in the proportion of returning
and non-returning urchins between the home-site types.

Relatively few juvenile urchins were observed in the study
site (Figure 2). Most urchins ranged from four to six

centimeters in test diameter. Ogden et al. (1973a) reported finding small urchins in shallow reef areas and suggested that urchins may recruit to shallow water habitats and then may migrate to deeper positions on the reef. We observed small urchins to be more abundant in shallow areas (<30 ft.) near Hydrolab, however, similarly sized individuals also were found in the deep study site, indicating that the urchins have the potential to recruit to deeper habitats. In addition to differential recruitment to habitats at varying depths the observed size-frequency distribution could be accounted for by episodic recruitment events or size selective predation on small urchins. Without an estimate of the frequency of recruitment events and the resulting abundance of juveniles none of these possibilities can be eliminated.

The results of the experimental disruption of the activity pattern of adult _Diadema_ _antillarum_, which subjected individuals in the experimental treatment to predation by large diurnal fish predators, were not analyzed statistically due to the preliminary nature of the results. However, our observations suggest that little or no fish predation on adult _D._ _antillarum_ occurs. The statement is supported by the virtual absence of large known or suspected predators in the study site that would be physically capable of preying on adult urchins (Table 5).

The caging experiment with juvenile _D._ _antillarum_ demonstrated a statistically significant treatment effect, however this experiment was confounded by caging technique which was only partially effective. As with adult urchins, we found no evidence of predation by fishes on smaller urchins. However, a

non-predatory interaction between a damselfish (_Pomacentrus leucostrictus_) and juvenile urchin was observed. Active interference behavior of another damselfish species (_Eupomacentrus planifrons_) toward _D. antillarum_ with subsequent displacement of urchins from fish territories has been reported (Williams, 1981). Displacement of urchins by territorial fish could effectively reinforce the diurnal-nocturnal activity pattern within fish territories by removing those individuals exposed during the day. Both _P. leucostictus_ and _E. planifrons_ were abundant in the study site (pers. obs.), however, caging treatments were deployed without regard to the location of fish territories, thereby preventing us from documenting the frequency of urchin displacement by territorial fishes.

The results of the present study, although preliminary in nature, suggest that the observed diurnal-nocturnal activity pattern of _Diadema antillarum_ in Salt River Canyon is not maintained by predation pressure from fishes. The conclusion is based upon our failure to demonstrate predation on urchins by smaller fish species suspected as predators and the absence of larger predatory fish species from the site. Alternative explanations are that (1) the behavior persists as it was genetically fixed under local conditions of higher predator density and not enough time has elapsed to genetically "erase" the behavior, or that (2) primary urchin recruitment occurs in other areas which are subjected to higher predator densities, and once the behavior is fixed at earlier life stages it is maintained even if migration to areas of lower predator density occurs. Furthermore, new evidence suggests that fish may affect

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urchin activity patterns through non-lethal interference behavior (Williams, 1981) rather than direct predatory interactions.

The intent of our study was to provide information on the predator-prey relationship between fishes and the long-spined urchin, _Diadema antillarum_. Although our study must be considered preliminary, the data suggest that fish predators presently have little impact on the abundance and distribution of the deep water urchin population in Salt River Canyon. Although anecdotal information suggests that urchin abundance increases as a result of overfishing (Ogden, pers. com.), it is premature to conclude that there is a direct relationship between decreased fish abundance and consequent increases in urchin abundance. No predictions may be made in regard to the effect of overfishing on the eventual density of urchins without adequate information on urchin and predator population dynamics. These data should be obtained through density estimates taken on a regular and long term basis, and further experimental investigations of factors, besides predation, that may exert an influence on urchin population abundance and distribution. Only after these types of data are collected can effective management policies and methodologies be developed for coral reef fisheries.

Acknowledgements

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Table 1. Fishes (Randall, 1967) and invertebrates (Randall, et al., 1964) identified as predators of <u>Diadema antillarum</u>. An asterisk indicates major fish predators (>10% <u>Diadema antillarum</u> remains in gut by volume).

* <u>Anisotremus surinamensis</u> (black margate)
* <u>Haemulon carbonarium</u> (Caesar grunt)
* <u>H. macrostonum</u> (Spanish grunt)
* <u>H. plumieri</u> (white grunt)
  <u>H. sciurus</u> (bluestriped grunt)
  <u>H. flavolineatum</u> (French grunt)
* <u>Calamus bajonado</u> (jolthead porgy)
* <u>Trachinotus falcatus</u> (permit)
* <u>Balisthes vetula</u> (Queen triggerfish)
* <u>Canthidermis sufflamen</u> (ocean triggerfish)
* <u>Bodianus rufus</u> (Spanish hogfish)
* <u>Halichoeres bivattatus</u> (slippery dick)
  <u>H. poeyi</u> (blackear wrasse)
* <u>H. radiatus</u> (puddingwife)
  <u>Lactophrys bicaudalis</u> (spotted trunkfish)
  <u>Diodon hystrix</u> (porcupine fish)
  <u>Sphoeroides spengleri</u> (bandtail puffer)
  <u>Canthigaster rostrata</u> (sharpnose puffer)
  <u>Cassis madagascariensis</u> (helmet shell)
  <u>C. tuberosa</u> (helmet shell)
  <u>Panulirus argus</u> (lobster)

Table 2. Fishes identified a priori as possible predators of Diadema antillarum.

Halichoeres garnoti (yellowhead wrasse)
Thalassoma bifasciatum (bluehead wrasse)
Lachnotaimus maximus (hogfish)
Melichthys niger (black durgon)
Acanthurus chirurgus (doctorfish)
A. coeruleus (blue tang)
A. bahianus (ocean surgeon)

Table 3. The number of home-sites occupied and vacant during dawn, midday, dusk, and night periods in the Salt River Canyon study site. The proportions of the total home-sites censused are indicated in parentheses.

| PERIOD | TIME | DATE | CENSUSED | TOTAL NUMBER OF HOME-SITES | | |
				VACANT	OCCUPIED	TRANSITIONAL*
Predawn	0430-0530	4/30	43	17(40)	15(35)	11(26)
Total			43	17(40)	15(35)	11(26)
Postdawn	0630-0730	4/30	52	9(17)	41(79)	2(4)
	0830-1130	5/01	58	12(21)	46(79)	0(0)
	0730-0800	5/02	30	16(53)	14(47)	0(0)
	0700-0900	5/03	37	19(51)	18(49)	0(0)
Total			177	56(32)	119(68)	0(0)
Midday	1149-1229	4/30	63	4(6)	59(94)	0(0)
Total			63	4(6)	59(94)	0(0)
Predusk	1634-1715	4/29	51	5(10)	46(90)	0(0)
Total			51	5(10)	46(90)	0(0)
Postdusk	1850-1915	4/29	25	9(36)	16(64)	0(0)
	1835-1935	4/30	50	41(82)	9(18)	0(0)
Total			75	50(67)	25(33)	0(0)
Night	2300-0100	4/29	42	39(93)	2(5)	1(2)
	0100-0300	5/01	52	43(83)	3(6)	0(0)
	0000-0215	5/02	19	19(100)	0(0)	0(0)
Total			113	101(76)	5(4)	11(<1)

*Urchins partially, but not completely, within the home-site.

Table 4. Density of _Diadema_ _antillarum_ within the Salt River Canyon study site. Densities were estimated within 4 m by 5 m quadrats. Counts were made once during the day (28 April 1983) and once at night (4 May 1983).

	DAY	NIGHT
Total Number of Quadrats:	8	4
Range of Densities/Quadrat:	9-42	17-38
Mean Number (Standard Deviation) of Urchins/Quadrat:	23.5(10.1)	27.8(10.3)
Mean Number of Urchins/m^2	1.2	1.4

Table 5. Abundances (#/140 m^3) of fish (J = juvenile, A = adult) and invertebrate predators on _Diadema antillarum_ at eight periods over the diel cycle. Standard deviations are presented in parentheses; n refers to the number of transects (70 x 2 x 1 m).

SPECIES		PREDAWN 0500-0600 n = 8	DAWN 0600-0630 n = 9	POSTDAWN 0630-0730 n = 8	DAY 1030-1330 n = 29	PREDUSK 1700-1800 n = 16	DUSK 1800-1830 n = 14	POSTDUSK 1830-1930 n = 3	NIGHT 0100-0215 n = 4
Labridae									
H. garnoti	J	0 -	0 -	0.1 (0.3)	1.2 (1.5)	0.8 (1.4)	0 -	0 -	0 -
	A	0 -	0.3 (0.7)	0.6 (1.1)	1.2 (0.9)	0.8 (1.2)	0.2 (0.4)	0 -	0 -
H. bivattatus	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
H. poeyi	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
H. radiatus	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
T. bifasciatum	J	0 -	1.3 (1.3)	3.4 (1.2)	6.3 (3.8)	5.7 (2.7)	3.9 (4.4)	0.3 (0.6)	0 -
	A	0 -	0 -	0 -	0.3 (0.7	0 -	0 -	0 -	0 -
H. rufus	J	0 -	0 -	0.1 (0.4)	0.7 (1.0)	0.8 (0.9)	1.0 (1.3)	0 -	0 -
	A	0 -	0 -	0 -	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0 -	0 -
L. maximus	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Acanthuridae									
A. chirurgus	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0.2 (0.6)	0.2 (0.5)	0 -	0 -	0 -
A. coeruleus	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	1.0 (1.1)	0.8 (0.4)	0.5 (0.8)	0.6 (1.1)	0.9 (1.3)	0 -	0 -
A. bahianus	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0.1 (0.4)	1.6 (1.6)	2.3 (1.5)	1.4 (1.3)	0.3 (0.6)	0 -
Balistidae									
B. vetula	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
C. sufflamen	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
M. niger	J	0 -	0 -	0 -	<0.1 (0.1)	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Pomadasyidae									
H. carbonarium	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
H. macrostomum	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
H. plumieri	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
H. sciurus	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
A. surinamensis	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Scaridae all species, juveniles and adults		0.1 (0.4)	0.2 (0.4)	0.9 (1.4)	2.9 (2.3)	2.6 (2.0)	5.4 (3.3)	1.0 (1.7)	0 -
Sparidae									
C. bajonado	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Ostraciidae									
L. bicaudalis	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Tetradontidae									
S. spengleri	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Diodontidae									
D. hystrix	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Carangidae									
T. falcatus	J	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
	A	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Invertebrates									
C. madagascariensis		0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
C. tuberosa		0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
P. argus		0.6 (0.9)	0 -	0 -	0 -	0 -	0 -	0 -	0 -

Table 6. The number of _Diadema antillarum_ missing from cage treatments. There were seven replicates of each treatment with one urchin per cage. Four trials were run (n=28).

| | | | TREATMENT | |
| | | | CAGES WITH TOPS | CAGES WITHOUT TOPS |
TRIAL	DATE	INITIAL NUMBER	NUMBER OF URCHINS LOST	NUMBER OF URCHINS LOST
1	MAY 2	7	2	4
2	MAY 2	7	0	3
3	MAY 3	7	0	1
4	MAY 4	7	1	4
TOTALS:		28	3	12

Figure 1. Change in the proportion of home-sites occupied throughout the day. Percentages were computed on the basis of all censuses combined for a given time period of the day (See Table 3 for times and number of censuses).
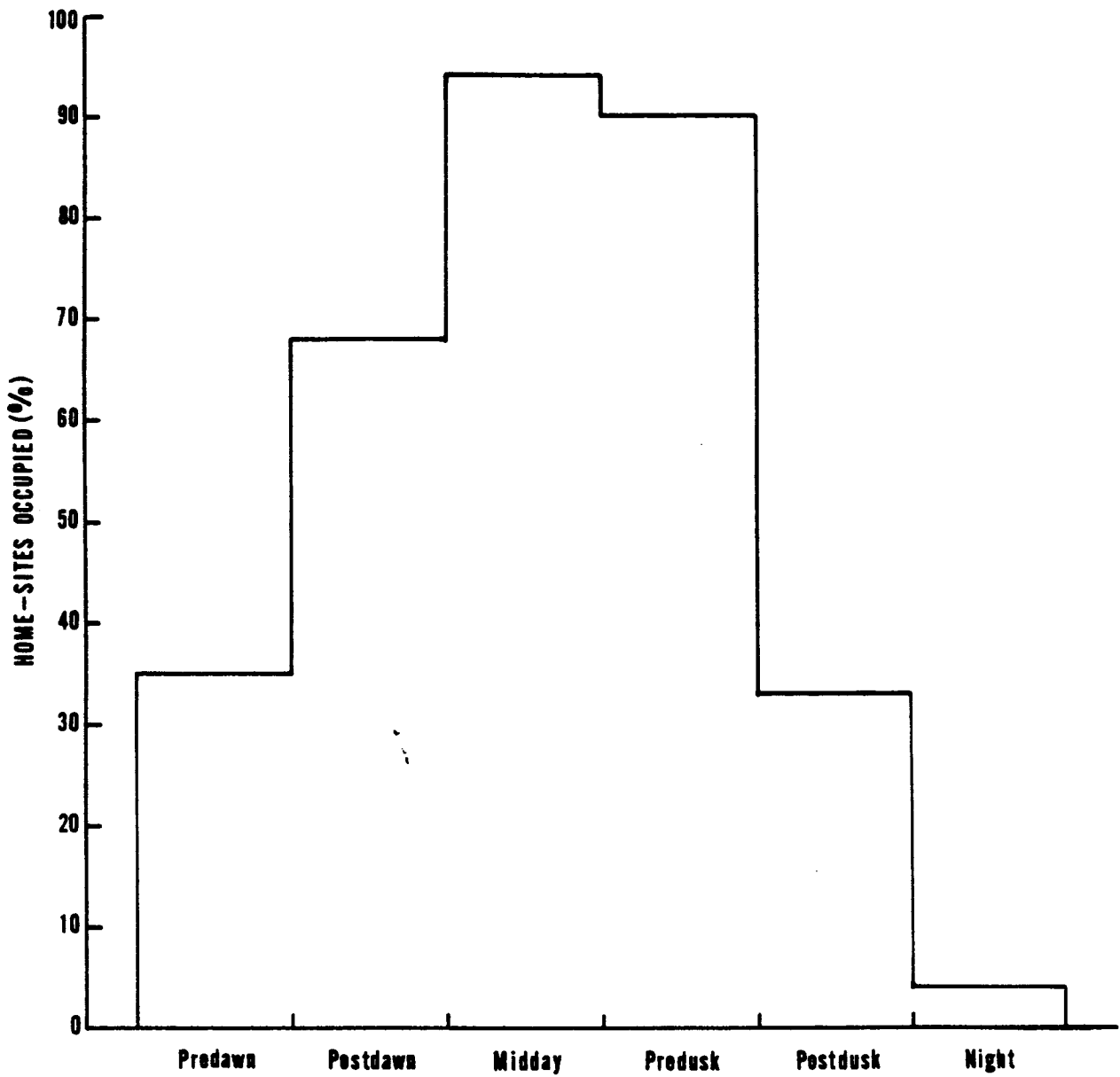
Figure 2.   Size-frequency (%) distributions of the test diameter
of _Diadema antillarum_ measured during the day (28 April 1983) and
night (4 May 1983).