

Chris:  
You tackled a difficult problem  
and carried out a well-conceived,  
integrated analysis. Your work has  
certainly shed light on part of the  
problem. A conclusion section at the  
end would have been helpful.

John

"The sea urchin is a MOST voracious  
AND promiscuous feeder  
always ready to eat..." T.R. Jones 1858

Chris Copeland  
Prof J.J. Colbert  
March 4 1980  
Discovery Bay Jamaica

The predominance of Diadema antillarum on the reef is undeniable. As a generalist grazer its high densities have profound effects on the entire reef community. SARMARCO (1978) has shown that any density of D. antillarum will decrease algal biomass. However, at low or zero levels algae do so well they choke out the coral causing gross adult mortality and preventing any future benthic larvae from settling. High densities crop the substrate so closely the coral is killed directly and larvae get nipped, too. Hunter (1977) and this paper show Diadema to be a major factor in  $\text{CaCO}_3$  cycling and overall reef growth as well.

The factors controlling its distribution and abundance thus become of prime concern. In this vein several observations are made

- ① Diadema become smaller as depth increases
- ② Diadema are restricted to shallow waters
- ③ Diadema are especially abundant in a zone of the reef devoid of

④ The density of Diadema appears to change with depth.

By knowing the limiting mechanisms impinging on an organism we are better able to understand how that organism functions ~~and~~ below its limits. Three prime factors come immediately to mind:

① food

② predation

③ physical conditions

As predators on the Diadema are supposedly rare at Discovery Bay, predation was initially dismissed as the prime mover. One would expect physical conditions to be very important yet the barren zone in which Diadema has the highest density (biomass) is an area of great physical disturbance (surge). Food was then thought to be a good bet as the controlling factor in Diadema distribution/abundance.

## METHODS

DATA CONSISTS OF TWO SETS. One quantifies the observed phenomenon ( $\Delta$  in density and size distributions of Diadema) and the other attempts to ~~measure~~ <sup>elucidate</sup> relevant mechanisms for these phenomenon. DATA thus consisted of four major parts: size and weight distributions, densities, organic content of food and ~~absorption~~ <sup>assimilation</sup> absorption efficiencies, and visual analysis of gut contents.

Density was assessed using a 2m x 1m plot, counting urchins, and repeating until an adequate sample size had been reached. In the Back reef site coral islands pock the flat sand. Here numbers of urchins on island and size of island were measured. To obtain an overall density measure for this highly patchy area a 20m x 30m Rectangle was counted. Densities were obtained for EAST Back Reef, Barren zone, Mixed zone, and edge of Acropora cervicornis zone.

Choice of sites: As Diadema may be a factor in coral reef zonation, Diadema populations were characterised for

each of the different zones along the fore reef. Lack of change in the Diadema community with a change in the coral community would indicate Diadema was not responsible for the change in zonation, at least not solely. Of particulate interest is the "Barren zone" which may be a direct result of grazing by D. antillarum.

Size and weight distributions. As densities are often of less ecological importance than biomass, ~~and as~~ size and weight distributions were also measured. This is especially true of grazing animals. The nature of the distribution also may shed light on the population dynamics of an organism by revealing cohorts, mortality, and possible reliance on allochthonous recruitment. Urchins were collected in the field, weighed and measured in the lab. At least 25 animals from each site were sampled. A pair of samples were also taken at the same site at different times of day - night to reveal any diurnal shift.

Feeding data 10 Diadema's from each site were brought back to the lab for dissection & micro-

③

scope analysis of gut contents. Urchins were dissected as soon as possible after capture although length of time for dissection made the last dissection some 6-7 hours after the first one. Samples of food pellets were obtained from the anus and the most forward part of the gut with pellets. The gut was slit, the test filled with water and pellets sucked out with a pipette or picked out with tweezers. Three to four samples from each site were analysed <sup>both fore-gut and hind-gut</sup> for relative abundances of gut contents. Pellets were broken up under the stereoscope, and gross percent cover by algae etc as well as identification were accomplished with the compound scope. Types that could not be identified were assigned OTU's corresponding with OTU designations used by Baldwin & Carlson so comparison between gut contents and abundance of types in the environment could be assessed. Pictures were drawn of each unidentified OTU and is inserted as an appendix.

The Organic content of food and absorption efficiency. Samples from beginning (ie 5th lobe) of gut and anus were dried at 60°C and subsequently ashed at 600°C, again until

until  
constant

constant weight was achieved, samples were weighed on a digital Mettler balance with an accuracy & precision to .001 gms. In this 70 <sup>replicated</sup> samples from the BAREN zone were made, as dry wt. in 3 was very small these were pooled with other ~~same~~ replicates. Of these 7 two never reached constant weight upon ashing so were rejected, 3 replicates were used for each of the other two sides, consisting in pooled samples to insure adequate sample size. After each drying or burning samples were cooled in a dessicator in a dehumidified ROOM. Weighing was done when samples had reached room temperature.

~~Proportion of~~ Organic content was calculated as  $\frac{\text{Ash free dry wt}}{\text{DRY WT}}$ . Assimilation efficiency was to be calculated as  $\frac{\text{ASH-FREE DRY WT ABSORBED}}{\text{ASH-FREE DRY WT INGESTED}} \times 100$

(Lawrence 1975).

Feeding MANIPULATIONS. To assess the propensity of Diadema to eat coral as observed by Bak and EVES (1973), octo wear down coral surfaces secondary as a product of its grazing (Sarmore <sup>et al</sup> (1973)). 12-15 Diadema

①

were placed in wire mesh enclosures at 20' in the barren zone and 12' in the East back reef. The two sites were chosen to see if Diadema would be ~~more~~ less apt to eat coral if an abundant alternate preferred

( ) food source was available: Thalassia testudinum & epiphytes. Diadema were also brought into the lab and kept in a tank with a variety of corals but no other food. One would expect amount of coral feeding to increase with scarcity of other foods & least in Back Reef → most in lab.

Observations were also made in the field noting ① Diadema grazing season/corals.  
② feeding behaviour of Diadema esp w/ its a vis substrate. Diadema was grazing ON.

## Results

### SITE DESCRIPTIONS

The East Back Reef is generally a flat shallow sandy bottom lagoon. Thalassia testudinum can grow in large beds and small ( $\approx 1\text{m}^2$ ) coral islands dot the sand.

Diadema is mostly restricted to these islands by day, venturing out at night. Triplaster is abundant in the sand and turtle grass seldom venturing onto the coral islands. Burrowing organisms such as seabiscuits, holothurians abound in the mud while the reef fish are tightly restricted to their respective islands.

Coming toward the reef crest the islands merge together and eventually form peninsulas connected to the main coral body of the reef crest. Tongues of sand still poke into the reef and form a barrier to Diadema distribution and movement. The second barrier and third substrate type are the Damselfish territories overgrown with algae. Diadema are completely excluded from these at least during the day. As opposed to all the other sites, the substrate is close to 100% covered and

9

much overgrowth is evident. Macroscopic Algae is abundant even outside Damselfish territories.

The reef crest drops off fairly sharply to this area - it is composed of a base of Acropora palmata which gives way to the mixed coral-sponge-zoanthid community, eventually giving way to the Tongues of SAND. A. cervicornis is abundant as small forms but not as massive networks of branches. GRAZING SCARS are <sup>abundant</sup> ~~abundant~~ <sup>M. gmelini</sup> ~~abundant~~

This site CAN be thought of as benign for the Diadema - food appears abundant and although surge is noticeable, the habitat is relatively calm. There are also <sup>abundant</sup> hiding places although many Diadema appeared in the open during the day.

The REEF CREST rises almost to the ~~sea~~ surface and is <sup>almost</sup> exclusively A. palmata. It is subject to much environmental stress - as wave surge, radiation, and occasional dessication. Many Massive corals (Diploria, etc) extend seaward until an abrupt boundary is reached with the barren zone.

The barren zone in this section of the reef is first encountered as a long sandy strip 20-30m wide depending on where it is intersected. It is totally bare, No living corals, No hard substrate, No Diadema. On the reef crest side, sparse dead coral blocks are populated only with Diadema which are packed extremely tightly under these blocks.

The SAND strip MAY be an extremely effective barrier to migration by Diadema <sup>into or out of the barren zone.</sup> Especially if Diadema can only travel 20m maximum per night (Braverman & Konigsberg). The coral also appears to have been killed in strips along its base - perhaps due to scouring by SAND. The area is obviously in a state of flux and equilibrium perspectives on its dynamics are likely to be misleading.

Towards sea the sand becomes thinner eventually turning into hard limestone with more frequent coral islands. Siderastrea is almost totally dominant with a brown hard encrusting sponge common - M. cavernosa, P. asteroides and

Palythoa are also present with M. annularis and Agaricia agarites both scarce. The bottom is  $\approx 90\%$  bare with the rest of the space as corals which appear evenly distributed.

Diadema is much less clumped than around the coral in sand and wanders over the open hard substrate. The increase in Diadema density from the nearly vacant sand is dramatic and appears closely tied to the appearance of hard substrate. Grazing scars are present on Agaricia, Millipora(?), and more especially M. annularis.

Nearing the 20' depth coral becomes thicker and open bottom steadily decreases. Siderastrea and the brown encrusting sponge give way to M. annularis and Agaricia in a seemingly tight correlation. Thus, the transition to the mixed zone is a gradual process, unlike the barren-reef crest interface.

This mixed assemblage of benthic organisms continues through the 45 foot level. At this depth A. cervicornis is commonplace but usually as dead branches

providing substrate and hiding places. <sup>It provides an average of 40-60% of the cover.</sup>  
The height of the coral is twice what it was at 20 feet and large standing sponges are taking a part in the community. Monastrea annularis is the dominant coral. Gorgonians are plentiful and hiding places couldn't possibly be in short supply.

The A. cervicornis gradually increases until the ground is 80-90% A. cervicornis much of which is alive. The environment seems to have lost some of its variability but none of its potential hiding places. There are, however, fewer Diadema.

Density estimates are presented in table 1 and Fig 1. Density is not a simple linear function of depth but increases steadily to the mixed zone 45', then drops abruptly in the A. cervicornis. Deeper than 65 feet Diadema are extremely scarce, if present at all. Echinometra and Lytechinus also seem to peak at the mixed zone.

Size distributions provide a slightly different story. Each depth is significantly different. Instead of peaking in the mixed

zone, sizes are largest in the Barren zone and actually smallest in the mixed zone. The absence of small whelms and the slightly bimodal distributions of areas outside the mixed zone are notable. Juveniles are either very secretive, <sup>1</sup>so to avoiding daytime collection, <sup>2</sup>or those areas are dependent on others for their recruitment, or <sup>3</sup>mortality is high for these young and many years few or none will survive, then in an exceptional year (low predators, or especially favorable physical conditions) the entire juvenile class survives creating a noticeable cohort in the adult population, this is known to be the case with barnacles in the intertidal (Connell 1961) and implies the young must reach a critical size after which they are invulnerable. Such a strategy may also explain the extreme secretive-ness of the tiny Diadema - once they have reached the invulnerable size, they may afford exposure. If such is the case with Diadema antillarum, the differences between the 45' and 20' size distributions

(14)

could be due to a <sup>recent</sup> successful recruitment in the 40 foot area while one has not occurred recently in any of the areas. However, it is hard to believe the East Back Reef

would have been so unsuccessful for the time required to have no individuals  $\geq 20$  grams.

Either young are hatching very well or out migration of young is occurring on a one way street.

Although urchins have to be small sometime, a set of urchins doesn't have to have large individuals or to have been part of a group of larger individuals. Thus it is entirely possible Dradema simply cannot get larger than 36gms in the barren-mixed zone.

Such an absolute limit would be due to food gathering ability?

① predation ~~assumes~~

③ environmental extremes.

The first of these was assessed in this study. Size was <sup>also</sup> measured by test diameter. All samples again are statistically different. They present the same pattern as weights but are

(19)

more tightly clumped and do not exhibit any bimodality.

Now Biomass per unit area can be assessed - As urchins are smallest where they are most dense, the Biomass per unit area peaks in the BARREN ZONE.

### Food

The percent organics in the gut contents WAS found to vary very little between different habitats or ingestion and excretion. Results were however very precise with an overall mean of  $46.58 \pm 3.2\%$  in the fifth lobe of the gut and  $44.57 \pm 3.79\%$  in the anus. These are NOT statistically different. They are also in close agreement with visual estimates of Algae, detritus or sand and coral (see Table 3-6)

Although ashing did not reveal any differences in the organic proportion of gut contents from different habitats, a microscopic examination of pellets revealed substantial differences. 48 overall categories were found on the examination of 9 urchins (see listing and drawings in appendix). Generally,

algae was fairly common in the barren zone dominated by CRUSTOSERES and filamentous greens. DATA From Baldwin, Carlsen on the abundances of algae at 25, 45, 85 feet outside Damselfish territories shows Encrusting Reds providing  $43 \pm 31\%$  of the cover, ~~whereas~~ filamentous greens are also at their highest % cover of any depth  $10 \pm 8.6\%$ . These both correlate well with contents of the Diadema gut, ~~thus~~ this indicates Diadema may be fairly nonselective at this depth. However, Herposiphonia is fairly abundant in the gut but not even encountered in the environment samplings. Herposiphonia was also the most highly preferred alga for D. antillarum at St Croix (Atkinson, Hopley, Mendelson, Yacowitz 1973).

Paradoxically, the mixed zone which appears richer in algal food for Diadema and has less sand is where gut contents are the sparsest. There are only isolated bits of filamentous algae and a general increase in rocky content. Although the algal composition goes down, consistent samples of spicules, zooxanthellae,

and spongia are found. This is highly suggestive Diadema is eating sponges and would correspond with their greater abundance in the environment. There is also an abundance of Diadema spines, pedicellariae, and tube feet sometimes comprising up to 25% of the pellets. These might be associated with the very high densities at this depth (22/m<sup>2</sup>) and related intraspecific aggression. In contrast to what was found in the environment, Lyngbya is abundant in the gut and few ~~few~~ crustose reds occur in the gut even though they comprise 34% of the cover in situ.

The back reef again follows the distribution in situ. Filamentous Reds are dominant, while crustose reds are common but not near dominance. Filamentous Reds esp. Coelothrix irregularis are cultivated by damselfish in the back reef and although the 3 spot damselfish excludes Diadema from these lawns (Stahmer 1978), there are decent growths outside the lawns.

One further point on algal distributions  
 § Diadema: At 85 feet below the lower  
 limit of Diadema, Cladophora, Lyngbya,  
Coelothrix irregularis, Ceramium, Herposiphonia,  
Polysiphonia, Dictyota § Pocockiella are all  
 abundant in situ for the first time.  
 These are all preferred algae for Diadema  
 as determined by Mendelson et al. All  
 but Cladophora § Pocockiella were also  
 found in the guts at 245 or 15 feet  
 when they were not found in the environment,  
 further attesting to their preferability.

This seems very strong evidence  
 that food is not what limits the depth  
 of Diadema and probably its size decrease  
 as well - Abundant preferred food is available  
 but Diadema does not expand into these  
 deep areas to exploit it. Coupled with the  
 lack of differences in organic content  
 with depth, it is unlikely food is critical  
 in determining the distribution § size  
 variations in Diadema. The changes in  
 gut contents with depth seem to be  
 interpretable in terms of a <sup>generally</sup> nonselective

feeding strategy which does however select for certain especially choice items such as Herposiphonia. See also caveats of Algal sampling technique in appendix. This is not to say that in situations of high algal abundances as in <sup>the</sup> St. Croix study Diadema would not be selective. In fact, Diadema is probably being fairly selective in the lush Back Reef but no in situ census was taken. This is in agreement with Highton (1966, 1971) who concluded "that the grazing of Strongylocentrotus purpuratus and S. franciscanus is selective under conditions of abundant food ~~to~~ supply, but that selectivity disappears when grazing pressures become intense."

Now that my original hypothesis has been rejected (that food was the prime ~~move~~ factor controlling Diadema distribution and size) I am at a loss of data to speculate further. However, we may look into the relation of Diadema and the barren zone. A grazer such as Diadema has possibilities for affecting the sessile benthos. Most are deleterious at high levels of grazing, two are deleterious at low or no level of grazing and these two are beneficial at ~~high~~ intermediate levels.

- ① The Diadema can eat live coral (Bak & van Eys 1975; Kinzie 1972),
- ② it can grind down the dead coral heads thereby reducing the substrate available for settling (Sammacco et al. 1974, Hunter 1977),
- ③ it can prevent the planula from settling or prey on juveniles before they reach the critical invulnerable size (Sammacco 1978, Reizweiz),
- ④ it can graze on the algae and so reduce competition for the corals (Sammacco 1978, Dart 1973, UAYAS 1977).

~~What~~ ~~may~~ Evidence.

possibly ~~increase~~ was collected <sup>in this study</sup> for all four aspects of these relations. (1) a) Scars from grazing, were found consistently on M. annularis, b) an entire coral polyp was found in the fourth lobe of Diadema, vital zooxanthellae were also consistently ~~found~~ found, c) the results of the enclosure experiment found M. annularis scarred, all others were intact, No M. annularis had been put in the shallow Back Reef enclosure and what animals there were were ~~looking~~ somewhat coated with mucus & sediment. The lab test also revealed M. annularis and A. palmata were eaten, d) spongy pellets chock full of spicules were ingested. #2. There were fresh coral ~~fish~~ chips in the gut indicating bioerosion. The lab & field tests uphold this as well. Diadema is also almost always on dead coral so if it is to graze it is bound to scrape away bits of  $CaCO_3$  if even by accident. #3. Hindrance of settling by larvae is substantiated (?) as I am 95% sure I SAW A planula larvae in my wheel

(Bergquist; similar, Hyman Vol 1) ~~pg~~ used for identification. How it got in is a mystery.

Extence of 4 - choking of coral by ungrazed algae is shown by the state of damselfish territories.

It has been shown in Barbados (Hunter 1977) that Diadema antillarum <sup>alone</sup> can actually break down the reef as fast as it is being built up by both corals and coralline alga.

see blue ink pages.

Clearly such rates are critically important in the cycling of  $\text{CaCO}_3$  on the reef and the reef building process.

But is it enough to produce or maintain the barren zone? It seems <sup>intuitively</sup> that this bio-erosion did not account for the

original production of the barren zone,

but now plays the key role in keeping it clear of settling larvae. Why the lower border to the barren zone?

In a fit of rampant speculation, I might

suggest that the maintenance of a bare zone relies on a certain critical level of erosion. When the Diadema biomass/m<sup>2</sup> is high, the Diadema is able to surpass this critical level of erosion and keep the zone bare. However, as Diadema biomass/m<sup>2</sup> decreases with depth it can no longer meet this critical bioerosion level and the substrate is colonized by corals. What causes the Diadema to decrease in size with depth and change densities in the first place is still unresolved.

In conclusion, food was thought to control Diadema distributions and sizes, but was rejected in the light of

- 1) copious food where Diadema don't exist

- 2) no change in food quality as expressed by organic matter with depth.

However, algal turnover rates may be very low at depth and incapable of maintaining grazers.

The actual bio erosion caused by Diadema antillarum in different areas of this reef can be estimated. By comparing this rate with known rates of  $\text{CaCO}_3$  accretion on the fore reef at Discovery Bay (Meadey, 1973), a measure of the importance of Diadema in  $\text{CaCO}_3$  cycling and substrate availability can be assessed. Stearn and Scottin<sup>(1976)</sup> have derived a table relating daily <sup>erosion</sup> production of  $\text{CaCO}_3$  by Diadema with size class. By this was derived from 1733 individuals found in a wide variety of rocky substrate habitats, and is assumed to be representative for D. antillarum at Discovery Bay.

Size range mm	$\text{CaCO}_3$ gm/day/individual
5-10	
10-20	0.305
20-30	0.655
30-40	1.953
40-50	5.035
50-60	7.405

By using this data on the size distributions established here and compensating for density observed, gms  $\text{CaCO}_3$  /  $\text{m}^2$  / day is found for each reef site. One then multiplies this by the fraction freshly chipped coral is of total  $\text{CaCO}_3$  ingested and the figure for bioerosion is reached.

why exclude consolidated  $\text{CaCO}_3$  rock?

The percentage of  $CaCO_3$  ingested which is fresh coral can be taken from observations of relative proportions found in the *Diadema* dissected. However with sample sizes ranging from only two to four in each case variability is apt to be so high no adequate characterization of % coral can be reached. This is due to the patchy distribution of substrate types on the reef and the slow movement of *Diadema* between patches. Hunter (1977) has means for 23 *Diadema* taken from a fringing reef in Barbados. His data however differs from ours in that a mean of 30% by wt.  $CaCO_3$  of the fecal pellets are made up of coralline algae. Detritus is either not counted or <sup>is</sup> plays a minor ~~to~~ constituent of the *Diadema* diet. A constant percentage of coral flakes & coral flakes & sand may be arbitrarily defined as .50. This is generally in line with my observations and is close to the 57% value of carbonate as new sediment Hunter offers.

			Accretion of $CaCO_3$	Bioerosion Accretion
	Bioerosion by <i>D. antillarum</i>		Mixed Acrocorals	
Back reef	observed (94) $8.8 \times 10^3 \text{ g/m}^2/\text{yr}$			67.7%
	S conversion $4.7 \times 10^3 \text{ g/m}^2/\text{yr}$		$13 \times 10^3$	36.1%
Batten zone	observed (46) $9.49 \times 10^3 \text{ g/m}^2/\text{yr}$			12.3%
				3.5%
Mixed zone	conversion observed (64) $4.56 \times 10^3$			25.2%
	S conversion $3.28 \times 10^3$			

## References

- Reef 1910 CONTRIBUTIONS TO THE PHYSIOLOGY OF MARINE  
INVERTEBRATES, JOURNAL OF Physiology 39 in Hyman  
The Invertebrates vol W pg 565.
- Lewis JB 1964 Can. J. Zool. 42: 549-557  
Feeding and digestion in the tropical sea  
urchin Diadema antillarum Philippi
- Hunter J & 1977 Sediment Production by Diadema  
antillarum on a Barbados fringing reef  
Proc. Third Int Coral Reef Symp May 1977  
106-109
- Stearns CW, Scott WA, Martindale W 1977a Calcium  
Carbonate budget of a fringing reef on the  
west coast of Barbados. Pt. I zonation &  
productivity 479-511 Bull. Mar. Sci 27: 499-511
- Bergquist PR & Sinclair ME The morphology &  
Behaviour of <sup>larvae of</sup> some intertidal sponges  
NZ JI MAR Freshwater Res 2: 426-37
- Frost SH 1977 Ecological controls of Caribbean  
and Mediterranean Oligocene Reef coral  
communities. Proc. Third Int Coral Reef  
Symp. May 1977 367-373
- Ridzie 1972 The zonation of West Indian  
Octo corals Bull Mar. Sci 23 pg 93-155
- Stearns & Scott WA 1977b Carbonate budget on a fringing  
reef, Barbados Proc 3rd Int Symp Coral  
Reef Symposium May 1977 pg 474  
472-476

Atkinson, Hopley, Mendelsohn, Yacovitz 1973 "Food Studies  
on Diadema Antillarum on a Patch Reef,  
St. Croix "in Studies of the Activity & Food of the Echinoid  
Diadema antillarum Phillippi on a West Indian  
patch reef.

Stahmer Sarah 1978 A study <sup>of</sup> ~~between~~ the Interactions  
between two species of damselfish and the sea urchin Diadema  
Dartmouth Tropical Biology Program

Leighton 1966 Pacif. Sci 20: 109-113

1971 Nova Hedwigia 32: 421-453

in Lawrence JM Marine Plant & Sea Urchin  
Relationships Oceanogr. Mar. Biol Ann Rev  
13 (213-286) pg 233

Persueg HM The population dynamics of  
Three Jamaican Demospongiae.

Sammarco 1978 PhD dissertation abstract.

DARCY 1973 ECHINOIDS, Algal Lawn, and Recolon-  
ization (NATURE)

HYMAN L 1996 The Invertebrates vol 1 pg 251-252  
433-434

Table 2

## Size DATA

	weight (gms)	TEST DIAMETER (CM)	BIOMASS/AREA gms/m <sup>2</sup>
EAST BACK REEF NEW CRUST	33.4 ± 10.4	3.78 ± .47	<del>537.7</del> <del>284</del> 248.8
Barren Zone 5:00 PM	38.1 ±	3.98 ± .44	613.4
11:00 PM	40.8 ± <del>13.63</del>	3.63 ± .67	
Mixed Zone Interface	20.63 ± 6.68	3.24 ± .40	
Mixed	15.6 ± <del>2.46</del>	2.46 ± .62	343.2
EDGE OF A. LUTICORNIS	11.75 ± <del>2.9</del>	2.94 ± .41	140.4

# Density Estimates

TABLE 1

## EAST BACK REEF

## DIADEMA

All SD between 2 m<sup>2</sup> subsamples

## ECHINOMETRA

## LYTECHINUS

>100m FROM REEF CREST	coral islands	9				
		5.64 m <sup>2</sup>	7.7/m <sup>2</sup>	3.59	(not sampled)	
	rubble patch	12.5 m <sup>2</sup>	1.5/m <sup>2</sup>			
	RANDOM 20Mx30M	600 m <sup>2</sup>	0.14/m <sup>2</sup>			
	FRINGE OF REEF CRST-NO SAND	70 m <sup>2</sup>	7.45/m <sup>2</sup>	6.3	0.69/m <sup>2</sup> SD=1.13	0.17/m <sup>2</sup> ?

## EAST FORE REEF

BARREN ZONE 10-12' deep

72 m<sup>2</sup> 16.1/m<sup>2</sup> 10.3

MIXED ZONE 40-45' 24 m<sup>2</sup> 22.0/m<sup>2</sup> 15.6 6.0/m<sup>2</sup> SD=9.9 2.4/m<sup>2</sup> SD=5.6

Edge of A. cervicornis 50-55' 12 m<sup>2</sup> 12.0/m<sup>2</sup> 9.8 4.2/m<sup>2</sup> 3.8/m<sup>2</sup> SD=6.7

0 to 1 per 200 sq. dm.

EXTREMELY SCARCE (S. Crawford, J. Baldwin pers. comm.)

DEEP 70-90'

Fig 1

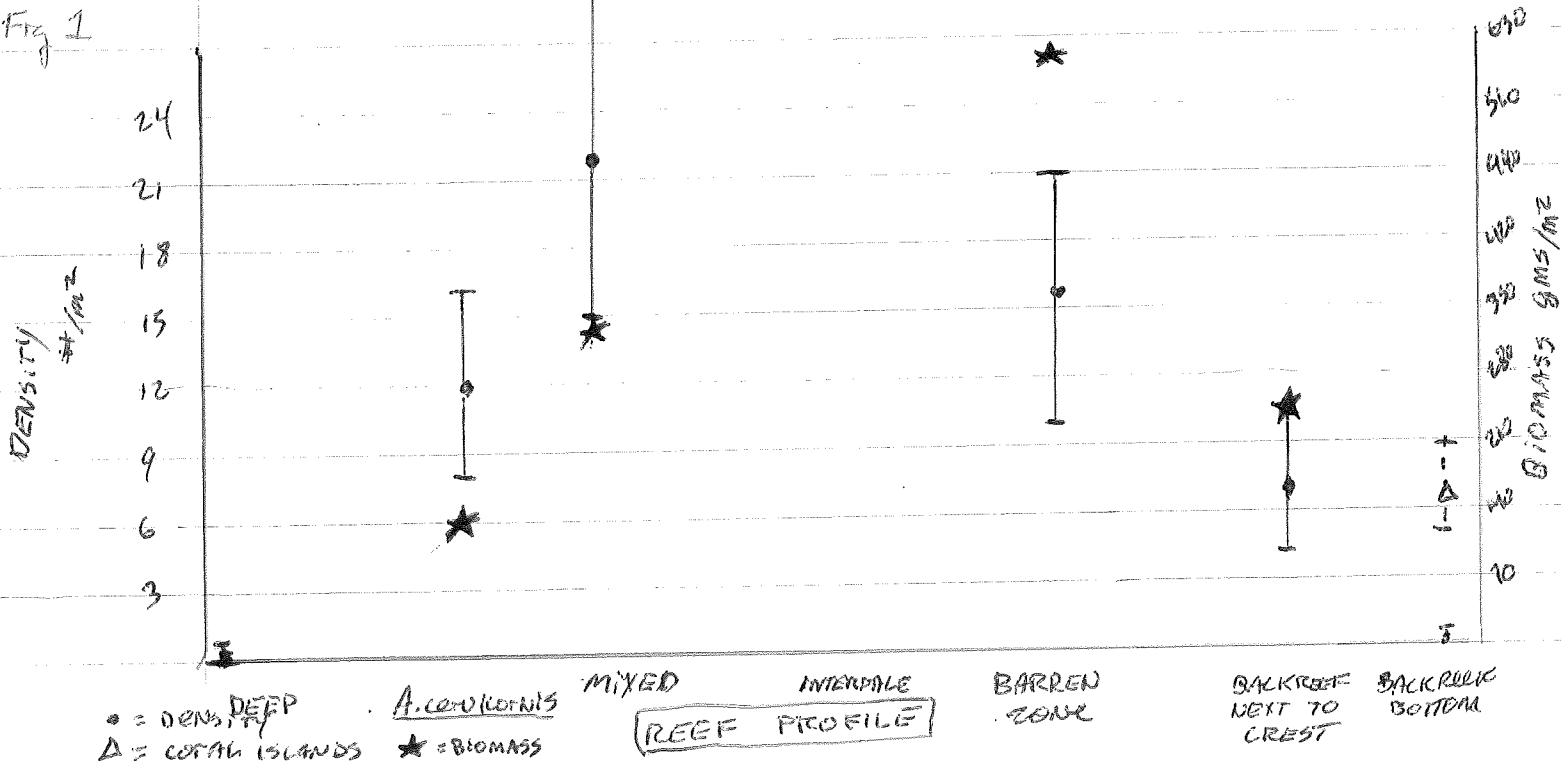


Fig 2

# DISTRIBUTION OF WEIGHT CLASSES

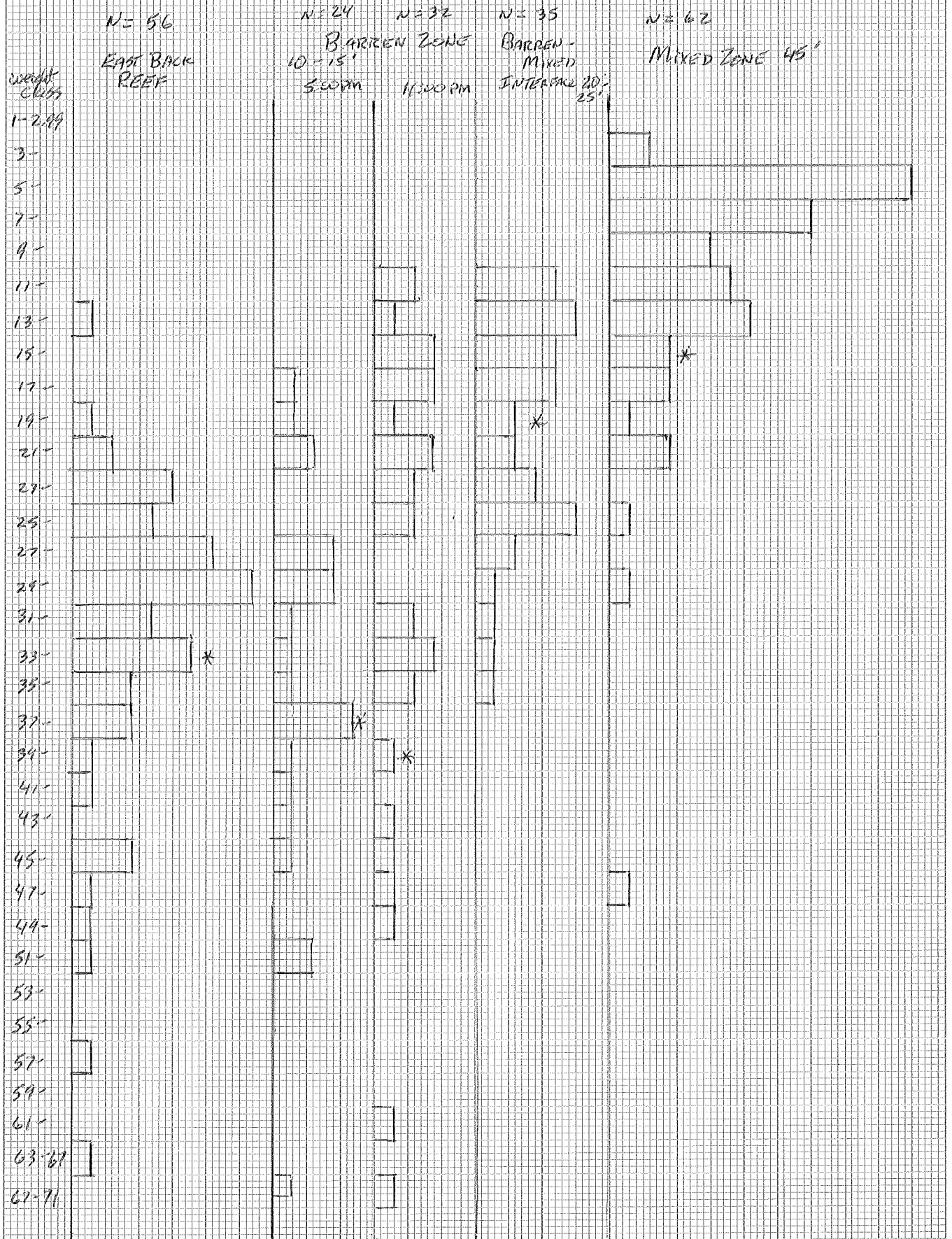
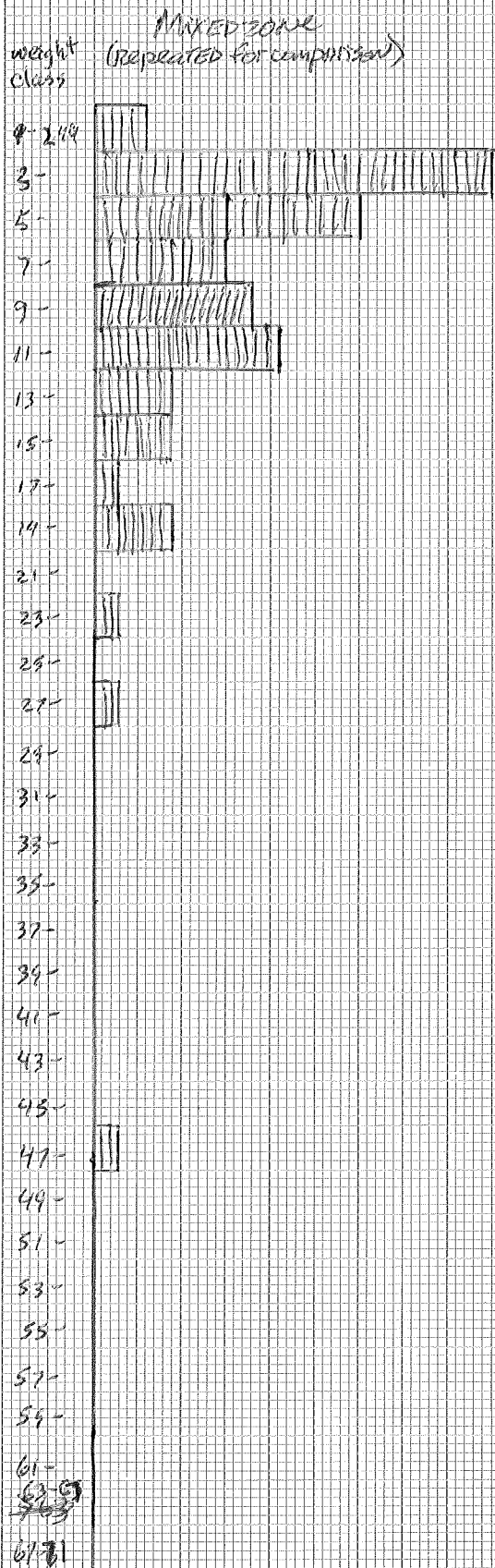
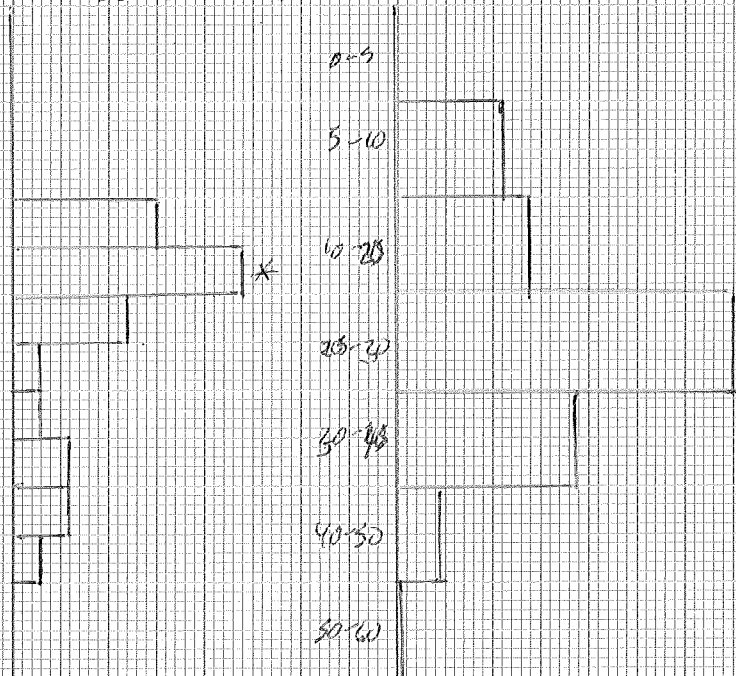


Fig 2 (cont)



Border of A. COVILLO'S  
ZONE 50-55'



Size DISTRIBUTION  
TEST DIAMETER (mm)  
Each square = 5000  
N = 1733

DRAWN FROM  
STEIN & SCORIN 1977b

# ORGANIC COMPONENTS OF BUT LORRAINS

Organics

TABLE 3 Set 1 Batten zone

	Dry wt	Ash wt	Ash free x Dry weight	Ash free dry wt dry wt
lobes				
	.174	.098	.077	44.25 %
	.427	.237	.190	44.50 %
	.361	.200	.161	44.60 %
	.380	.205	.175	46.05 %
	.105	.053	.052	49.52 %
				$\bar{x} = 45.78 \pm 2.20$

lobes 10

	.149	.075	.074	49.66 %
	.368	.200	.168	45.65 %
	.241	.133	.108	44.81 %
	.275	.144	.131	47.64 %
	.105	.053	.052	49.52 %

$$\bar{x} = 47.46 \pm 2.20$$

lobes 11 habitats :

lobes 11

$$46.58 \pm 3.20$$

lobes 12

$$44.57 \pm 3.79$$

weights in grams

TABLE 4 Set 2 Back Reef

	Dry wt	Ash wt	Ash-free Dry wt	Ash-free Dry wt / Dry wt
<u>lobe 5</u>				
2+4	.292	.163	.129	44.18 %
1+3	.506	.230	.276	54.55 %
5	.116	.063	.053	45.69 %
<u>lobe 10</u>				$\bar{x} = 48.14 \pm 5.60$

2+4	.570	.354	.216	37.89 %
1+3	.456	.274	.182	39.91 %
5	.215	.118	.097	45.12 %
				$\bar{x} = 40.97 \pm 3.73$

TABLE 5 Set 3 Fore Reef

lobe 5

1+2	.182	.093	.089	48.90 %
3+4	.187	.103	.084	44.92 %
5+6	.573	.314	.259	45.20 %
				$\bar{x} = 46.34 \pm 2.22$

lobe 10

1+2	.117	.064	.053	45.30
3+4	.374	.212	.152	40.64
5+6	.399	.223	.176	44.11
				$\bar{x} = 43.35 \pm 2.42$

# Core Analysis

## BATREN

FORAMS - NOT DIGESTED

CRUSTOSE RED - digested

Herposiphonia

Oscillatoria

Filamentous greens 3 of 4 sections all cases very abundant

3 species

## Poly P

## MIXED

Paucity of filamentous algae

No forams

\* abundance of spicules; spongy pellers

abundance of diadema parts

Lynbya as base

General increase in rocky content.

zooxanthellae & endolithic algae

## Back Reef

CRUSTOSE RED common but NOT dominant

Oscillatoria; Lynbya continue to be imp.

2 out of 3 w/ spicules!

## SPINES

FILAMENTOUS REDS DOMINANT.

doesn't coincide well w/ Bill & Jan's assay  
indicating Uchima may be selective

# 48 categories

## Cont ANALYSIS

No Differences

5<sup>th</sup> 10<sup>th</sup> lobe

Zooxanthellae 3 urchins

Crystalline spicules 3

Sponge 6

every mixed zone

Spongin 1

Forams BARREN zone

Bluegreens

5 types

Browns

Lyngbya

Oscillatoria

Stigonematales  
type a

type b

colonial

Dictyota

ENCrusting

Zooxanthellae

Diatoms

Greens 7

coenocytic green

filamentous b

filamentous c

filamentous a

endolithic

Ceramium

Halimeda

Reds

13 types

Crustose

coralline A

filamentous A

Herposiphonia

Filamentous C

Filamentous B

Polysiphonia

Laurencia

Type E filamentous

Filamentous D

Siphonaceous

Filamentous F

pencil only = some live, some DEAD  
some partly degenerate

☐ = mostly alive

☐ = dead

+ present

1 uncommon

2 moderately common

3 very common

based on  
biomass,  
not just  
individuals

# Core Analysis - Abundance scales

Bare

Type

Barren Zone

Mixed Zone

Back Reef

		1	2	3	✓ 5	✓ 1	✓ 2	✓ 3	✓ 4	✓ 2	✓ 3	✓ 1	3
gastropod	+	+		+	+								+
forams	+	2	3	2	2								
ciliates	+	+	+										
DIATOMS	+	1	1	+	+					+	1	1	
coralline red	✓	1											
Lyngbya	✓	2			1			1	2	+	2		
crustose red	✓	+		2	2	3				3			2
eggs	1	+			+								
<del>Hydrozoa</del>	+	+											
caenocytic green	✓									+			
filamentous red			+	1	2								
leptorhiza	✓		3					2					
dictyota	✓		1							1			
scabatoria	✓		2	2	3			1		3			
<del>unknown red</del>													
<del>degenerate</del>													
filamentous green	✓		3	3									
ERAMIA	✓	2											
picules				+	+			+	1				
gorgonian	+			+	+			+	3	+			+
sponge				+	+	+	2	+	3	+			
NEURONIA				2									
STIGMONOMERIS	✓												
blue green type	1				2								
lamellaria	✓				1			2					
CRUSTACEAN	1				1			+					

# Back reef

[illegible]

# In situ Algal abundances

From Baldwin & Carlsen

Types ranked 1-5 on presence/absence in 5 samples

	25'		45'		85'	
	presence Absence rank	%	presence absence rank	% cover	presence Absence rank	% cover
<u>Bluegreens</u> - unknown	4	>1%	2	1 ± 2.2	0	33 ± 41%
Lyngbya	0		0		2	
<u>Greens</u>		10 ± 8.6		7.4 ± 10		3.33 ± 5.11
Filamentous greens						
Cladophora	0		0		3	
Halimeda sinubus	0		0		2	
H. tuna	0		0		4	
Percellus dimidiatus	0		0		1	
Udotea confertifolia	0		0		1	
Valonia verticosa	0		1		0	
Unknown coarctate	1		2		0	
<u>Reds</u>		<1%		9.6 ± 13		1.6 ± 7.6
Filamentous Reds		43 ± 31		34 ± 21		5 ± 1.3
Live Encrusting Reds						
Amphicarpia <del>sp.</del>	0		0		1	
Corallina sp. <del>Gelidium</del>	0		0		1	
Ceramium <del>Gelidium</del>	0		0		5	
Coelothrix irregularis	2		1		1	
Erythrocladum	0		0		1	
Galaxaura cylindrica	0		0		2	
Herposiphonia	0		0		1	
Polydora	0		0		2	

	presence	25%	presence	45%	presence	85%
Unknown Filamentous Red	0		3		2	
Unknown Calcareous Crust	0		0		1	
Pink	5		3		3	
Red	0		3		4	
Type 1 Fuzz	0		0		4	

### BROWNS

<i>Dicoryora diuaneata</i>	0	0	2
<i>Dilophus alternans</i>	0	0	2
<i>Pocockiella variegata</i>	0	0	3
<i>Sargassum polyceratum</i>	0	0	3

### Petrus

6.6 ± 1.1

6 ± 10.3

?

less detritus on algae at 85 feet although plenty in sand,

## METHOD OF ASSESSMENT OF ALGAL COVER - Baldwin & Carson

5 samples taken from each area

examined under dissecting scope for

relative composition by gross taxonomic unit

individual species identified under compound scope. areas are approximately the size of a damselfish territory (24" x 36") and samples are taken from all over the area but consist mostly in A. cervicornis tips as these were feasible to collect.

Thus two caveats on samples:

① MAY get bias on tips as they are exposed habitats and may be differently susceptible to grazing or wave disturbance.

② Algae on the reef MAY be distributed in patches 1m<sup>2</sup> or larger. if this is so, the species found in this sample may not be representative of algae growing at that depth. For instance, Herposiphonia may ~~be~~ account for 80% of the filamentous algae on the reef, but, due to a mosaic distribution, is absent from the small area of the sample. A better sampling method would be to take the five samples from an area with a wide radius, say 50 meters.

Items of Note on algal composition with depth

① MANY FORMS MOST ABUNDANT IN SEA URCHINS are NOT seen at the depth the urchins are found.

implies either a) urchins very selective

b) sample biased or ~~not~~ or

c) result of patchy algal distribution

d) urchins move from one depth to

another readily

The samples were <sup>② see only on drift material</sup> ~~thoroughly~~ thoroughly and carefully analyzed so are representative of the area from

which they were taken, eliminating b & c has been discussed as a possibility. d is unlikely in that urchins at 45, 25 and 12 feet contained algae only found in the 85 foot zone.

Braverman & Koenigsberg reports Diadema can travel a maximum of 10 meters from a patch reef in order to return, that puts travel at 10 meters per 6 hours.

gut contents were present ~~probably~~ <sup>8-12 hours</sup> ~~12 to 24 hours~~ after ingestion (~~Boesman~~, Lewis 1964, ~~C. Fabree~~) giving the maximum

distance an alga could have come from

about ~~20~~ <sup>30</sup> meters. Clearly not enough to account for the observed discrepancies.