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BIOMONITORING STUDY OF MUNICIPAL SEWAGE IMPACTS ON SELECTED CORALS

Red Point Sewage Outfall
St. Thomas, U.S. Virgin Islands

[In support of 301(h) Waiver Application
of the Virgin Islands Port Authority
to the U.S. Environmental Protection Agency]

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

This report by the Island Resources Foundation for Maguire Group, Inc., concludes the three-month biological monitoring program carried out as part of a 301(h) waiver application (required by U.S. Environmental Protection Agency [EPA]). The study area is immediately west of the airport at Red Point, which is located in the southwestern portion of St. Thomas in the U.S. Virgin Islands. The biomonitoring program itself was developed at the request of U.S. EPA Region II 301(h) Review Team, in a cooperative effort involving the Review Team; the U.S. EPA Office of Research and Development in Narragansett, Rhode Island; the Maguire Group, Inc., consultants to the Virgin Islands Department of Public Works; and biological consultants in the Virgin Islands including Shoreline Associates and Island Resources Foundation.

In order to evaluate the stress caused by the effluent from the Red Point sewer outfall on the surrounding biological community, several experiments using whole, live organisms were set-up. Six experimental platforms were set up; four platforms were placed in the outfall area, one in Brewers Bay, and one in Perseverance Bay (the control site, presumably uncontaminated by outfall effluent). The organisms selected for the biomonitoring experiment represent a variety of sensitive indicators of water quality in the area.

Montastrea annularis was selected for this study because of its tolerance to high sedimentation and because its growth rate has been shown to be related to water quality variables. The effect of water quality on the growth rate of M. annularis was studied in depth by Tomascik and Sander (1985). They concluded, after evaluating fourteen environmental variables, that growth rate exhibits a high correlation with a number of water quality variables. Suspended particulate matter was the best univariate estimator of M. annularis skeletal extension rates. Therefore, one of the environmental variables selected to be measured in this study was total suspended solids.

Acropora cervicornis is very sensitive to sedimentation. Both survival and growth rate are expected to vary dramatically with changes in water quality. Acropora cervicornis was chosen for the study as it is an early indicator of deteriorating water quality, especially increases in sedimentation and subsequent light level reduction.

Corals are very sensitive to even small increases in the amount of sediment which fall on them. Corals must expend large amounts of energy to rid themselves of this sediment to survive. To quantify sedimentation rates found at the six platforms, sediment traps were installed.

In addition to measuring sedimentation rates, the total amount of organic carbon was also measured at each platform. An elevated level of organic carbon would indicate an accumulation of organic material in bottom sediments.

The long-term viability of a coral community is dependent on successful coral recruitment. Altering the amount of nutrients and particulate material in the surrounding waters could effect coral recruitment. Increasing nutrient loads could promote the growth and reproduction of algae, which compete directly with coral larvae for space. Decreasing light levels, increasing sedimentation or toxicity could stress corals, decreasing the energy available for reproduction. Because of these concerns, EPA requested relative coral recruitment data be collected. It was realized from the beginning however, that due to the short duration of the study, it was unlikely that we would obtain any coral settlement.

Algal growth and species composition change in response to nutrient enrichment. To examine possible differences in algal growth and species composition due to the effluent, the biomass of algal turfs taken from coral rubble and settling plates were analyzed. Algal turfs are the most productive components of shallow coral reef communities.

At the request of EPA Region II, an *in situ* toxicity test was performed using the red algae *Champia parvula*. Dr. Thursby of U.S. EPA Environmental Research and Development Laboratory in Narragansett, Rhode Island, has developed an *in vitro* toxicity test to assess chronic effect of pollutants to marine algal reproduction (Steele and Thursby, 1983). Using this test, the toxicity of effluents is evaluated by *C. parvula's* reproductive sensitivity.

METHODS

Experimental Site Selection

Six platform locations were selected. The approximate location of the platforms was determined by an agreement between the Maguire Group and EPA Region II officials (file memo dated March 24, 1987 by Bruce Bender [CE Maguire]). Perseverance Bay was selected as the control

site (Platform 1) and also the collection site for all coral and algae samples to be used at all the experimental sites. A second site was established in Brewers Bay (Platform 2) presumably also uncontaminated by outfall effluent, but subject to runoff from the airport construction. There were four sites in the vicinity of the outfall: 3 platforms in a transect along the 30 ft contour of Red Point reef (Platforms 3, 4 and 5) and one near the outfall in the plume 150 ft west of the diffuser (Platform 6). Platform 6, considered as the worst-case control, was anchored in 65 ft depth of water with the platform parallel to the bottom at approximately 40 ft depth from the surface. Platform 3 was in the plume, but north, near the on-going airport construction. Platforms 4 and 5 were on the 30 ft contour but south of the diffuser. Platform 5 represents the closest reef area at Red Point, south of the diffuser.

Six Lexan platforms 4 ft X 4 ft were anchored to the bottom, one at the control site and five at experimental sites. The approximate location of these platforms is shown in Figure 1. These biologically inert platforms were anchored parallel to the bottom. Five of the platforms were anchored using bags of cement while the sixth was suspended using screw anchors and a buoy. Coral and algae samples were mounted directly on each platform.

Coral Growth

Seventy-two specimens of Montastrea annularis (head form) were collected from Perseverance Bay on June 23-24, 1987. Each sample was greater than 150 cm^2 and they were all collected at approximately 30 ft depth of water (measurements taken on heads are found in Appendix I-A). The collection site is shown in Figure 2 (taken from Nichols and Towle, 1977). The heads were all left at a nearby worksite in 20 ft of water until stained. Figure 2 also shows the location of Platforms 1 and 2.

Sixty heads were stained on June 26, 1987, for distribution to Platforms 2 through 6 the following day. The heads were placed in gallon plastic Ziplock bags where 25 mg of Alizarin Red-S dye was released into the plastic bag from where it had been secured in a corner of the bag using a twist tie. Corals remained in the dye from 4 to 6 hours. The Alizarin dye was expected to be deposited in the coral during the calcification process and remain a permanent marker in the skeleton to later be used to measure growth (Gladfelter and Monahan, 1977). The remaining 12 coral heads were stained on June 27, 1987. These heads had already been mounted on Platform 1 the previous day.

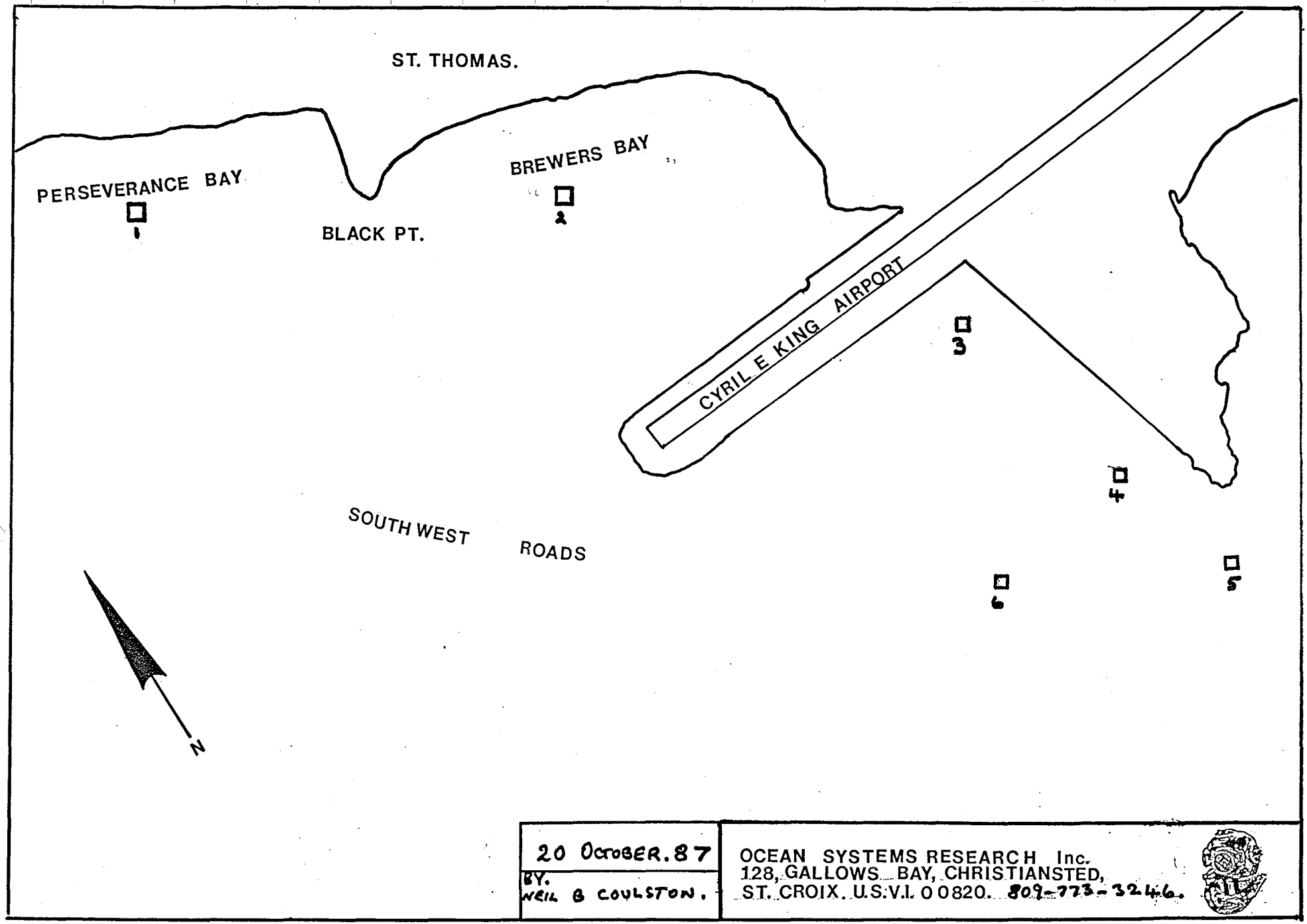


Figure 1. The approximate location of experimental platforms 1 through 6.

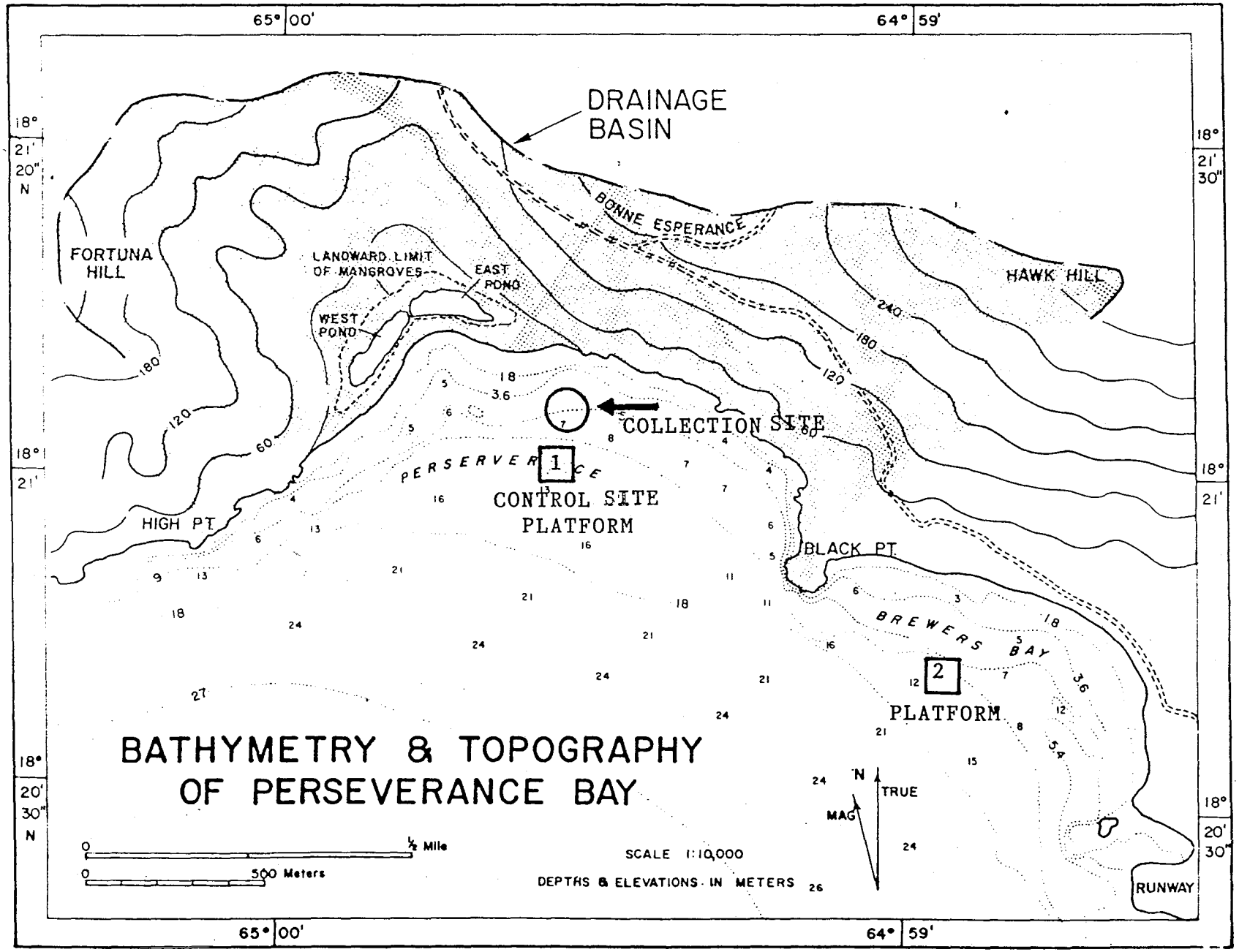


Figure 2. Location of collection site and Platform 1 (control site) in Perserverance Bay and Platform 2 in Brewers Bay. These sites are all at 30 ft depth.

The stained heads were moved and mounted on Platforms 2 through 6 on June 27th. They had been transported from the control site in Perseverance Bay in buckets of seawater, taken directly to the platform sites, placed on the bottom and mounted. All coral heads were mounted using Pettit two-part underwater adhesive compound.

On June 29, the platforms were photographed. On September 26 and 27, 1987, the Montastrea annularis heads were photographed and collected. Each platform is shown in the photographs provided (see page 59 through 70) of this report.

After collecting, samples were immediately taken from each head and preserved for later counting the number of zooxanthellae. The heads were then placed in 50/50 solution of clorox and fresh water for one-half hour. The heads were dried, packed and shipped back to the laboratory in St. Croix for sectioning and measuring growth.

The heads were cut, with a diamond blade, along an axis through the apex where maximum growth was expected to occur. In the larger specimens, a second cut was made parallel to the first cut so that the slabs could fit under the microscope. A dissecting microscope, fitted with an ocular grid measuring to .1 mm, was used to measure growth from the inner most part of the dye mark to the outer skeletal extension. The measurement was taken at the point of maximum growth. Maximum growth occurred, in most cases, at the recorded apex.

Seventy-two fragments of Acropora cervicornis (branching form) were collected in Perseverance Bay at depths between 20 and 30 ft on June 23 to 24. On June 25, they were measured and mounted on Platforms 1 through 3 and the remainder were mounted June 27 on Platforms 4 through 6. The fragments were measured again on August 1 and 2 (36 day interval), August 29 (27 day interval), and September 26 (27 day interval). At the end of the 90-day study period the specimens of A. cervicornis were left on the platforms and could, in theory, be remeasured at some future date.

Coral Zooxanthellae Count

The number of zooxanthellae from a one centimeter square of surface (taken to a depth to include all live coral tissue) of each M. annularis head was counted. Two (2) one centimeter square ($1\ cm^2$) samples were taken from each head; one on either side of the apex. Samples were removed using a sharp, wood chisel (1 cm wide) and cut to a depth so that no pigment remained within the cm^2. The samples were placed in a solution of 10% formalin and filtered seawater.

In the laboratory, 10% HCl in filtered seawater was added to the homogenized sample until all calcium carbonate was dissolved. Homogenization was done twice, first using a mortar and pestle and then using a Thomas teflon pestle tissue grinder operated by a drill press. The volume of the sample was measured. A small aliquot was taken and placed on an American Optical Bright Line improved Neubauer (.01mm depth) hemocytometer, where four counts of two different aliquots were made by two technicians. The counts were made on 25 groups of 16 squares where the volume observed was a cubic mm as determined by the manufacturer. The conversion was made (10,000 mm^3 = 1 cm^3 X sample volume) to determine the total number of zooxanthellae within a centimeter square of surface of the coral.

Sediment Analysis

Two (2) rebar stakes with two (2) sediment traps on each were installed near each platform. The traps consisted of plastic jars 9.5 cm in height with a diameter of 8.2 cm. The traps were secured with two electrical ties. In addition, sediment traps, 20.3 cm high by 7.0 cm in diameter, were attached directly to the platform with cable ties by Ocean Surveys, Inc. (OSI).

The first set of sediment traps were installed during the initial set-up (June 26-27) and collected 15 days later on July 11. On August 1 and 2, clean traps were installed and collected September 27.

Small organisms were removed and the sediments were filtered through pre-weighed Whatman #2 filters. The samples were rinsed with distilled water to remove salts and dried in a drying oven at 60 C and re-weighed. Rates were expressed in mg sediment/cm^2/day based on the area of the trap aperture and the time interval.

Between 3 and 5 plugs of sediment were collected at each platform and analyzed for total organic carbon using the loss on ignition method according to Dean (1974). Samples at suspended Platform 6 were taken on the bottom immediately below the platform. Samples were dried at 60° C and allowed to cool to room temperature. Twenty grams of sediment was transferred to a pre-weighed crucible and ashed at 550°C for one hour, cooled, re-weighed, and percentage lost calculated.

Coral Recruitment

Six settling plates (slabs of Acropora palmata skeleton) were placed at the control platform (Platform 1) on June 27, 1987. On August 1, the plates were detached and examined for juvenile corals. No juvenile corals had settled on any of the plates. The plates were covered by several millimeters of sediment and a few species of turf algae (Microcoleus, Cladophora, Ceramium, Heterosiphonia, Spermothamnion). These plates remained in this uncontaminated area for 36 days, after which five were distributed to the other platforms.

Although the lack of juveniles on the plates will not allow for the assessment of juvenile survival as planned, the plates were nonetheless removed and distributed to the other platforms according to plan. These plates, along with six "clean" plates will be used in evaluating algal growth.

Slabs of Acropora palmata skeleton placed at the control platform for 90 days and all the other platforms for 60 days were collected on September 27 and 28 and examined for juvenile corals. No juvenile corals were observed on any of the settling plates throughout the study.

Algal Growth

Six pieces of dead coral skeleton covered with algal turf were obtained from the collection site. All pieces were taken from approximately 30 ft of depth. The turfs were composed largely of Amphiroa and Wurdemannia with smaller amounts of other algal turf species. One piece was transplanted to each platform and inserted into a small cage fixed to the Lexan platforms. The algae were allowed to grow protected from herbivory for ninety days, then collected and analyzed for biomass and species composition. Algal biomass was also determined from weighing the algae on the settling plates.

One (1) 25 cm square of turf algae was removed from the rubble and each of the two settling plates by scraping. A solution of 10% HCl was added to the samples to dissolve the calcium carbonate material. All visible invertebrate tissue was removed. The samples were then filtered through pre-weighed Whatman #2 filters, rinsed to remove the salts, dried at 60°C and re-weighed. Algal biomass measurements are expressed in $mg/25cm^2$.

Single-species Algal Test

Dr. Thursby from EPA supplied juvenile male and female Champia parvula plants for the toxicity test. These resulted from the August 21, and 24, 1987, settlement of tetraspores formed from cultured tetrasporophytes. Three-inch pipettes upon which the tetraspores settled, were shipped to St. Croix in individual bottles containing nutrient media. Many pipettes had visible algal material while some appeared to have little or none. Pairs of pipettes, attached together by plastic tubing, were secured to 12-inch mesh cages. Two pairs were attached via cable ties to the inside of the cages which were protected from grazers, and one pair was attached to the outside. One cage was fastened to each of the six platforms on August 1, 1987. The cages were inspected on August 28, and collected on September 26-27.

Total Suspended Solids

Water samples of 500 ml were taken at 30 ft, in the vicinity of the platform, and at the surface of the water above each platform each time the site was visited (June 29, July 11, August 1, August 2, and September 26, 1987) for use in determining total suspended solids (measured in mg/l).

Methods for determining suspended solids were taken from Strickland and Parsons (1968). A Millipore filtration system was used with pre-weighed 47 mm diameter discs with a pore size of 0.45 microns. Samples were dried in a constant-temperature drying oven at 60^C, placed in a desiccator until weighed on a Sartorius balance, weighing accurately to the nearest tenth of a milligram.

RESULTS

Coral Growth: Statistical Analyses

The average growth, expressed in millimeters, of Montastrea annularis at each platform is presented in Table 1. Figure 3 illustrates the differences between the growth at each platform showing the sample range, mean and the 95% confidence limit of the mean.

The Fmax test showed homogeneity of variance between the six samples ($F_{max}=2.30$, $P<.05$). A one-way ANOVA was used to compare the amount of variation in coral growth among platforms to the variation within each platform. The ANOVA showed significant differences in mean coral growth

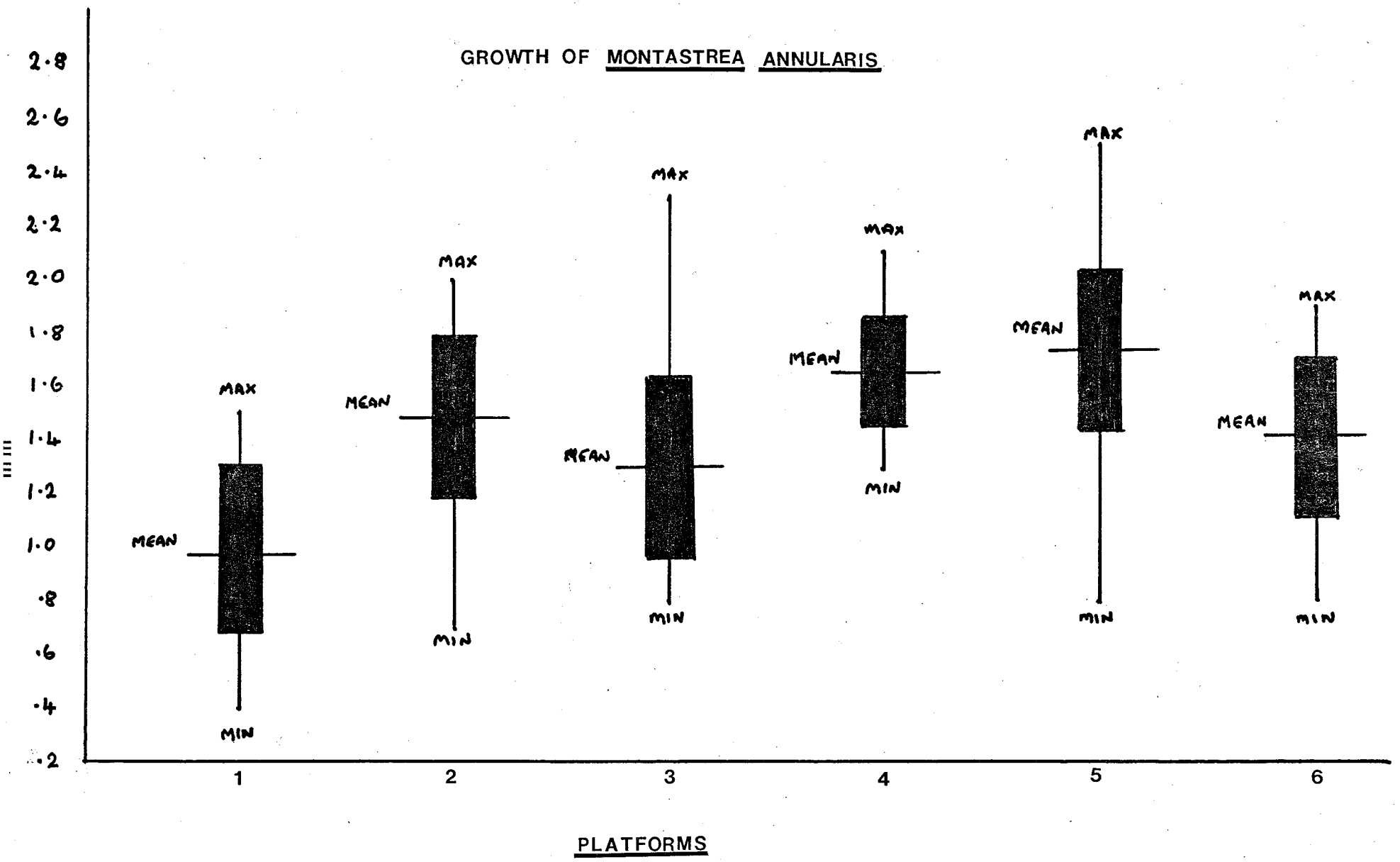


Figure 3. The average growth of Montastrea annularis at each platform.

Table 1. Average growth, in millimeters, of Montastrea annularis at each platform

	PLATFORM 1	PLATFORM 2	PLATFORM 3	PLATFORM 4	PLATFORM 5	PLATFORM 6
N OF CASES	10	10	9	10	11	8
MINIMUM	0.40	0.70	0.80	1.30	0.80	0.80
MAXIMUM	1.50	2.00	2.30	2.10	2.50	1.90
MEAN	0.97	1.49	1.33	1.66	1.75	1.43
STANDARD DEV.	0.45	0.40	0.44	0.30	0.43	0.35
VARIANCE	0.21	0.16	0.19	0.09	0.19	0.12
STD. ERROR	0.14	0.13	0.15	0.10	0.13	0.12

Fmax = 2.30 $F_{\alpha}.05[10,9] = 9.91$

ANOVA: Comparison of mean growth rates among stations.
Ho: There are no differences in the mean growth rates of coral among the stations.

Source	SS	df	MS	F value Sign.
Between	3.847	5	0.769	4.8 $p < 0.001$
Within	8.336	52		

Therefore, reject Ho, P<0.001.
There are differences in mean growth rates between platforms.

rates among platforms (F=4.8, P=0.001). Independent t-tests were used to evaluate specific site differences. These differences are shown in Table 2.

Platform 1 corals showed significantly less growth than the corals at Platforms 2, 4, 5 and 6. Maximum growth occurred in the coral at Platform 5. This growth at Platform 5 was significantly greater than coral growth on both Platforms 1 and 3.

Platform 1. Comparing the results with field notes and photographs, we were able to relate data to field conditions. We found that the two coral heads that fell over had rates of growth considerably lower than those that remained upright. The mean growth rate for Platform 1 was .97 cm ± .45. Since growth is maximum at the apex, when the apex is no longer positioned toward the water surface (as the coral is now on its side), then it is expected that growth will slow down. Coral Head #9 was found on its side during the 60-day visit, its maximum growth was 0.6 cm. Coral Head #10 was found on its side at the 90-day visit and its maximum growth was 0.4 cm. Coral #6 was also found on its side, however, its maximum growth was 1.3 cm. When finding corals on their side it is not possible to know just how long they have been in that position. Even with three heads falling over, their mean growth was 0.8 cm, which would have very little effect changing mean growth of M. annularis on Platform 1.

Coral Head #4 was not at its placed position during the 90-day visit and we suspected that one coral head near the platform or one in a different place on the platform might be #4. When both coral heads were sectioned no dye was found, therefore we were not sure if either one of the coral heads were Coral Head #4. In the zooxanthellae study, we used both of these heads for sampling.

Platform 2. During the August 1 visit to Platform 2, all corals exhibited severe stress. The summary of the condition of Montastrea annularis on the 36-day visit to the platform is presented in Appendix I-B. In the 36-day report, these corals were evaluated for percent dead coral. However, on the 60-day visit, the signs of stress had disappeared. What appeared to have been dead coral was really "bleached" coral which had recovered 30 days later. For Platform 2 heads, growth of heads was significantly higher than on Platform 1, but there was no difference between Platform 2 and Platforms 3, 4, 5 and 6. So, even with the period of observed stress, it did not seem to affect growth rates of the coral heads.

Table 2. T-test for significant ($P<0.05$) differences between platforms for average growth in Montastrea annularis.

PLATFORM	1	2	3	4	5	6
1	..					
2	*	..				
3	ns	ns	..			
4	*	ns	ns	..		
5	*	ns	*	ns	..	
6	*	ns	ns	ns	ns	..

The "bleaching" did not seem to have a significant effect on the final outcome of the number of zooxanthellae found in the tissues. The number of zooxanthellae was significantly higher on Platform 2 than on Platform 1 and 6, but was the same as Platforms 3, 4 and 5. Even Coral Head #10, that was reported 90% dead (actually bleached), had an average of 1.42 X 10^6 zooxanthellae/cm^2 (Platform 2 mean is 1.48 X 10^6 zooxanthellae/cm^2).

Platform 3. Coral Head #6 had no dye present. In examining the photograph it can be clearly seen that the coral head was mounted on its side with the apex at a 90 degree angle to the surface of the water. There was probably no growth due to change in orientation of the apex. In future studies of this type, it is clearly necessary that the original apex be noted when collecting the sample and the coral mounted so that the apex is pointing toward the surface of the water when mounted on the platform if maximum growth is to occur.

Coral Head #11 also did not have any growth even though dye was found on the ridges at the its surface. This can be easily explained when examining the photograph showing Coral Head #11. The apex, at the time of mounting on the platform, was dead. Apparently that coral also was mounted on the platform wrong, without consideration as to the location of the apex when the coral was collected. The coral contained the dye, but did not grow because of its change in orientation when placed on the platform.

Coral Head #1 fell over sometime prior to the final collection. The maximum growth was 1.1 cm and the average for the platform was 1.33 cm + 0.2. The effect was not significant (within 95% confidence limit of the mean).

The mean number of zooxanthellae for Platform 3 was 1.6 x 10^6 zooxanthellae per cm^2, which was the highest number found for all the platforms. Coral Head #1 had 2.41 X 10^6, Head #6 had 1.85 X 10^6 and Head #11 had 1.40 X 10^6 zooxanthellae per cm^2. The orientation of the apex does not seem to have any relationship to the number of zooxanthellae in the coral tissues, at least in these three cases.

Platform 4. Only one coral, Head #3, had no visible dye. When examining the photograph, the head is obviously mounted on its side with its apex at an angle more than 90% from the surface of the water. The mean number of zooxanthellae for the platform was is 1.32 X 10^6 $\pm$.33. Head #3 had an average of 0.83 X 10^6, which was considerably below the mean.

Platform 4 had a number of corals that were pale (#2, #3, #4 and #9), with some that had whitish splotches throughout (#1, #2, #3, #4, #5, #9 and #11). Even with

those color characteristics indicating losses in zooxanthellae, Platform 4 had a significantly greater number of zooxanthellae than Platform 1 and significantly fewer than Platform 3. There was no significant difference between Platform 4 and Platforms 2, 5 and 6.

Platform 5. During the 60-day visit, Head #2 was reported to have 20% of the its polyps dead. This may have only been a "bleaching," as the white area, still there, looked normal except it was white. Usually a dead area will become scoured and worn down and algae will grow over the dead surface. Other corals also were beginning to show signs of bleaching. Heads #4 and #8 had white spots equal to 10% of the area and Heads #6 and #12 were splotchy with light areas.

Platform 6. All the coral heads appeared healthy. Head #3 was splotchy in color on 10% of its area. During the 36 day visit, Heads #3, #4, #5, and #12 had 10% bleached areas. These had recovered by the 60-day visit.

Four of the heads showed no dye when they were sectioned. There is no explanation for not finding dye as all 72 experimental heads were treated equally during the dying process and there was no reason for these heads not to grow. The heads showing no dye were mounted properly.

Growth on Platform 6 was significantly greater than on Platform 1, but not different from any of the other platforms. The coral heads had not yet become completely engulfed by algae. If the experiment had continued for a longer time the algae would definitely have had an impact on the coral heads.

The general appearance of Montastrea annularis at the end of the study, as indicated in the photographs and field notes, was good. The corals were much darker in color and healthier in appearance than when the corals were originally transferred to the platforms. There was considerable stress in the cutting, dying and in transporting of corals heads used in the experiment. The photographs provide a clear picture of the differences at the beginning of the study and the condition of the corals at the end of the study. It seems that the corals were stressed due to the move, recovered after time, and may just be beginning to show new signs of stress due to the placement in the new environment. It is possible, as in the case of Platform 2, stresses are cyclic and coral go through periodic stress and recovery, with the long-term effect of adapting to changing environments without impact to over-all growth and survival. The study corals were not, unfortunately, in place long

enough to show the long-term effects of being moved and implanted in a changed environment. The short-term effects are obviously not negative in terms of survival, growth and numbers of zooxanthellae.

The growth of Acropora cervicornis was measured at three time periods (T1 = 36 days, T2 = 27 days, and T3 = 27 days, for a total of 90 days). These results were corrected to reflect equal 30-day time periods and all negative growth measurements were eliminated from the statistical analysis. Original measurements, actual growth in centimeters, including incidences of negative growth are presented in Appendix III with corresponding graphs presented in Appendix IV. The positive growth data corrected for 30-day periods is presented in Table 3.

There are significant differences in Acropora cervicornis growth between time periods as determined by ANOVA where $F[2,172] = 4.553$ ($P = 0.01$). The Bartlett test for homogeneity was significant at $P = .002$. The statistics on the three time periods are presented in Table 4 and are shown in Figure 4.

Growth was slow during period one, increased dramatically during time period two and decreased during time period three.

Within time periods 1 and 2 there were no significant differences between platforms. Within time period 3 there was significant differences in growth between platforms as determined by Kruskal-Wallis test ($P = 0.002$). Figure 4 presents the statistics of range, mean, and 95% confidence limit of the mean for each platform within each time period.

Within time period 3 there were differences in growth between platforms. Significant differences are shown in Table 5. The greatest growth occured on Platforms 4, 3 and 2, which was significantly different from the growth occurring on Platforms 5 and 6. The control platform coral growth was less than 4, 3 and 2 and greater then 5 and 6, but not significantly different from any of the platforms.

On Platform 6, growth during time period 3 had declined dramatically from the previous time period. At the time of final measurement on Platform 6, the A. cervicornis branches were covered with algae. The photographs provided, illustrate the extent of coverage with algae. All branches of coral, with the exception of Branch #4, were completely white. Branch #4 still had the growing tips protruding from the algae cover and the entire piece was brown and healthy in appearance. (Note: November 6, 1987, Dana Fagan while diving during another different project, was in the area of Platform 6 and he confirmed that all the white branches of

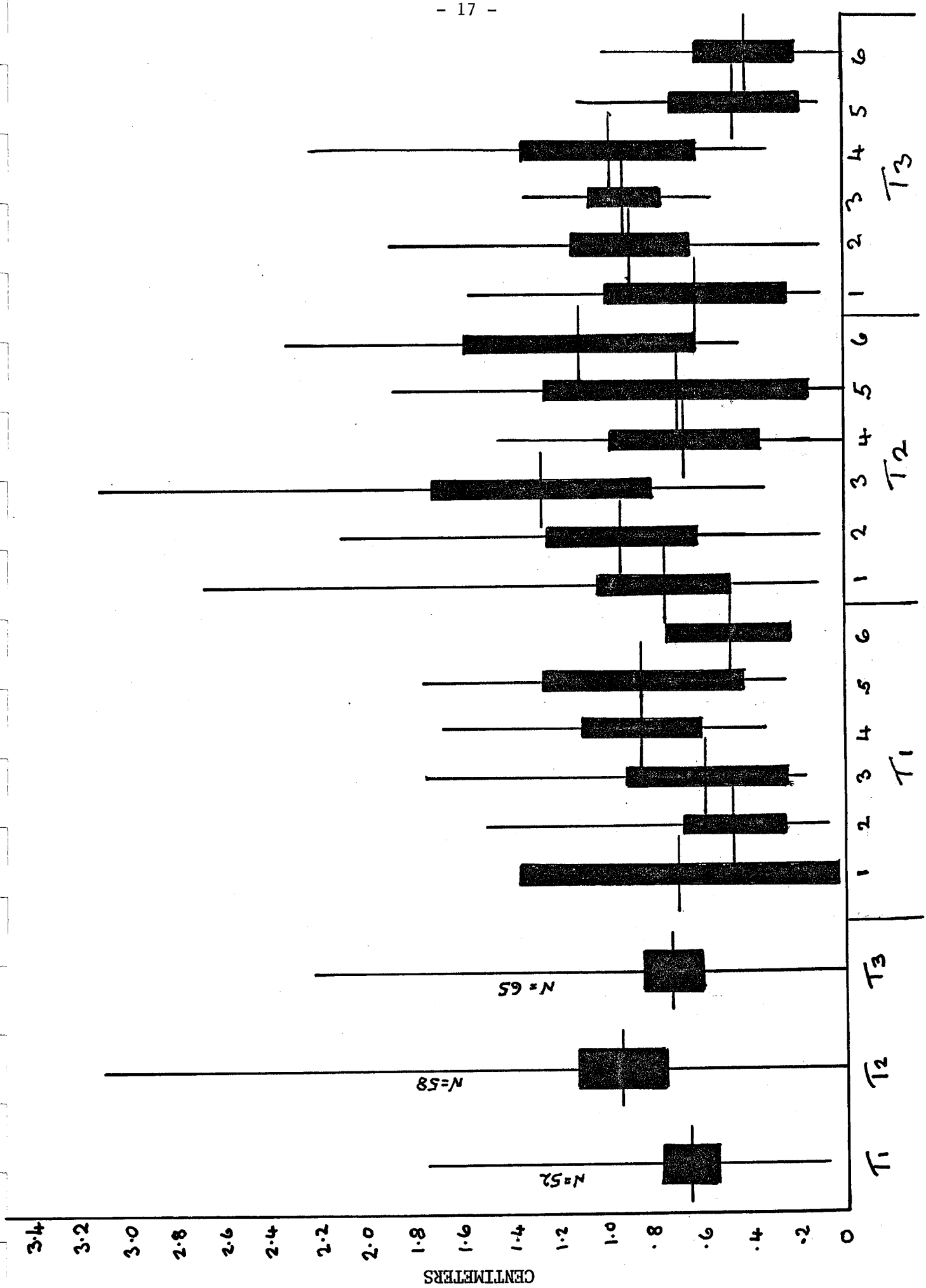


Figure 4. Growth of Acropora cervicornis during time periods T1, T2 and T3 for all platforms and within time periods at each platform (shown are range, mean, and 95% confidence limit).

Table 3. Acropora cervicornis growth rates (in centimeters) for each time period on each platform standardized for 30 day periods.

PLATFORM 1			PLATFORM 2			PLATFORM 3			PLATFORM 4			PLATFORM 5			PLATFORM 6		
T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
0.6		0.4	0.2	0.7	1.6	0.8	1.2		0.7	0.9	0.7	1.3	0.7	0.2	0.4	0.4	0.0
0.2	0.2	0.2	0.2	1.0	0.8	0.3	1.8	0.9	0.8	0.4	0.3	0.3	0.1	0.1	0.3	1.0	0.1
	0.3	0.8		0.6	0.1	0.2	1.0	0.6	0.3	0.6	0.8	0.3	0.8	1.1		1.4	0.3
	0.4	0.9	0.4	1.1	1.1	0.9	0.8	0.7	1.0		1.9	1.5		0.1		2.2	1.1
	0.1	1.6	1.5	1.6	0.7	0.3	1.3	1.0	0.6	1.4	0.9		0.0			0.8	0.9
	2.7		0.6	0.6	0.8		1.1	1.0	0.8	1.2	2.2	1.8		0.2		0.9	0.1
			0.3	0.1	0.7	0.6	1.4	0.8	1.7		1.0				0.7	0.6	0.2
		0.7	0.5	1.1	0.7		3.1	1.2	0.7	0.4	1.0	0.8		0.8		2.3	0.6
		0.3	0.5	1.0	1.9	0.5	0.3		0.7	0.6	0.6		1.9		0.8		0.3
0.8			0.3	2.1	0.8	0.3	0.9	1.0	1.3	0.0	1.0	0.3	0.7	0.8		1.0	0.6
			0.1				2.2	1.3	1.0	0.6	0.3	0.8	0.8	0.4	0.3	0.4	0.1
1.3		0.1	0.6	1.0	1.0			1.1		0.7	1.1	0.6		0.3			0.6
			0.6	1.1	0.8	1.8	0.7	0.8									
			0.4	0.3	1.0	0.0	0.0	0.0									
						0.3	0.7										
N OF CASES	4	5	8	13	13	13	10	13	11	11	10	12	9	7	9	5	10	12
MEAN	0.7	0.8	0.6	0.5	0.9	0.9	0.6	1.3	0.9	0.9	0.7	1	0.9	0.7	0.5	0.5	1.1	0.4
STD DEV	±0.5	±1.1	±0.5	±0.4	±0.5	±0.4	±0.5	±0.7	±0.2	±0.4	±0.4	±0.6	±0.6	±0.6	±0.4	±0.2	±0.7	±0.3

Table 4. Growth of Acropora cervicornis during three time periods.

	T1	T2	T3
N of Cases	52	58	65
Minimum	0.080	0.000	0.000
Maximum	1.750	3.110	2.220
Mean	0.661	0.954	0.737
Variance	0.188	0.449	0.217
Std. Dev.	0.434	0.670	0.466
Std. Error	0.060	0.088	0.058

Bartlett Test for Homogeneity of Group Variances:

Chi-square = 12.862 Df = 2 Probability = .002

Analysis of Variance:

Source	Sum of Squares	Df	Mean Square	F	Prob.
Between	2.579	2	1.298	4.553	.012
Within	49.052	172	0.285		

Table 5. Significant differences between platforms in the growth rate of Acropora cervicornis in time period #3.

	PLATFORM 1	PLATFORM 2	PLATFORM 3	PLATFORM 4	PLATFORM 5	PLATFORM 6
PLATFORM 1		ns	ns	ns	ns	ns
PLATFORM 2			ns	ns	*	*
PLATFORM 3				ns	*	*
PLATFORM 4					*	*
PLATFORM 5						*
PLATFORM 6						

Highest to lowest growth:

4 > 3 > 2 > 1 > 5 > 6

A. cervicornis had died. Even though the algae had been removed on September 26, the corals were so severely stressed that they were unable to recover. Mr. Fagan also observed that Branch #4 was alive at the time of his dive.)

There were 35 cases of negative measurements of growth. Within each time period the percentage of negative measurements were as follows: T1 = 60%, T2 = 29% and T3 = 11%. Within platforms, percent of negative growth measurements occurred as follows: P1 = 28%, P5 = 28%, P6 = 22%, P3 = 14%, P4 = .08% and P2 = .03%. Table 6 presents these occurrences.

Coral Zooxanthellae Count

Table 7 presents a summary of mean values per head on each platform for the number of zooxanthellae found per centimeter square taken from each coral head. Data on original counts corrected for dilution and rounded off to the nearest one hundredth of a million zooxanthellae appears in Appendix II. The mean number of zooxanthellae per head were compared between platforms. A graph (Figure 5) presents the statistics (minimum, maximum, mean and 95% confidence limit of the mean) for each platform. A test of homogeneity of variances was found to be significant ($F_{max} = 2.37$, $P < .05$) and an ANOVA was used to reject the null hypothesis that there are no differences between platforms ($F=6.06$, $P < .05$). Independent t-tests were used to determine where significant differences had occurred. Significant differences (at $P < .05$) between platforms are shown in Table 8.

Sediment Analysis

Table 9 provides sedimentation rates at the six platforms during two time periods. Sedimentation rates for both time periods were combined to test for significant differences of sedimentation rates between platforms. The Kruskal-Wallis test (at $P < 0.05$) indicated that Platforms 3 and 4 received significantly greater amounts of sediment than Platform 6 and 1; Platform 5 was significantly greater than Platform 6 (Table 10). Figure 5a presents the range, mean and 95% confidence limit of the mean for sedimentation rates at each platform.

Table 11 provides percentage of total organic carbon present in bottom samples taken near the six platforms, mean and standard deviation. Results from the ANOVA indicates significant differences between platforms. The total organic carbon at Platform 6 was significantly greater than Platform 2 and 4.

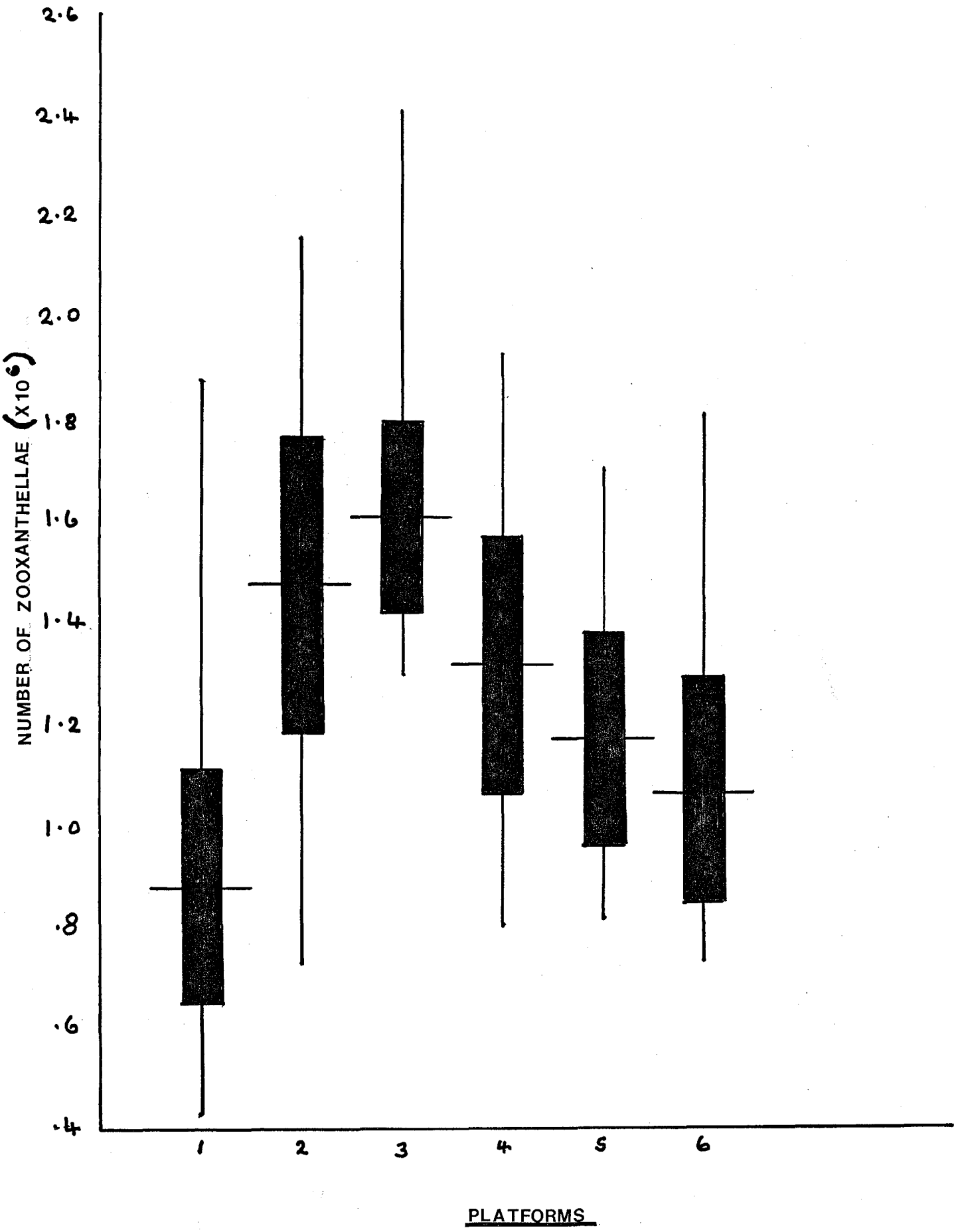


Figure 5. Number of zooxanthellae per centimenter square per head on each platform (mean, maximum, minimum, and 95% confidence limit).

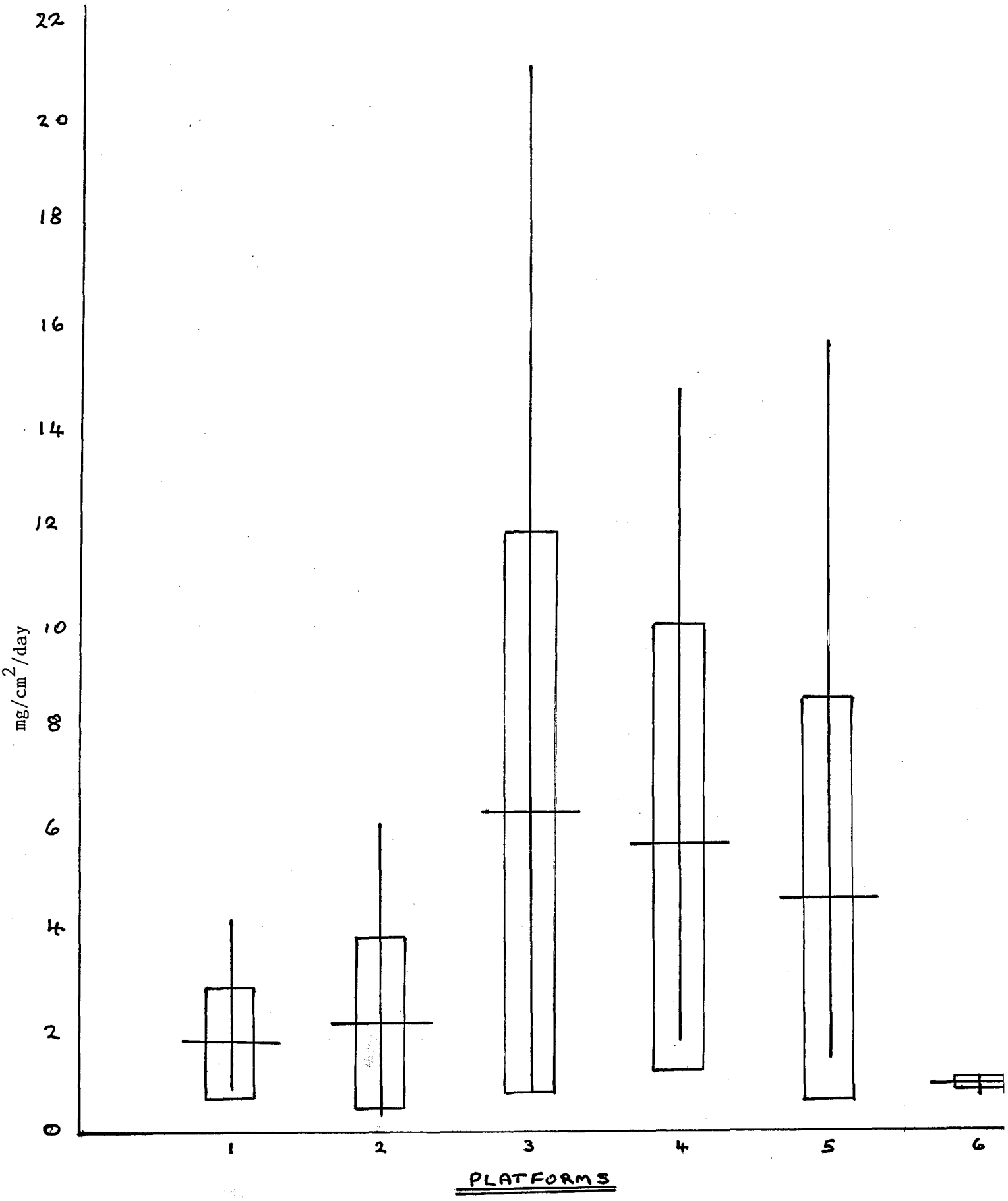


Figure 5a. Range, mean and 95% confidence limit of the mean of sedimentation rates at the six platforms.

Table 6. Occurrances of negative growth values for Acropora cervicornis during time periods #1, #2 and #3 at each platform.

Platform	Time Period #1	Time Period #2	Time Period #3	Total	Percent
1	6	2	1	9	28%
2	1	0	0	1	03%
3	3	0	2	5	14%
4	1	2	0	3	08%
5	3	4	2	9	28%
6	7	2	0	8	22%
Totals	21	10	4	35	
Percent	60%	29%	11%		

Table 7. Average number of zooxanthellae (X 10^6) per centimenter square per head on each platform.

PLATFORM 1	PLATFORM 2	PLATFORM 3	PLATFORM 4	PLATFORM 5	PLATFORM 6
0.76	1.65	2.41	1.12	0.91	0.76
0.43	0.73	1.44	0.97	1.46	0.86
0.57	2.16	1.48	0.83	1.70	0.83
0.46	2.04	1.30	1.08	1.60	1.16
0.89	1.38	1.54	1.84	0.81	1.04
1.14	1.65	1.85	0.80	1.12	1.81
1.88	1.05	1.60	1.59	0.87	0.88
0.96	1.35	1.61	1.47	0.83	0.94
0.60	1.51	1.86	1.93	0.83	0.73
0.77	1.42	1.51	1.73	1.56	1.41
0.93	2.07	1.40	1.11	1.17	1.37
1.18	0.78	1.34	1.36	1.24	
Mean 0.88	1.48	1.61	1.32	1.18	1.07
Std. Dev. 0.40	0.47	0.31	0.33	0.34	0.34

Analysis of Variance:

Source	Sum of Squares	Df	Mean Square	F	Probability
Beween Groups	4.322	5	0.864	6.061	$P < 0.05$
Within Groups	9.269	65	0.143		

Reject the null hypothesis that there are no differences between platforms.

Table 8. Significant differences between platforms in the number of zooxanthellae.

	PLATFORM 1	PLATFORM 2	PLATFORM 3	PLATFORM 4	PLATFORM 5	PLATFORM 6
PLATFORM 1		*	*	*	ns	ns
PLATFORM 2			ns	ns	ns	*
PLATFORM 3				*	*	*
PLATFORM 4					ns	ns
PLATFORM 5						ns
PLATFORM 6						

3 > 2 > 4 > 5 > 6 > 1

Table 9. Sedimentation rates ($mg/cm^2/day$) at platforms 1-6.

Platform Number	Sedimentation Rate ($mg/cm^2/day$) 6/26 to 7/11	Sedimentation Rate ($mg/cm^2/day$) 8/1 to 9/29	Average	Std. Dev.
1	0.82	4.22		
1	1.05	0.97		
1	3.32	2.03		
1	1.28	0.85	1.82	±1.20
2	1.24	4.31		
2	1.15	6.03		
2	2.03	0.92		
2	0.21	1.00	2.11	±2.00
3	2.29	10.50		
3	1.90	21.21		
3	6.19	5.01		
3	3.84	0.74	6.34	±6.70
4	1.88	13.97		
4	1.75	14.65		
4	2.50	4.10		
4	3.06	3.25	5.65	±5.40
5	1.34	7.62		
5	2.62	15.64		
5	2.70	2.09		
5	2.59	1.79	4.55	±4.90
6	0.90	0.95		
6	0.99			
6	0.80			
6	0.68		0.86	±0.13

3 > 4 > 5 > 2 > 1 > 6

Type II Sediment traps set out by Ocean Surveys, Inc.

1	1.83	2.26	2.05
2	1.73	4.72	3.23
3	2.86	4.07	3.47
4	2.37	6.03	4.20
5	3.94	3.77	3.86
6	2.24	1.56	1.90

4 > 5 > 3 > 2 > 1 > 6

Table 10. Significant differences in sedimentation rates ($mg/cm^2/day$) between platforms.

	PLATFORM 1	PLATFORM 2	PLATFORM 3	PLATFORM 4	PLATFORM 5	PLATFORM 6
PLATFORM 1		ns	ns	*	ns	ns
PLATFORM 2			ns	ns	ns	ns
PLATFORM 3				ns	ns	*
PLATFORM 4					ns	*
PLATFORM 5						*
PLATFORM 6						

3 > 4 > 5 > 2 > 1 > 6

Table 11. Percent of total organic carbon found in bottom sediments near each platform.

	PLATFORM 1	PLATFORM 2	PLATFORM 3	PLATFORM 4	PLATFORM 5	PLATFORM 6
	3.44	3.75	2.54	2.92	3.06	5.12
	3.88	3.38	4.40	2.92	3.23	4.83
	5.85	3.17	4.07	3.15	4.40	4.84
		2.97				
		4.00				
MEAN	4.39	3.45	3.67	2.99	3.56	4.93
STD. DEV.	1.28	0.42	0.1	0.08	0.42	0.17

BARTLETT TEST FOR HOMOGENEITY OF GROUP VARIANCES = 13.001
APPROXIMATE F = 2.271 DF = 5 PROBABILITY = 0.049

ANALYSIS OF VARIANCE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F	PROBABILITY
BETWEEN GROUPS	7.605	5	1.521	2.988	0.048
WITHIN GROUPS	7.126	14	0.509		

INDEPENDENT TTEST AT P < 0.05

TOTAL ORGANIC CARBON AT PLATFORM 6 IS SIGNIFICANTLY GREATER THAN PLATFORMS 2 AND 4.

Algal Growth

Cursory observations of caged turfs on August 1 and 2, showed a significantly greater amount of algal growth on the turfs and cages of Platform 6. Large fleshy reds were abundant over the entire platform. Cages were overgrown with algae to the point where light available to the turf algae inside the cages may have been significantly limited.

Observations made on September 27 and September 28 showed that Platform 6 had significantly more macroalgae than the other platforms (see photographs page 50 - 70). Many species of macroscopic reds and greens dominate the platform. Long trains of the filamentous green (Cladophora) bedecked the platform.

The amount of turf algae found on settling plates was not noticeably different between platforms, see Table 12 (sample size too small for statistical analysis) The greatest amount of algal growth on coral rubble in cages is probably a factor of light entering the cage. Where cage algal growth was dense, turf algal growth diminished.

Coral Recruitment

No juvenile corals were found on any of the settling plates at any of the platforms throughout the study.

Single-species Algal Test

Four weeks after the installation of Champia to the platforms (August 28), living Champia plants were observed only on Platforms 3 and suspended Platform 6. On Platform 3, the three small plants observed, all occurring on the inside of the cage protection, appeared heavily epiphytized. The Champia plants on Platform 6 were larger and more abundant. Several Champia plants were observed on the cage itself, indicating that reproduction and subsequent settlement had already occurred.

During the final collection on September 26 to September 28, all experimental Champia apparatus was retrieved from the platforms. Close examination of all pipets and cages revealed that Champia plants were present only on the cage (not on the pipets) from Platform 6. Fewer plants were noted than on the previous inspection. The plants were highly epiphytized with pennate diatoms and small red and blue-green algae (Calithamnion, Polysiphonia, Microcoleus). Some plants were highly branched and at least one plant was reproductive, i.e. had cystocarps.

Table 12. Algal Biomass in mg/25cm taken from experimental settling plates and protected rubble fragments.

Platform	Source	mg/25cm2	Average
1	Plate	62.2	
	Plate	98.3	
	Turf	122	80.2
2	Plate	46	
	Plate	8	
	Turf	32.9	39.8
3	Plate	296.3	
	Plate	38.1	
	Turf	82.4	60.2
4	Plate	381.5	
	Plate	52	
	Turf	43.8	47.9
5	Plate	89.1	
	Plate	42.6	
	Turf	58.8	50.7
6	Plate	84.5	
	Plate	47	
	Turf	68	57.5

Total Suspended Solids

The amount of total suspended solids (mg/l) found during the five sampling periods is presented in Table 13, and illustrated in Figures 6 and 7.

An ANOVA was used to determine that there were no significant differences in suspended solids between platforms, surface of the water, and 30 ft depth samples. The only significant difference was between sampling periods.

During the July 11 sampling, on all but Platform 1, there was significantly lower suspended solids than found in any other period. On that day the wind was predominantly from the south (normally easterly). This could account for offshore water displacing normal inshore water at the more southerly platforms. Offshore tropical waters are expected to have low total suspended solids when compared to inshore waters. In general, all platforms experience no difference in suspended solids unless wind direction shifts from its normal direction, which occurs very infrequently.

DISCUSSION

Coral Growth

Montastrea annularis. The coral Montastrea annularis was used in this study as a biological indicator of the effect of sewer effluent on the survival, growth and number of zooxanthellae present in the coral tissue.

All coral heads survived and appeared healthy at the end of the 90 day study period. The corals appeared to go through periods of "bleaching" and recovery throughout the study, and Platforms 4 and 5 corals showed light splotchy areas at the time of final collection however, there was no obvious mortality of any of the corals.

The corals from all of the experimental platforms grew at a much greater rate than at the control platform. In every case, the corals subjected to direct contact with the sewer effluent grew faster than the control. This is not unexpected as sewage provides large amounts of nutrients that are not normally abundant in tropical coastal waters.

Growth rates obtained for M. annularis at the Red Point sewer outfall are considerably lower than that found by Tomascik and Sanders (1985) for the same species on the west coast of Barbados and higher than those found by Dustan

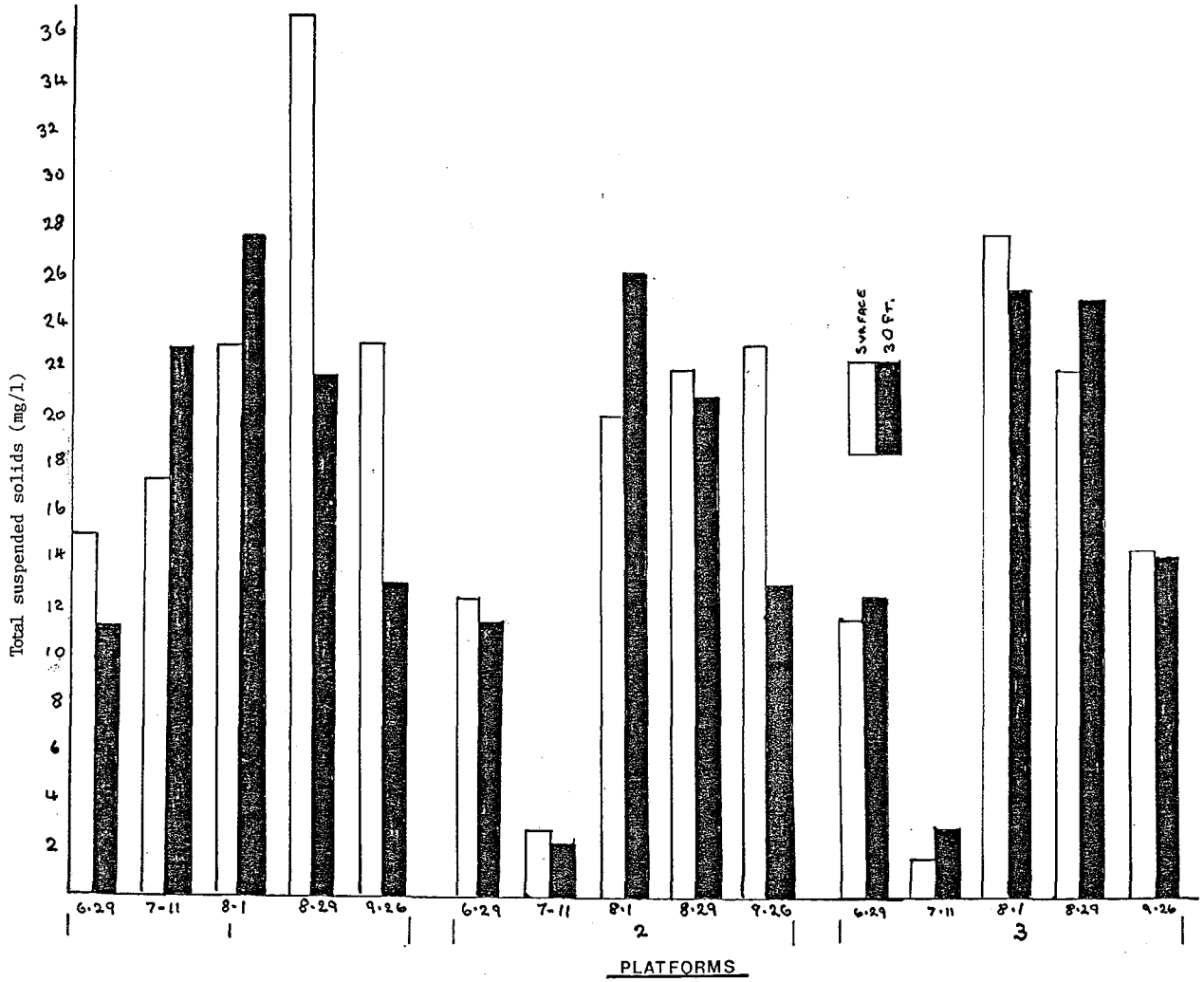


Figure 6. Total suspended solids (mg/l) for surface and 30 ft depth at platforms 1,2 and 3.

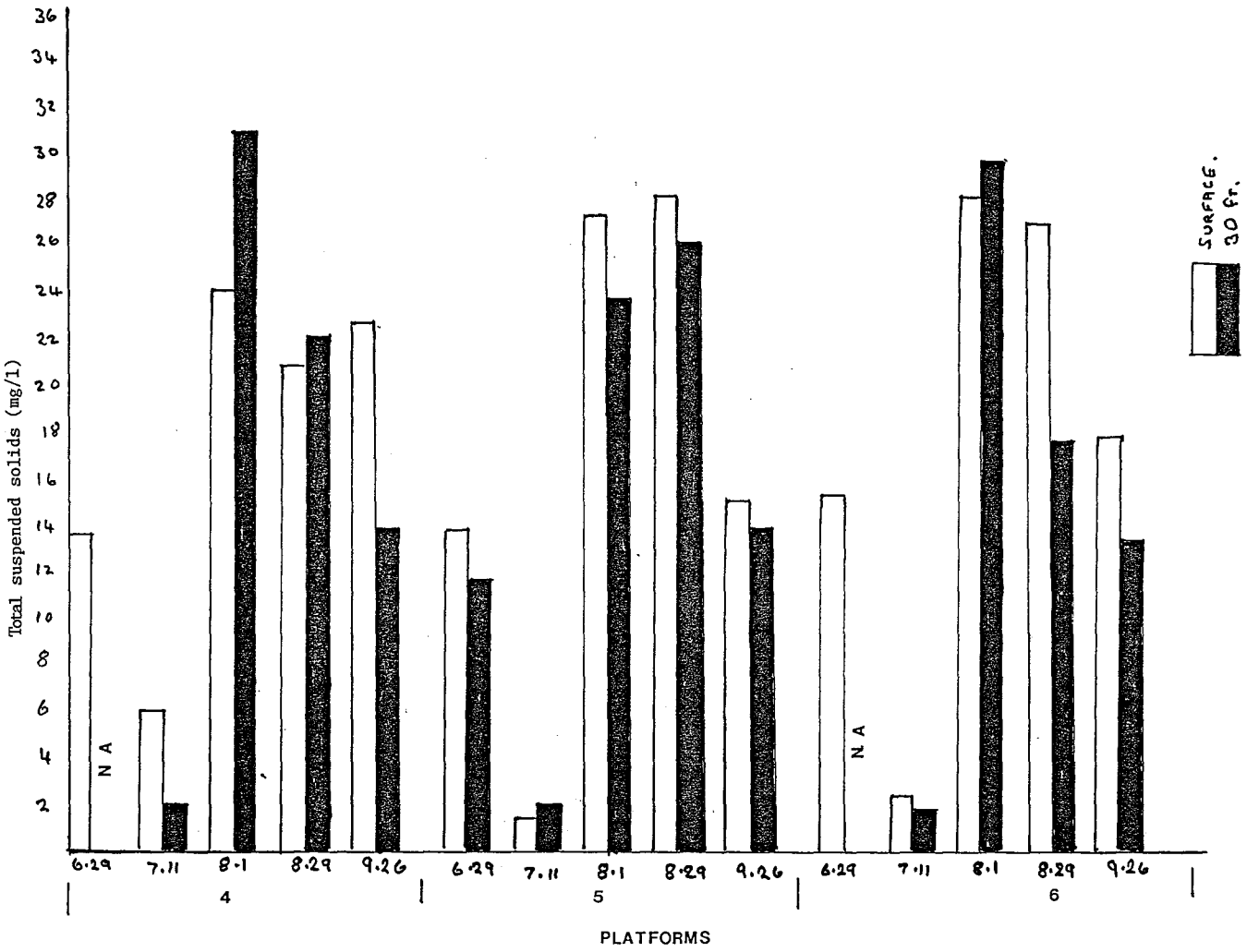


Figure 7. Total suspended solids (mg/1) for surface and 30 ft depth for platforms 4, 5 and 6.

Table 13. Total Suspended Solids (mg/1), Red Point Sewer Outfall Study, St. Thomas, U.S.V.I., taken during five sampling periods as indicated.

Location	Depth	6-29-87 TSS mg/1	7-11-87 TSS mg/1	8-1-87 TSS mg/1	8-29-87 TSS mg/1	9-26-87 TSS mg/1	Mean/SD
Platform 1	surface	15.0	17.2	22.8	36.8	23.0	23.0 ± 8.4
Platform 1	30 ft.	11.2	22.8	27.2	21.6	13.0	19.2 ± 6.8
Platform 2	surface	12.4	2.8	20.0	22.0	13.8	14.2 ± 7.5
Platform 2	30 ft	11.4	2.2	26.0	20.8	16.0	15.3 ± 9.1
Platform 3	surface	11.6	1.6	27.6	22.0	14.4	15.4 ± 9.9
Platform 3	30 ft	12.4	2.8	25.2	26.0	14.2	16.1 ± 9.7
Platform 4	surface	13.6	6.0	24.0	20.8	22.6	17.4 ± 7.5
Platform 4	30 ft	no data	2.0	30.8	22.0	13.8	17.2 ±12.3
Platform 5	surface	13.8	1.4	27.2	28.0	15.0	17.1 ± 1.0
Platform 5	30 ft	11.6	2.0	23.6	26.0	13.8	15.4 ± 9.7
Platform 6	surface	15.2	2.4	28.0	26.8	17.8	18.0 ±10.3
Platform 6	40 ft	no data	1.8	29.6	17.6	13.4	15.6 ± 1.5
Surface mean/SD		13.6 ±1.4	5.2± 6.1	24.9 ±3.2	26.1± 6.0	17.8± 4.1	17.5 ± 8.9
30 ft depth mean/SD		11.7 ± .5	5.6± 8.4	27.1 ±2.7	22.3± 3.2	14.0± 1.0	16.5 ± 9.0

(1975) in Jamaica. We found a mean range of 3.88 - 7.00 mm/yr (at 30 ft) for St. Thomas, 6.10 - 12.4 mm/yr (at 15 to 25 ft) was found on the reefs of Barbados, and a mean of 1.86 mm/yr (at 30 ft) was found in Jamaica. In Barbados, their samples were measured along a gradient of increasing eutrophication and in Jamaica increased nutrients were not necessarily present. However, in both comparative cases the corals did not go through the stress of transplantation.

Even though the growth of coral at the Red Point sewer outfall area grew faster than the control, we must consider the validity of our control platform. At this time we have no quantitative data available to evaluate our control. The range of skeletal extension rates seems reasonable when compared to the work of others. For future studies, several controls located away from the study site are recommended.

Recent studies (reported in Marszalek, 1987) have shown that corals are relatively resistant to sewage toxicity, whereas similar concentration are fatal to fish and shrimp. In addition, these studies reported that corals do not take up a variety of toxic substances such as lead, cadmium, chromium, copper or zinc and were particularly resistant to chlorinated effluents. Therefore, we are probably not looking at the toxic effects of sewage, but the effects of nutrient loading on the system. What we saw, in the worst case situation (Platform 6) was eutrophic conditions favoring algal growth. We predict mortality for Montastrea annularis in the very near future on Platform 6 as algal growth will cause decreasing light levels, a mass exodus of zooxanthellae, and eventual death of the coral.

Only Platform 6 seemed to be affected by extensive algal growth. Platform 6 represents a situation which was down current from the sewer outflow. It shows that the major concentration of nutrients was going away from shore and away from the natural reef. Platforms 3, 4 and 5 did not exhibit the same proliferation of algal growth, indicating a much lesser concentration of nutrients.

In the report by Marszalek (1987) it is suggested that nutrient loading and its stimulation of algal growth is a primary cause of the destruction of coral reefs in sewage polluted environments. Coral mortality can result from overgrowth by algae, and can occur in the absence of toxic substances in the effluents. Our study suggests that as long as the nutrients continue to be dispersed offshore and do not appreciably effect the inshore reef area, causing extensive algal growth, the Montastrea annularis will probably survive and grow at the rate we have measured.

Because of the short duration of this study we can not conclusively say that inshore corals will not begin to show gradual degradation due to algal growth. Emphasis should be placed on a long-term monitoring program, especially when conditions of: 1) amount of effluent, 2) chemical composition of effluent 3) and treatment of effluent change.

The sewage at the Red Point sewer outfall we were monitoring was raw sewage. During the study the sewage was not treated. With changes in the chemical composition of the sewage, by treatment, the outcome of our study could be different.

Acropora cervicornis. Growth of Acropora cervicornis during the first 30 days (T1: time period 1) was slow, probably the result of stress from being moved to the platforms. The second 30 days (T2: time period 2), the growth rate increased as the coral adapted to the new environment and recovered from the stress of being moved. The growth rate during the last 30 days (T3: time period 3) of the study began to reflect the impact from the change and the differences in the experimental environments.

The study was not long enough to evaluate the long-term effects except in the case of Platform 6. However, the trend was towards a decrease in growth during the third time period, most noticeable at Platforms 5 and 6.

High nutrient levels at Platform 6 were responsible for the prolific growth in the algae. Within 90 days, the algal cover was sufficient to smother the corals, reducing light levels which decreased zooxanthellae photosynthesis, causing the corals to die.

What will happen to the corals on the other platforms is uncertain. Platform 5 was showing a trend of decreasing growth rates throughout the study. Platform 3 was also decreasing in the amount of growth during time period 3. However, Platforms 1, 2 and 4 are similar in their trends of slightly increasing or having steady growth rates.

The decrease in growth on Platform 5 and 3 cannot be attributed to algae smothering. If left for a longer period of time, the experiment would be much more valuable and stronger conclusions could be made for the outcome and thus a much better interpretation of the effects of the effluent could be made.

Negative growth measurements occurring in Acropora cervicornis can be explained in some cases. Since most of the negative growth numbers were obtained in time period #1,

we can speculate that the stress of initial breaking, handling, measuring and attaching of experimental corals could account for undue stress. Fish biting or hitting the coral would account for breakage and a recorded negative growth. During the initial set-up a large dolphin swam very near to the platform. Such a large animal hitting the platform could account for the damage that was observed at the end of time period #3 (see photograph).

Platform 1 also was damaged during time period #2. The final photographs of Platform 1 illustrate how the platform had been hit and the coral knocked over. The damage could have occurred from anchoring in the area or by divers disturbing the platform. During sampling at the end of time period #2, it was noted that pieces of A. cervicornis were not on their original pegs, indicating human interference.

Coral Zooxanthellae Count

The zooxanthellae count in corals at all experimental platforms was greater or equal to the control platform when sampled at 90 days. There is no reason to conclude that the system has stabilized and this is the equilibrium number based on the conditions present at each platform. We can pretty well conclude that the coral heads on Platform 6 will eventually lose additional zooxanthellae and die (as did the Acropora cervicornis) due to shading and suffocation from the algae.

In future studies it would seem much more appropriate to sample heads of M. annularis that are already growing at the experimental site. There is an abundance of M. annularis heads in the vicinity of each platform (excluding Platform 6). We can be sure that the heads obtained in the area have not been subjected to artificial stress from being dyed, cut, moved, improper orientation when mounted on the platform, etc., and that any stress the corals are subjected to is from the natural environment surrounding the already adapted corals.

Apart from concluding that transplantation corals, after 90 days, do not exhibit stress due to the loss of zooxanthellae to any greater extent than the control, other conclusions cannot be made.

Sediment Analysis

The possibility that the sewage effluent significantly increased sedimentation rates at Platform 6 is not supported by our data. Nor did the adjacent coral area

(Platform 5) have significantly higher sedimentation rates than more distant platforms in Perseverance or Brewers Bays (Platforms 1 and 2).

The low total organic carbon values indicate that organic material is not accumulating near Platform 6 in appreciable amounts. Even though total organic carbon is significantly greater at Platform 6 than at Platforms 2 and 4, it is not significantly different from the control. The plugs taken under Platform 6 were in a Halophila (seagrass) bed, which would naturally have higher total organic carbon than sediment in coral reef areas.

Coral Recruitment

The lack of coral settlement over such a short period of time as the study allowed was not unexpected. Previous Caribbean coral recruitment work showed that longer time intervals were required to obtain significant numbers of juveniles settling (Rogers, et al., 1984).

Algal Growth

Algal growth increases directly with the amount of available nutrients. The large increase in macroscopic algae on Platform 6 was therefore expected. The lack of a significant increase in algal biomass found on settling plates probably resulted from shading by larger macroscopic algae which enveloped underlying turfs.

Single-species Algal Test

A unialgal culture was introduced at each study site in an attempt to test the toxicity of the effluent. Because local waters have different chemical characteristics than the normal environment of the algae, the low survival rate and therefore lack of any quantitative data was not surprising. However, two conclusions can be drawn from this experiment.

1. The cultured Champia used in EPA bioassays do not compete well with coral reef algae when placed in this environment.

2. The conditions present at Platform 6 were better able to support the growth and reproduction of Champia.

Total Suspended Solids

The total amount of suspended solids do not differ between platforms, therefore differences in any of the measured parameters cannot be directly attributed to this water quality indicator.

CONCLUSIONS

*** All coral heads of Montastrea annularis survived and appeared healthy at the end of the 90-day study. The long-term projection, based on the 90-day data, indicates that the inshore corals will survive and continue to grow, while the corals down current, not part of the natural reef, will probably die.

*** Skeletal extension in Montastrea annularis appears to be in the normal range when compared to other studies. This growth was significantly greater at experimental platforms near the sewer outfall than at the control platform, probably the result of increased nutrients.

*** Platform 6, placed down-current from the diffuser, indicates that the major concentration of nutrients are being carried away from the natural reef.

*** Growth of Acropora cervicornis was decreasing during the final sampling period. Three of the five experimental platforms had appreciable decreases in the coral growth rate, with the Platform 6 corals dying. Long-term projection, based on the 90-day data, indicates that corals of A. cervicornis are probably stressed, however, decreased growth rate on all platforms was not significantly different from those of the control platform. Again, the projection is not conclusive, as the study time period was too short.

*** Numbers of zooxanthellae found in the tissues of Montastrea annularis are, in all cases, greater at the experimental platforms near the sewer outfall than at the control site. No loss of zooxanthellae can be attributed to stress 90 days after transplantation.

*** The time period allowed for the study was too short to study coral recruitment.

*** Cultured Champia, suggested by EPA to study toxicity of sewage effluent, was unable to compete with local coral reef algae.

*** Sedimentation rates are not significantly higher at experimental sites than at the control site.

*** Accumulation of total organic carbon, even though significantly higher at Platform 6 than at several other platforms, it is not significantly higher than at the control platform. In addition, the amount of total organic carbon in all samples is low.

*** Total suspended solids are uniformly distributed at all study sites.

*** A long-term marine monitoring program must be part of any waste water disposal system to recognize early signs of degradation in order to implement a timely correction plan.

Appendix IA. Length and width in centimeters of Montastrea annularis heads.

Sample Number	Platform 1		Platform 2		Platform 3	
	Length	Width	Length	Width	Length	Width
1	14.5	7.6	14.1	14.1	11.4	14.4
2	10.6	13.7	11.7	11.7	13.6	12.5
3	13.4	11.2	13.1	11.7	11.9	13.4
4	10.6	17.0	16.5	11.5	14.8	11.9
5	11.8	11.5	11.8	14.1	11.2	14.3
6	11.1	11.4	14.8	8.7	13.7	14.7
7	12.5	17.7	18.1	10.1	11.8	17.5
8	7.8	13.7	13.1	10.9	14.2	19.4
9	14.0	17.2	14.1	10.8	12.7	16.6
10	11.7	13.2	15.4	11.2	13.4	12.4
11	13.2	12.1	15.0	14.9	15.9	16.2
12	12.6	11.6	13.2	11.2	14.7	17.3
	Platform 4		Platform 5		Platform 6	
	Length	Width	Length	Width	Length	Width
1	11.2	11.8	9.8	12.0	20.1	16.1
2	13.8	11.4	10.4	12.6	12.6	20.8
3	12.7	15.9	14.0	14.1	11.6	12.1
4	12.7	14.2	12.9	11.1	12.9	10.0
5	12.2	11.1	10.9	13.0	15.1	13.1
6	9.9	12.2	15.6	10.6	9.6	12.3
7	16.9	16.2	11.6	12.7	16.1	19.3
8	11.9	10.6	15.0	11.9	15.1	15.0
9	12.3	12.6	9.8	15.5	11.5	13.5
10	10.5	10.2	11.5	17.5	10.5	12.4
11	15.7	16.2	12.7	12.2	10.5	14.2
12	15.6	13.9	9.5	17.8	12.4	11.2

Appendix IB. Summary of the condition of Montastrea annularis heads found on Platform #2 during the August 1, 1987 visit (appeared as Table 3 in the 15 and 36 day monitoring report).

Sample	Condition	% Dead Polyps
1	Partially dead	20
2	Partially dead	10
3	Alive, but pale in color	--
4	Partially dead	20
5	Partially dead	40
6	Alive, but pale in color	--
7	Partially dead	20
8	Partially dead in spots	10
9	Alive,but pale in color	--
10	Almost all dead	90
11	Partially dead	30
12	Partially dead and spotty	10

Zooxanthellae count/correction for dilution/correction for hemacytometer volume/average per head.

PLATFORM 1

Head	Sample in ml	Original Count 1	2	3	4	Correction for Dilution 1	2	3	4	Number of Zooxanthellae (X 10^6) 1	2	3	4	Average
1	2.6	18	21	16	19	46.8	54.6	41.6	49.4	0.47	0.55	0.42	0.49	
1	3.4	35	37	24	26	119.0	125.8	81.6	88.4	1.19	1.26	0.82	0.88	0.76
2	1.9	28	27	24	27	53.2	51.3	45.6	51.3	0.53	0.51	0.46	0.51	
2	1.9	21	22	19	15	39.9	41.8	36.1	28.5	0.40	0.42	0.36	0.29	0.43
3	2.2	16	9	11	10	35.2	19.8	24.2	22.0	0.35	0.20	0.24	0.22	
3	4.4	23	25	20	12	101.2	110.0	88.0	52.8	1.01	1.10	0.88	0.53	0.57
4	3	12	9	14	10	36.0	27.0	42.0	30.0	0.36	0.27	0.42	0.30	
4	2.5	17	26	27	22	42.5	65.0	67.5	55.0	0.43	0.65	0.68	0.55	0.46
5	2.8	37	31	30	21	103.6	25.2	84.0	58.8	1.04	0.25	0.84	0.59	
5	3.7	35	43	25	15	129.5	159.1	92.5	55.5	1.30	1.59	0.93	0.56	0.89
6	2.6	36	48	35	36	93.6	124.8	91.0	93.6	0.94	1.25	0.91	0.94	
6	3.8	27	40	36	31	102.6	152.0	136.8	117.8	1.03	1.52	1.37	1.18	1.14
7	3.2	55	47	58	43	176.0	150.4	185.6	206.2	1.76	1.50	1.86	2.06	
7	2.4	70	68	92	96	168.0	163.2	220.8	230.4	1.68	1.63	2.21	2.30	1.88
8	2.1	78	67	73	74	163.8	140.7	153.3	155.4	1.64	1.41	1.53	1.55	
8	3	15	8	17	11	45.0	24.0	51.0	33.0	0.45	0.24	0.51	0.33	0.96
9	2.7	36	21	19	15	97.2	56.7	51.3	40.5	0.97	0.57	0.51	0.41	
9	2.4	34	28	24	12	81.6	67.2	57.6	28.8	0.82	0.67	0.58	0.29	0.60
10	2.6	50	37	39	36	130.0	96.2	101.4	93.6	1.30	0.96	1.01	0.94	
10	2.4	17	32	21	12	40.8	76.8	50.4	28.8	0.41	0.77	0.50	0.29	0.77
11	4.6	28	21	21	15	128.8	96.6	96.6	69.0	1.29	0.97	0.97	0.69	
11	3.7	18	14	32	31	66.6	51.8	118.4	114.7	0.67	0.52	1.18	1.15	0.93
12	2.9	40	39	40	38	116.0	113.1	116.0	110.2	1.16	1.13	1.16	1.10	
12	3	27	41	49	47	81.0	123.0	147.0	141.0	0.81	1.23	1.47	1.41	1.18

Zooxanthellae count/correction for dilution/correction for hemacytometer volume/average per head.

PLATFORM 2

Head	Sample in ml	Original Count 1	2	3	4	Correction for Dilution 1	2	3	4	Number of Zooxanthellae (X 10^6) 1	2	3	4	Average
1	3.1	42	61	55	54	130.2	189.1	170.5	167.4	1.30	1.89	1.71	1.67	
1	3.4	45	69	41	39	153.0	234.6	139.4	132.6	1.53	2.35	1.39	1.33	1.65
2	3	25	32	24	22	75.0	96.0	72.0	66.0	0.75	0.96	0.72	0.66	
2	2.6	24	23	24	18	62.4	59.8	62.4	91.6	0.62	0.60	0.62	0.92	0.73
3	4.4	52	77	41	77	228.8	133.4	174.4	251.4	2.29	1.33	1.74	2.51	
3	6.2	52	30	29	40	322.4	186.0	179.8	248.0	3.22	1.86	1.80	2.48	2.16
4	4.4	58	39	40	54	255.2	171.6	176.0	237.6	2.55	1.72	1.76	2.38	
4	6.3	26	29	39	32	163.8	182.7	245.7	201.6	1.64	1.83	2.46	2.02	2.04
5	3.4	27	39	34	52	91.8	182.7	245.7	176.8	0.92	1.83	2.46	1.77	
5	3.3	27	24	35	37	89.1	79.2	115.5	122.1	0.89	0.79	1.16	1.22	1.38
6	3.9	26	28	49	47	101.4	109.2	191.1	183.3	1.01	1.09	1.91	1.83	
6	3.9	56	48	50	34	218.4	187.2	195.0	132.6	2.18	1.87	1.95	1.33	1.65
7	4.7	13	27	37	22	61.1	126.9	173.9	103.4	0.61	1.27	1.74	1.03	
7	4.4	18	27	24	17	79.2	118.8	105.6	74.8	0.79	1.19	1.06	0.75	1.05
8	1.9	79	65	45	79	150.1	123.5	85.5	150.1	1.50	1.24	0.86	1.50	
8	3.6	35	70	26	27	126.0	252.0	93.6	97.2	1.26	2.52	0.94	0.97	1.35
9	5.2	21	25	29	24	109.2	130.0	150.8	124.8	1.09	1.30	1.51	1.25	
9	4.7	33	39	32	44	155.1	183.3	150.4	206.8	1.55	1.83	1.50	2.07	1.51
10	3	50	55	87	51	150.0	165.0	261.0	246.0	1.50	1.65	2.61	2.46	
10	3.4	22	27	31	13	74.8	91.8	105.4	44.2	0.75	0.92	1.05	0.44	1.42
11	3.3	66	87	57	58	217.8	287.1	188.1	191.4	2.18	2.87	1.88	1.91	
11	3.4	89	49	43	46	302.6	166.6	146.2	156.4	3.03	1.67	1.46	1.56	2.07
12	4.4	36	22	14	18	158.4	96.8	61.6	79.2	1.58	0.97	0.62	0.79	
12	4.2	26	19	18	18	30.2	49.2	75.6	75.6	0.30	0.49	0.76	0.76	0.78

Zooxanthellae count/correction for dilution/correction for hemacytometer volume/average per head.

PLATFORM 3

Head	Sample in ml	Original Count 1	2	3	4	Correction for Dilution 1	2	3	4	Number of Zooxanthellae (X 10^6) 1	2	3	4	Average
1	3.1	57	51	72	58	176.7	158.1	223.2	179.8	1.77	1.58	2.23	1.80	
1	3.2	88	92	81	112	281.6	294.4	259.2	358.4	2.82	2.94	2.59	3.58	2.41
2	9.6	21	15	14	20	201.6	144.0	134.4	192.0	2.02	1.44	1.34	1.92	
2	3.5	42	32	17	46	147.0	112.0	59.5	161.0	1.47	1.12	0.60	1.61	1.44
3	4	37	65	27	26	148.0	260.0	108.0	104.0	1.48	2.60	1.08	1.04	
3	2.9	52	41	51	51	150.8	118.9	147.9	147.9	1.51	1.19	1.48	1.48	1.48
4	3.8	30	33	29	34	114.0	125.4	110.2	129.2	1.14	1.25	1.10	1.29	
4	2.8	39	59	55	46	109.2	165.2	154.0	128.8	1.09	1.65	1.54	1.29	1.30
5	4.4	45	55	51	45	198.0	242.0	224.4	198.0	1.98	2.42	2.24	1.98	
5	4.4	23	19	26	16	101.2	83.6	114.4	70.4	1.01	0.84	1.14	0.70	1.54
6	3.4	64	64	56	60	217.6	217.6	190.4	204.0	2.18	2.18	1.90	2.04	
6	3.4	65	44	35	48	221.0	149.6	119.0	163.2	2.21	1.50	1.19	1.63	1.85
7	3	82	73	34	51	246.0	219.0	102.0	153.0	2.46	2.19	1.02	1.53	
7	2.5	64	62	54	45	160.0	155.0	135.0	112.5	1.60	1.55	1.35	1.13	1.60
8	3.6	65	51	43	47	234.0	183.6	154.8	169.2	2.34	1.84	1.55	1.69	
8	3	32	65	43	41	96.0	195.0	129.0	123.0	0.96	1.95	1.29	1.23	1.61
9	3.8	22	40	25	38	83.6	152.0	95.0	144.4	0.84	1.52	0.95	1.44	
9	3	96	76	89	76	288.0	228.0	267.0	228.0	2.88	2.28	2.67	2.28	1.86
10	4.3	47	39	37	30	202.1	167.7	159.1	129.0	2.02	1.68	1.59	1.29	
10	5.2	37	26	25	18	192.4	135.2	130.0	93.6	1.92	1.35	1.30	0.94	1.51
11	6	23	27	31	19	138.0	162.0	186.0	114.0	1.38	1.62	1.86	1.14	
11	3.9	33	38	30	32	128.7	148.2	117.0	124.8	1.29	1.48	1.17	1.25	1.40
12	2.4	55	68	67	54	132.0	163.2	160.8	129.6	1.32	1.63	1.61	1.30	
12	3.7	38	32	28	33	140.6	118.4	103.6	122.1	1.41	1.18	1.04	1.22	1.34

Zooxanthellae count/correction for dilution/correction for hemacytometer volume/average per head.

PLATFORM 4

Head	Sample in ml	Original Count 1	2	3	4	Correction for Dilution 1	2	3	4	Number of Zooxanthellae (X 10^6) 1	2	3	4	Average
1	4.2	27	33	34	27	113.4	138.6	142.8	113.4	1.13	1.39	1.43	1.13	
1	3.7	24	22	29	46	88.8	81.4	107.3	170.2	0.89	0.81	1.07	1.70	1.12
2	1.9	29	29	37	39	55.1	55.1	70.3	74.1	0.55	0.55	0.70	0.74	
2	3.2	44	42	33	44	140.8	134.4	105.6	140.8	1.41	1.34	1.06	1.41	0.97
3	2.6	40	26	36	42	104.0	67.6	93.6	109.2	1.04	0.68	0.94	1.09	
3	2.4	37	27	28	29	88.8	64.8	67.2	69.6	0.89	0.65	0.67	0.70	0.83
4	2.4	43	38	63	55	103.2	91.2	151.2	132.0	1.03	0.91	1.51	1.32	
4	2	50	60	37	46	100.0	120.0	74.0	92.0	1.00	1.20	0.74	0.92	1.08
5	3.1	56	69	59	51	173.6	213.9	182.9	158.1	1.74	2.14	1.83	1.58	
5	2.7	86	53	68	69	232.2	143.1	183.6	186.3	2.32	1.43	1.84	1.86	1.84
6	2.7	41	40	23	22	110.7	108.0	62.1	59.4	1.11	1.08	0.62	0.59	
6	2.2	34	38	29	37	74.8	83.6	63.8	81.4	0.75	0.84	0.64	0.81	0.80
7	2.5	68	92	61	56	170.0	230.0	152.5	140.0	1.70	2.30	1.53	1.40	
7	2.2	58	49	72	83	127.6	107.8	158.4	182.6	1.28	1.08	1.58	1.83	1.59
8	3.3	45	41	57	35	148.5	135.3	188.1	115.5	1.49	1.35	1.88	1.16	
8	2.8	47	63	45	56	131.6	176.4	126.0	156.8	1.32	1.76	1.26	1.57	1.47
9	2.9	67	67	88	70	194.3	194.3	255.2	203.0	1.94	1.94	2.55	2.03	
9	3.2	73	47	32	67	233.6	150.4	102.4	214.4	2.34	1.50	1.02	2.14	1.93
10	3.2	62	87	50	87	198.4	278.4	160.0	278.4	1.98	2.78	1.60	2.78	
10	2.7	35	36	47	55	94.5	97.2	126.9	148.5	0.95	0.97	1.27	1.49	1.73
11	2.9	34	50	40	23	98.6	145.0	116.0	66.7	0.99	1.45	1.16	0.67	
11	3	53	38	34	29	159.0	114.0	102.0	87.0	1.59	1.14	1.02	0.87	1.11
12	1.7	68	80	87	66	115.6	136.0	147.9	112.2	1.16	1.36	1.48	1.12	
12	2.2	74	55	67	66	162.8	121.0	147.4	145.2	1.63	1.21	1.47	1.45	1.36

Zooxanthellae count/correction for dilution/correction for hemacytometer volume/average per head.

PLATFORM 5

Head	Sample in ml	Original Count 1	2	3	4	Correction for Dilution 1	2	3	4	Number of Zooxanthellae (X 10^6) 1	2	3	4	Average
1	2.8	30	51	24	32	84.0	142.8	67.2	89.6	0.84	1.43	0.67	0.90	
1	3.8	32	23	13	23	121.6	87.4	49.4	87.4	1.22	0.87	0.49	0.87	0.91
2	2.6	46	67	45	31	119.6	174.2	117.0	80.6	1.20	1.74	1.17	0.81	
2	2.6	90	73	48	48	234.0	189.8	124.8	124.8	2.34	1.90	1.25	1.25	1.46
3	2.2	64	69	45	42	140.8	151.8	99.0	92.4	1.41	1.52	0.99	0.92	
3	2.6	82	63	105	88	213.2	163.8	273.0	228.8	2.13	1.64	2.73	2.29	1.70
4	4.9	26	53	24	28	127.4	259.7	117.6	137.2	1.27	2.60	1.18	1.37	
4	3	46	76	47	43	138.0	228.0	141.0	129.0	1.38	2.28	1.41	1.29	1.60
5	2.3	28	28	24	19	64.4	64.4	55.2	43.7	0.64	0.64	0.55	0.44	
5	2.9	41	39	38	27	118.9	113.1	110.2	78.3	1.19	1.13	1.10	0.78	0.81
6	3.4	38	31	43	30	129.2	105.4	146.2	102.0	1.29	1.05	1.46	1.02	
6	3.4	35	36	27	23	119.0	122.4	91.8	78.2	1.19	1.22	0.92	0.78	1.12
7	2.5	41	31	23	22	102.5	77.5	57.5	55.0	1.03	0.78	0.58	0.55	
7	2.5	15	33	51	61	37.5	82.5	127.5	152.5	0.38	0.83	1.28	1.53	0.87
8	2.6	22	41	55	59	57.2	106.6	143.0	153.4	0.57	1.07	1.43	1.53	
8	2.8	16	18	19	21	44.8	50.4	53.2	58.8	0.45	0.50	0.53	0.59	0.83
9	2.9	22	27	28	24	63.8	78.3	81.2	69.6	0.64	0.78	0.81	0.70	
9	3	44	32	33	15	132.0	96.0	99.0	45.0	1.32	0.96	0.99	0.45	0.83
10	2.6	49	63	31	36	127.4	163.8	80.6	93.6	1.27	1.64	0.81	0.94	
10	3.1	63	61	69	59	195.3	189.1	213.9	182.9	1.95	1.89	2.14	1.83	1.56
11	3.1	17	23	36	30	52.7	71.3	111.6	93.0	0.53	0.71	1.12	0.93	
11	3.3	35	31	49	69	115.5	102.3	161.7	227.7	1.16	1.02	1.62	2.28	1.17
12	3.7	20	26	31	30	74.0	96.2	114.7	111.0	0.74	0.96	1.15	1.11	
12	3.6	47	44	41	34	169.2	158.4	147.6	122.4	1.69	1.58	1.48	1.22	1.24

Zooxanthellae count/correction for dilution/correction for hemacytometer volume/average per head.

PLATFORM 6

Head	Sample in ml	Original Count 1	2	3	4	Correction for Dilution 1	2	3	4	Number of Zooxanthellae (X 10^6) 1	2	3	4	Average
1	1.6	66	61	35	46	105.6	97.6	56.0	73.6	1.06	0.98	0.56	0.74	
1	1.2	41	67	59	60	49.2	80.4	70.8	72.0	0.49	0.80	0.71	0.72	0.76
2	1.8	35	36	32	34	63.0	64.8	57.6	61.2	0.63	0.65	0.58	0.61	
2	1.9	66	70	53	44	125.4	133.0	100.7	83.6	1.25	1.33	1.01	0.84	0.86
3	2.9	32	25	38	41	92.8	72.5	110.2	118.9	0.93	0.73	1.10	1.19	
3	2.4	23	26	38	26	55.2	62.4	91.2	62.4	0.55	0.62	0.91	0.62	0.83
4	3.9	46	32	31	28	179.4	124.8	120.9	109.2	1.79	1.25	1.21	1.09	
4	2.2	47	52	38	41	103.4	114.4	83.6	90.2	1.03	1.14	0.84	0.90	1.16
5	2.7	24	30	33	36	64.8	81.0	89.1	97.2	0.65	0.81	0.89	0.97	
5	3.1	33	45	44	38	102.3	139.5	136.4	117.8	1.02	1.40	1.36	1.18	1.04
6	3.4	58	41	38	50	197.2	139.4	129.2	170.0	1.97	1.39	1.29	1.70	
6	3	55	62	77	78	165.0	186.0	231.0	234.0	1.65	1.86	2.31	2.34	1.81
7	3	16	32	30	17	48.0	96.0	90.0	51.0	0.48	0.96	0.90	0.51	
7	4.1	18	34	24	27	73.8	139.4	98.4	110.7	0.74	1.39	0.98	1.11	0.88
8	3.5	38	27	27	42	133.0	94.5	94.5	147.0	1.33	0.95	0.95	1.47	
8	2.9	21	21	32	23	60.9	60.9	92.8	66.7	0.61	0.61	0.93	0.67	0.94
9	3.3	15	11	16	14	49.5	36.3	52.8	46.2	0.50	0.36	0.53	0.46	
9	2.6	52	39	27	36	135.2	101.4	70.2	93.6	1.35	1.01	0.70	0.94	0.73
10	4	33	57	20	24	132.0	228.0	80.0	96.0	1.32	2.28	0.80	0.96	
10	4.5	29	34	27	42	130.5	153.0	121.5	189.0	1.31	1.53	1.22	1.89	1.41
12	2.4	41	50	70	47	98.4	120.0	168.0	112.8	0.98	1.20	1.68	1.13	
12	2.8	57	60	37	59	159.6	168.0	103.6	165.2	1.60	1.68	1.04	1.65	1.37

Appendix III. Acropora cervicornis growth: actual measurements/growth at various sampling periods/growth corrected for 30 day periods.

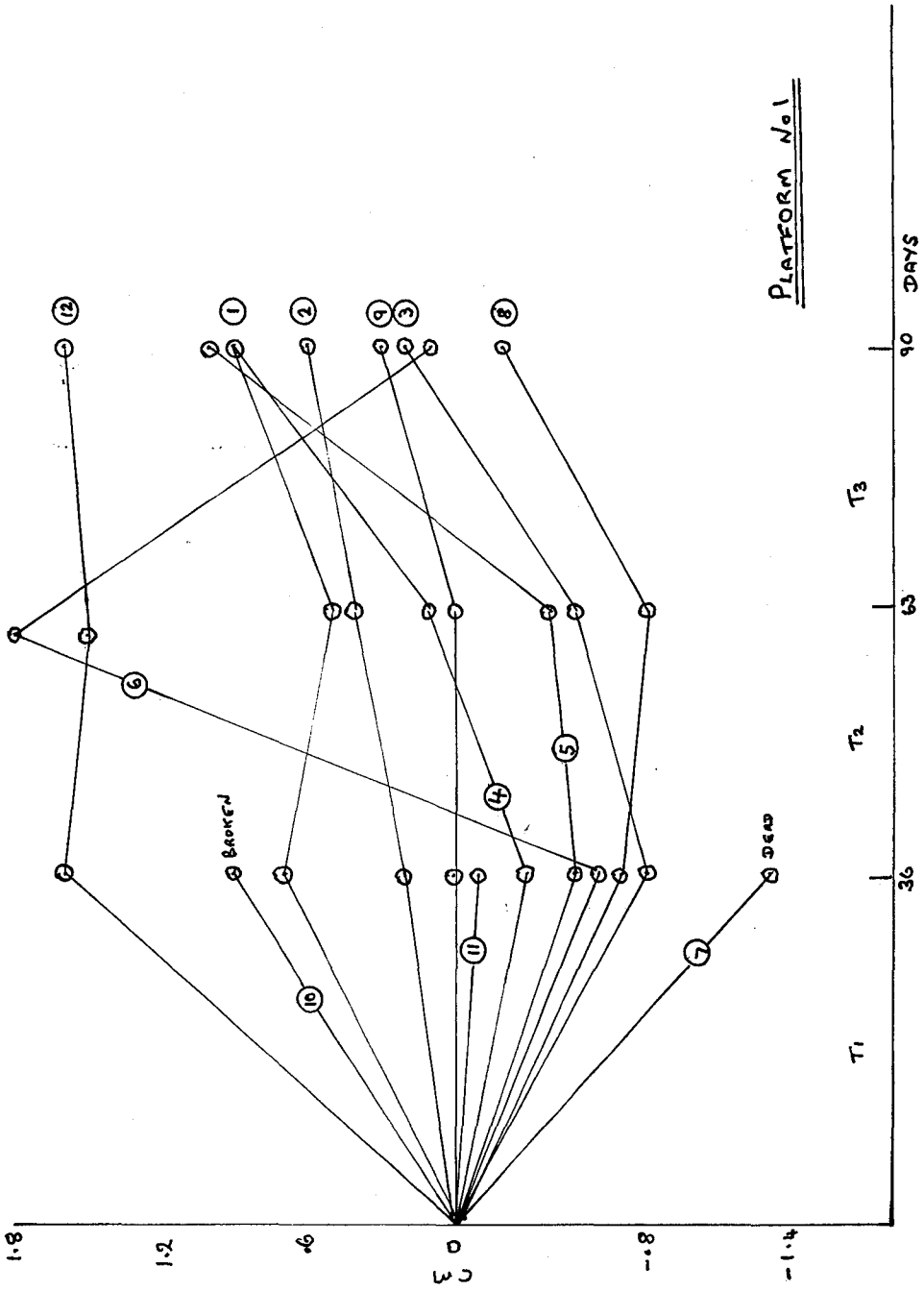
		Actual Measurements				Amount of Growth (cm)				Corrected for each 30 day period		
Platform	Branch	6-27-87	8-2-87	8-29-87	9-26-87	36 days	27 days	27 days	90 day	30day	30day	30day
1	1	22.5	23.2	23	23.4	0.7		0.4	0.9	0.6		0.4
1	2	10	10.2	10.4	10.6	0.2	0.2	0.2	0.6	0.2	0.2	0.2
1	3	7.2	6.4	6.7	7.4		0.3	0.7	0.2		0.3	0.8
1	4	4.1	3.8	4.2	5	-0.3	0.4	0.8	0.9		0.4	0.9
1	5	4.6	4.1	4.2	5.6	-0.5	0.1	1.4	1		0.1	1.6
1	6	5	4.4	6.8	5.1	-0.6	2.4	-1.7	0.1		2.7	
1	7	8	6.7	dead		-1.3						
1	8	9.1	8.4	8.3	8.9	-0.7	-0.1	0.6	-0.2			0.7
1	9	15.1	15.1	15.1	15.4	0	0	0.3	0.3			0.3
1	10	9.7	10.6			0.9				0.8		
1	11	6.5	5.5	broken		-1						
1	12	19.6	21.2	21.1	21.2	1.6	-0.1	0.1	1.6	1.3		0.1
2	1	17	17.2	17.8	19.2	0.2	0.6	1.4	2.2	0.2	0.7	1.6
2	2	4	4.2	5.1	5.8	0.2	0.9	0.7	1.8	0.2	1.0	0.8
2	3	17.1	16.9	17.4	17.5	-0.2	0.5	0.1	0.4		0.6	0.1
2	4	20	20.5	21.5	22.5	0.5	1	1	2.5	0.4	1.1	1.1
2	5	11.1	12.9	14.3	14.9	1.8	1.4	0.6	3.8	1.5	1.6	0.7
2	6	17.3	18	18.5	19.2	0.7	0.5	0.7	1.9	0.6	0.6	0.8
2	7	13.7	14.1	14.2	14.8	0.4	0.1	0.6	1.1	0.3	0.1	0.7
2	8	21.5	22.1	23.1	23.7	0.6	1	0.6	2.2	0.5	1.1	0.7
2	9	19.7	20.3	21.2	22.9	0.6	0.9	1.7	3.2	0.5	1.0	1.9
2	10	11.2	11.6	13.5	14.2	0.4	1.9	0.7	3	0.3	2.1	0.8
2	11	15	15.1	dead		0.1				0.1		
2	12	18.5	19.2	20.1	21	0.7	0.9	0.9	2.5	0.6	1.0	1.0
2	13	15.7	16.4	17.4	18.1	0.7	1	0.7	2.4	0.6	1.1	0.8
2	14	15.4	15.9	16.2	17.1	0.5	0.3	0.9	1.7	0.4	0.3	1.0

Appendix III. Acropora cervicornis growth: actual measurements/growth at various sampling periods/growth corrected for 30 day periods.

		Actual Measurements				Amount of Growth (cm)				Corrected for each 30 day period		
Platform	Branch	6-27-87	8-2-87	8-29-87	9-26-87	36 days	27 days	27 days	90 day	30day	30day	30day
3	1	18.4	19.3	20.4	17.5	0.9	1.1	-2.9	-0.9	0.8	1.2	
3	2	12.1	12.5	14.1	14.9	0.4	1.6	0.8	2.8	0.3	1.8	0.9
3	3	13.6	13.8	14.7	15.2	0.2	0.9	0.5	1.6	0.2	1.0	0.6
3	4	14.1	15.2	15.9	16.5	1.1	0.7	0.6	2.4	0.9	0.8	0.7
3	5	19.8	20.2	21.4	22.3	0.4	1.2	0.9	2.5	0.3	1.3	1.0
3	6	16.5	15.6	16.6	17.5	-0.9	1	0.9	1		1.1	1.0
3	7	14.8	15.5	16.8	17.5	0.7	1.3	0.7	2.7	0.6	1.4	0.8
3	8	14.8	12.5	15.3	16.4	-2.3	2.8	1.1	1.6		3.1	1.2
3	9	18.9	19.5	19.8		0.6	0.3			0.5	0.3	
3	10	20.2	20.6	21.4	22.3	0.4	0.8	0.9	2.1	0.3	0.9	1.0
3	11	21.2	19.9	21.9	23.1	-1.3	2	1.2	1.9		2.2	1.3
3	12	16.2		15.5	16.5			1	0.3			1.1
3	13	16.1	dead									
3		16.7	18.8	19.4	20.1	2.1	0.6	0.7	3.4	1.8	0.7	0.8
3		18	missing							0.0	0.0	0.0
3		18	18.3	18.9	18.8	0.3	0.6	-0.1	0.8	0.3	0.7	
4	1	16.4	17.2	18	18.6	0.8	0.8	0.6	2.2	0.7	0.9	0.7
4	2	16.2	17.1	17.5	17.8	0.9	0.4	0.3	1.6	0.8	0.4	0.3
4	3	13.6	14	14.5	15.2	0.4	0.5	0.7	1.6	0.3	0.6	0.8
4	4	18.7	19.9	18.3	20	1.2	-1.6	1.7	1.3	1.0		1.9
4	5	8.9	9.6	10.9	11.7	0.7	1.3	0.8	2.8	0.6	1.4	0.9
4	6	8.1	9	10.1	12.1	0.9	1.1	2	4	0.8	1.2	2.2
4	7	19.1	21.1	20.3	21.2	2	-0.8	0.9	2.1	1.7		1.0
4	8	8.6	9.4	9.8	10.7	0.8	0.4	0.9	2.1	0.7	0.4	1.0
4	9	17.1	17.9	18.4	18.9	0.8	0.5	0.5	1.8	0.7	0.6	0.6
4	10	17.3	18.9	18.9	19.8	1.6	0	0.9	2.5	1.3	0.0	1.0
4	11	15.6	16.8	17.3	17.6	1.2	0.5	0.3	2	1.0	0.6	0.3
4	12	11.6	11	11.6	12.6	-0.6	0.6	1	1		0.7	1.1

Appendix III. Acropora cervicornis growth: actual measurements/growth at various sampling periods/growth corrected for 30 day periods.

		Actual Measurements				Amount of Growth (cm)				Corrected for each 30 day period		
Platform	Branch	6-27-87	8-2-87	8-29-87	9-26-87	36 days	27 days	27 days	90 day	30day	30day	30day
5	1	20.5	22.1	22.7	22.9	1.6	0.6	0.2	2.4	1.3	0.7	0.2
5	2	6.6	7	7.1	7.2	0.4	0.1	0.1	0.6	0.3	0.1	0.1
5	3	6.6	7	7.7	8.7	0.4	0.7	1	2.1	0.3	0.8	1.1
5	4	20.3	22.1	21.3	21.4	1.8	-0.8	0.1	1.1	1.5		0.1
5	5	13.6	13.4	13.4	13.2	-0.2	0	-0.2	-0.4		0.0	
5	6	10	12.1	11.7	11.9	2.1	-0.4	0.2	1.9	1.8		0.2
5	7	17.9	17.2	dead		-0.7		0				
5	8	15.1	16.1	15.8	16.5	1	-0.3	0.7	1.4	0.8		0.8
5	9	20.4	19.7	21.4	21.2	-0.7	1.7	-0.2	0.8		1.9	
5	10	17.1	17.4	18	18.7	0.3	0.6	0.7	1.6	0.3	0.7	0.8
5	11	16.7	17.6	18.3	18.7	0.9	0.7	0.4	2	0.8	0.8	0.4
5	12	7.4	8.1	8	8.3	0.7	-0.1	0.3	0.9	0.6		0.3
6	1	14.8	15.3	15.7	15.7	0.5	0.4	0	0.9	0.4	0.4	0.0
6	2	22.2	22.5	23.4	23.5	0.3	0.9	0.1	1.3	0.3	1.0	0.1
6	3	18.4	17.9	19.2	19.5	-0.5	1.3	0.3	1.1		1.4	0.3
6	4	21.3	18.8	20.8	21.8	-2.5	2	1	0.5		2.2	1.1
6	5	20.2	20	20.7	21.5	-0.2	0.7	0.8	1.3		0.8	0.9
6	6	19.7	19.5	20.3	20.4	-0.2	0.8	0.1	0.7		0.9	0.1
6	7	18.2	19	19.5	19.7	0.8	0.5	0.2	1.5	0.7	0.6	0.2
6	8	18.8	17.2	19.3	19.8	-1.6	2.1	0.5	1		2.3	0.6
6	9	16.7	17.6	16.9	17.2	0.9	-0.7	0.3	0.5	0.8		0.3
6	10	17.8	17.7	18.6	19.1	-0.1	0.9	0.5	1.3		1.0	0.6
6	11	16.5	16.9	17.3	17.4	0.4	0.4	0.1	0.9	0.3	0.4	0.1
6	12	16.1	15.4	14.7	15.2	-0.7	-0.7	0.5	-0.9			0.6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36
T3
T2
T1
BROKEN
DEAD
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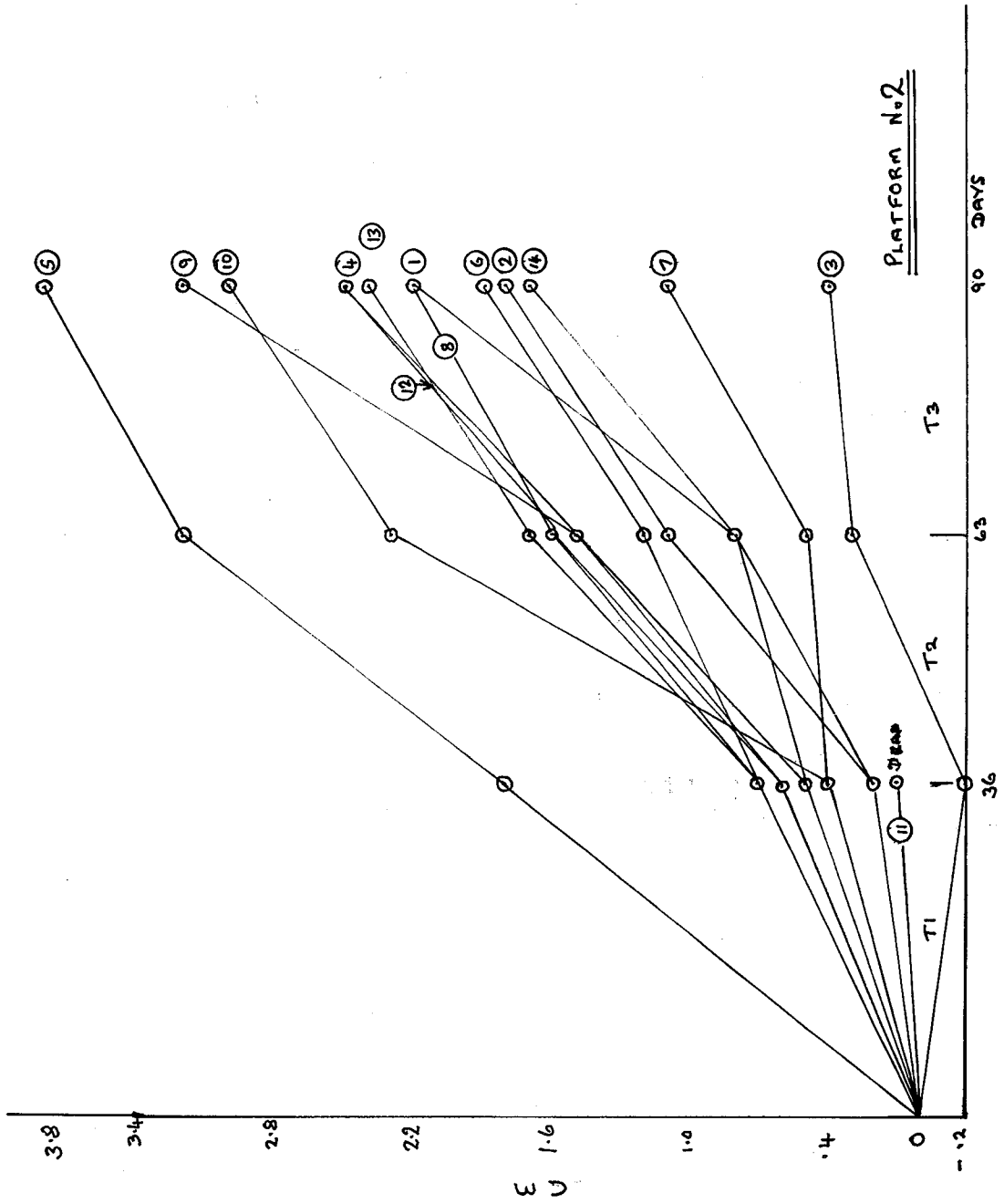
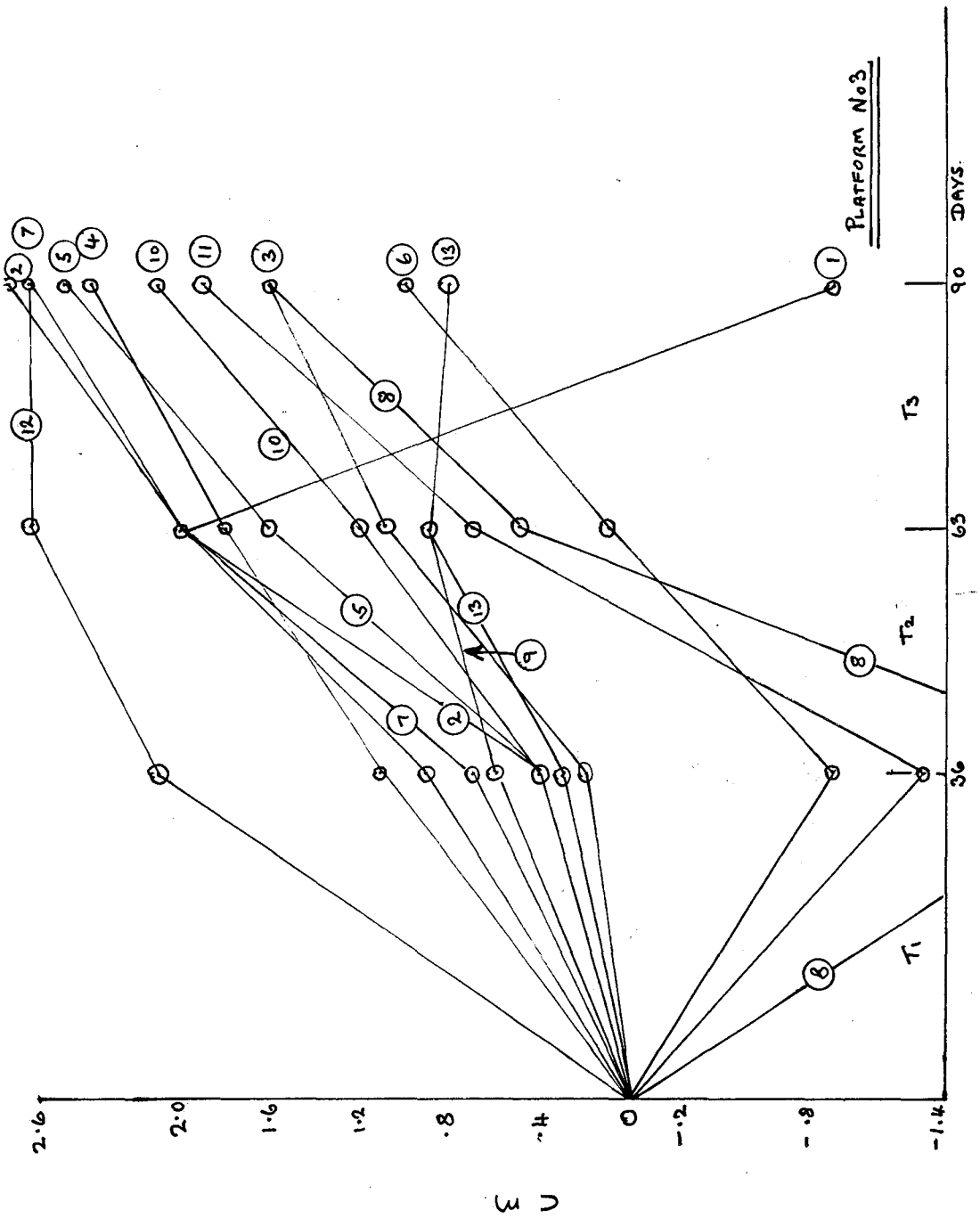
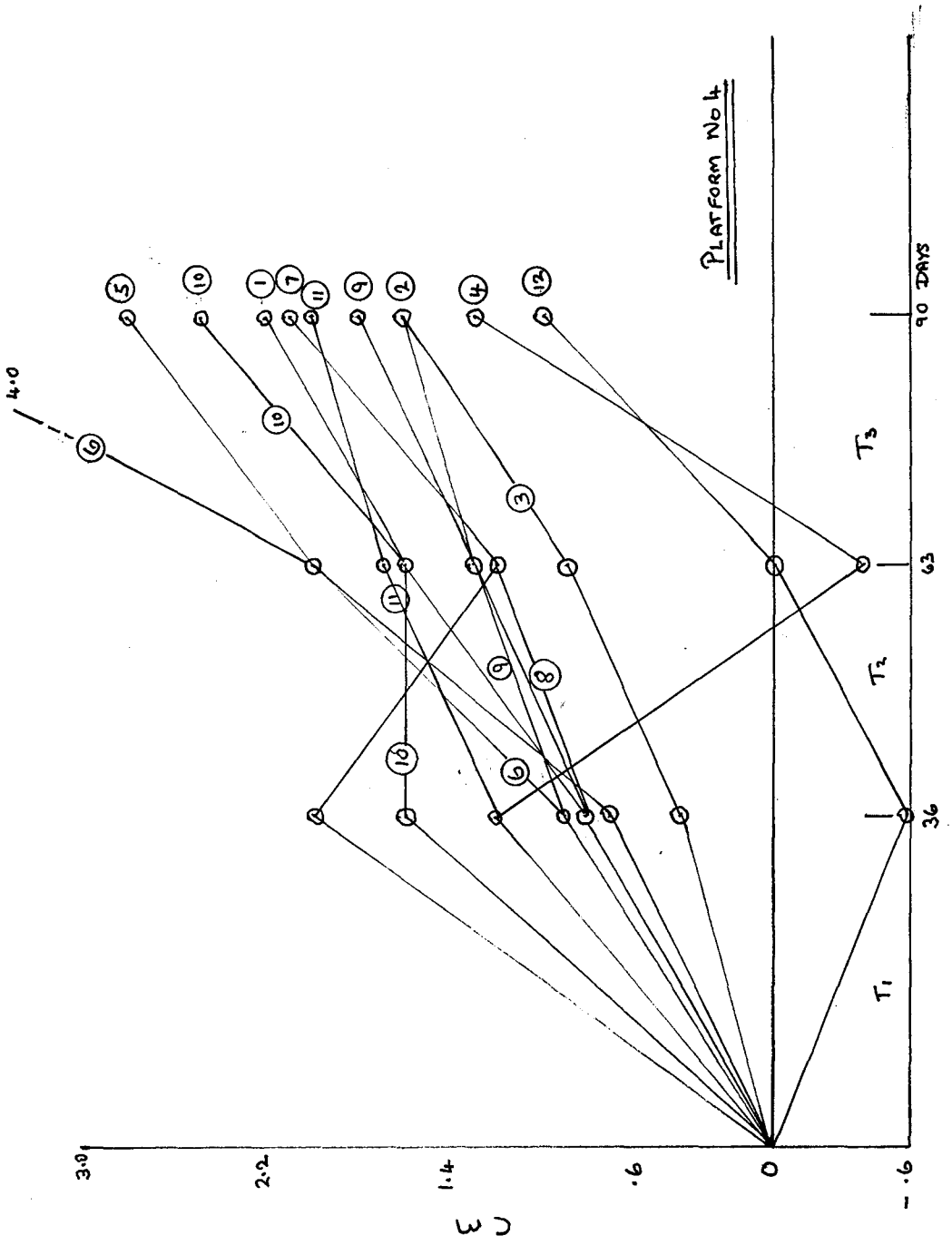
1.2
.6
0
-.8
-1.4
C.G.


PLATFORM No.2
DAYS
90
63
36
T3
T2
T1
MEAN
3·8
3·4
2·8
2·2
1·6
1·0
·4
0
-·2
ε U


PLATFORM No3
DAYS
90
63
36
T3
T2
T1
2·6
2·0
1·6
1·2
·8
·4
0
-·2
-·8
-1·4
C M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T3
T2
T1
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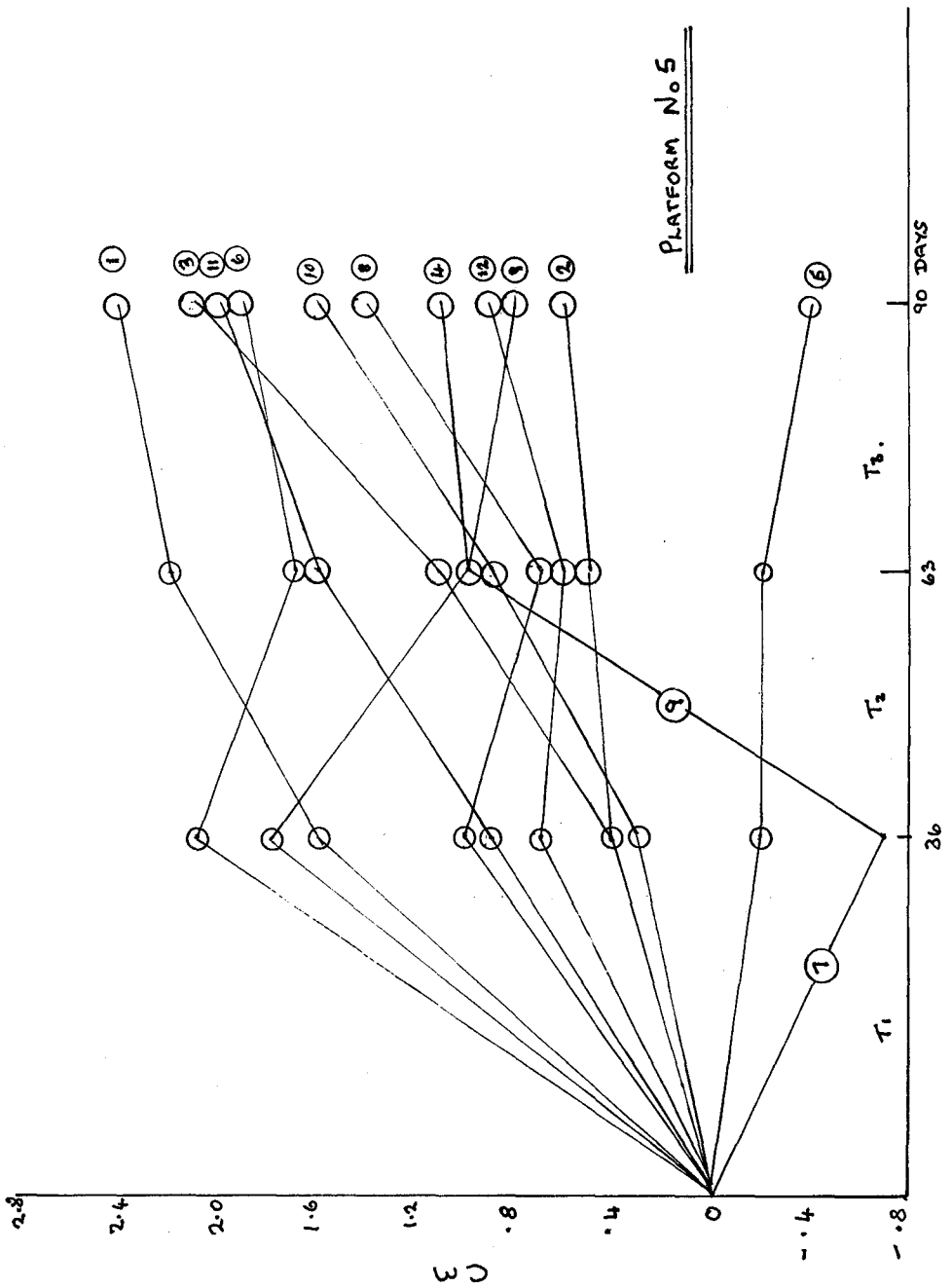
3.0
2.0
1.4
.6
0
-.6
C D


PLATFORM No 5
90 DAYS
63
36
T3.
T2
T1
2.8
2.4
2.0
1.6
1.2
.8
.4
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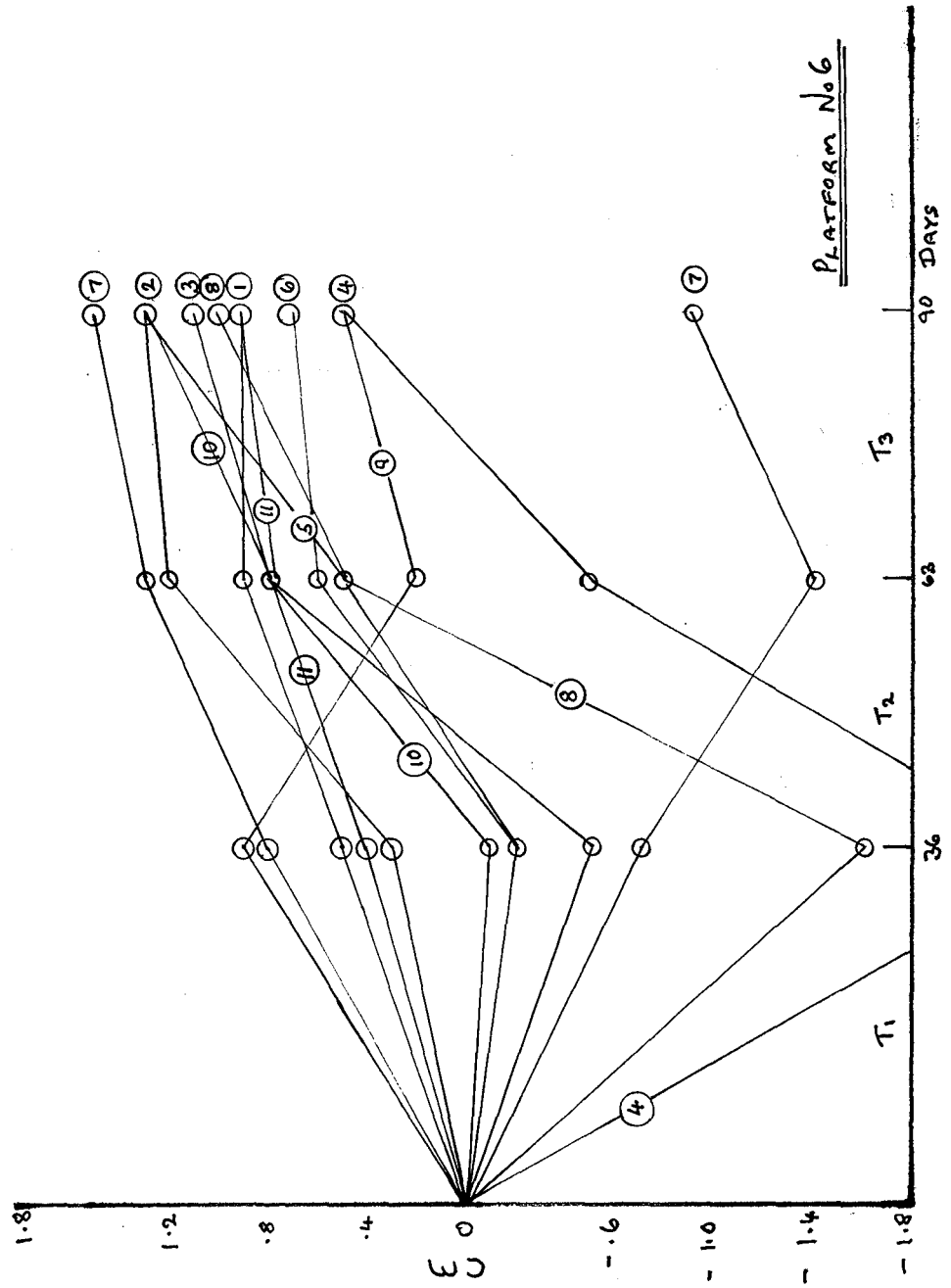
-.4
-.8
C.D.


PLATFORM No 6
DAYS
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63
36
T1
T2
T3
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1.2
.8
.4
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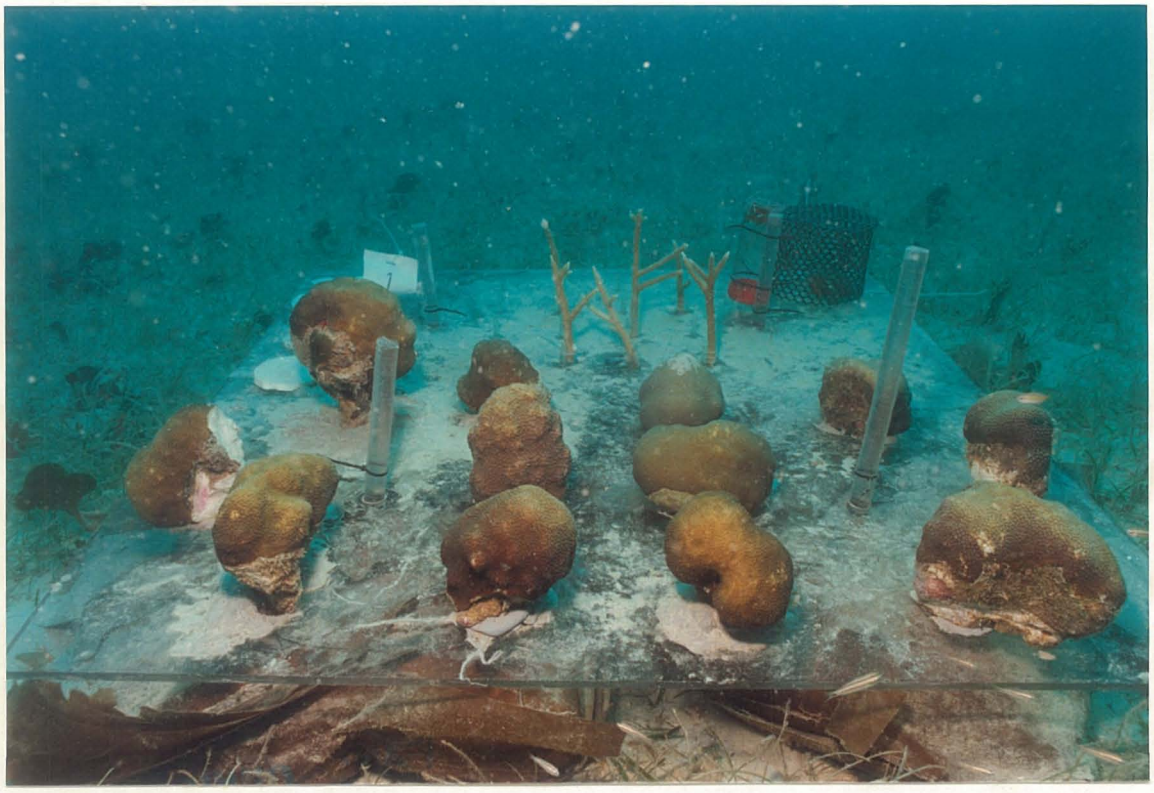
-.6
-1.0
-1.4
-1.8
ω



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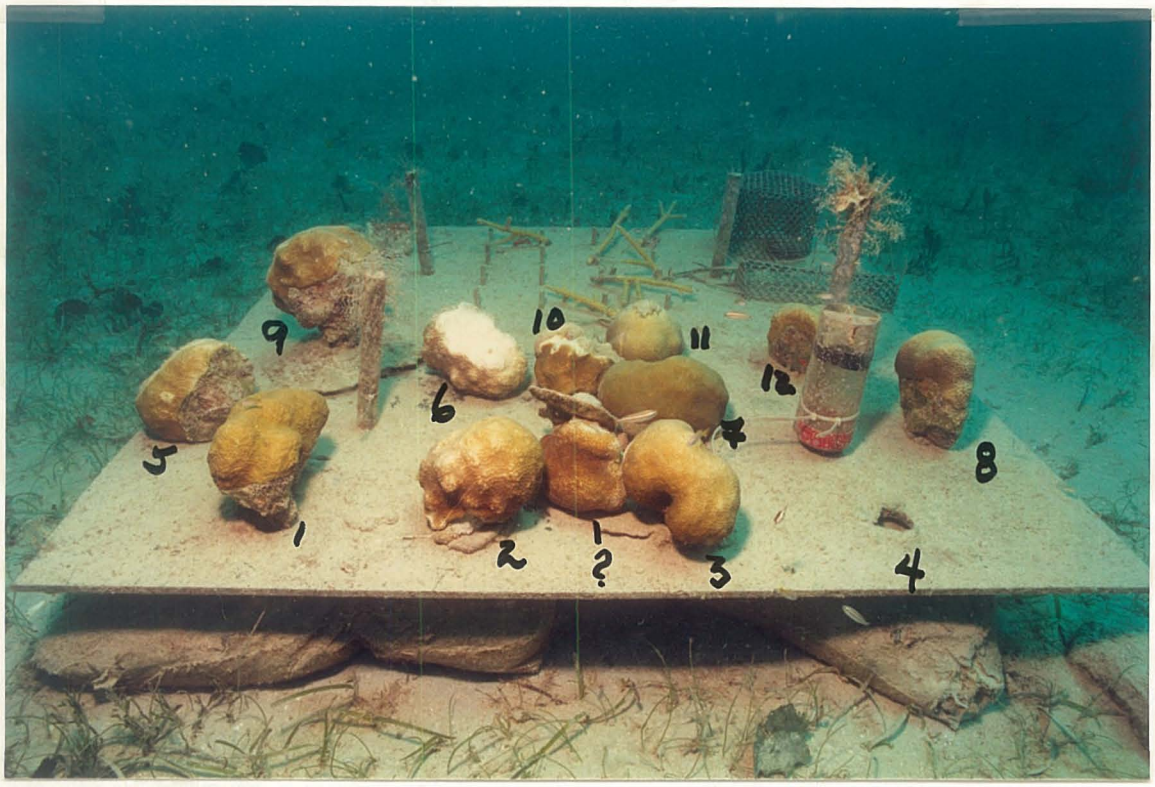


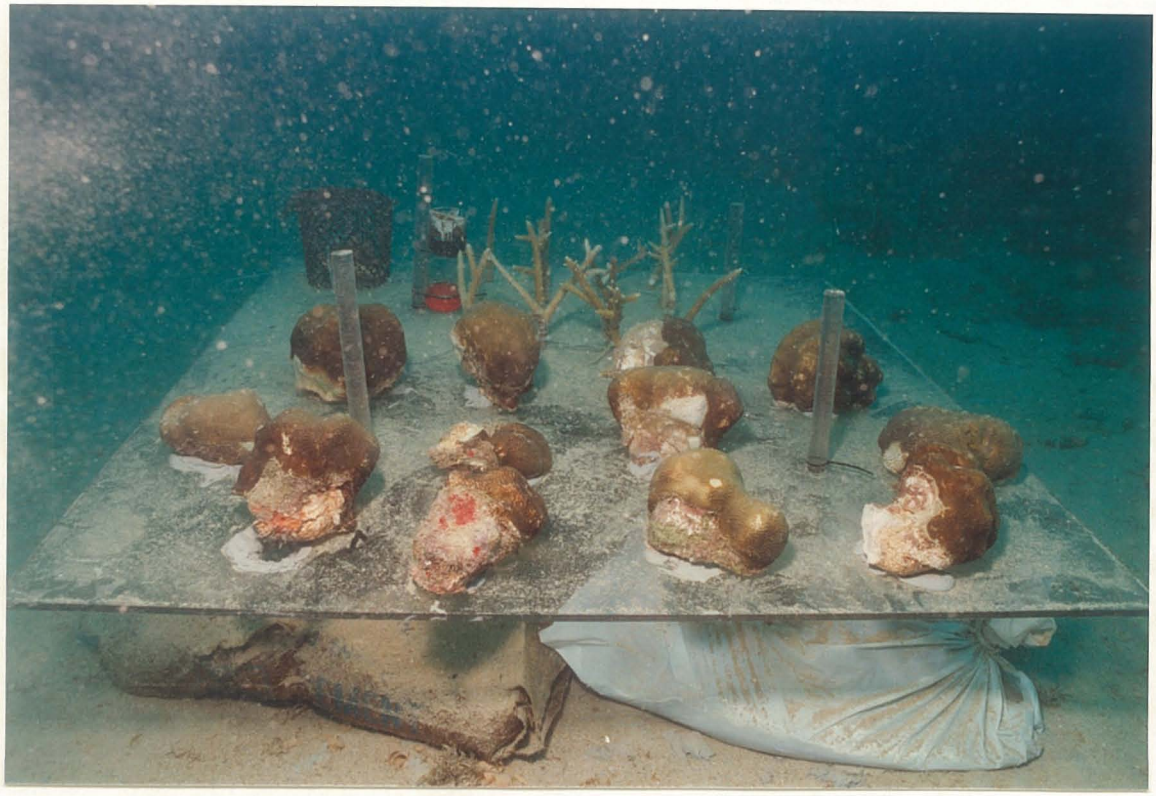
PLATFORM #1. Taken September 26, 1987 (DAY 90)

PLATFORM 1. Taken September 26, 1987 (DAY 90)

PLATFORM #2. Taken June 29, 1987 (DAY 1)

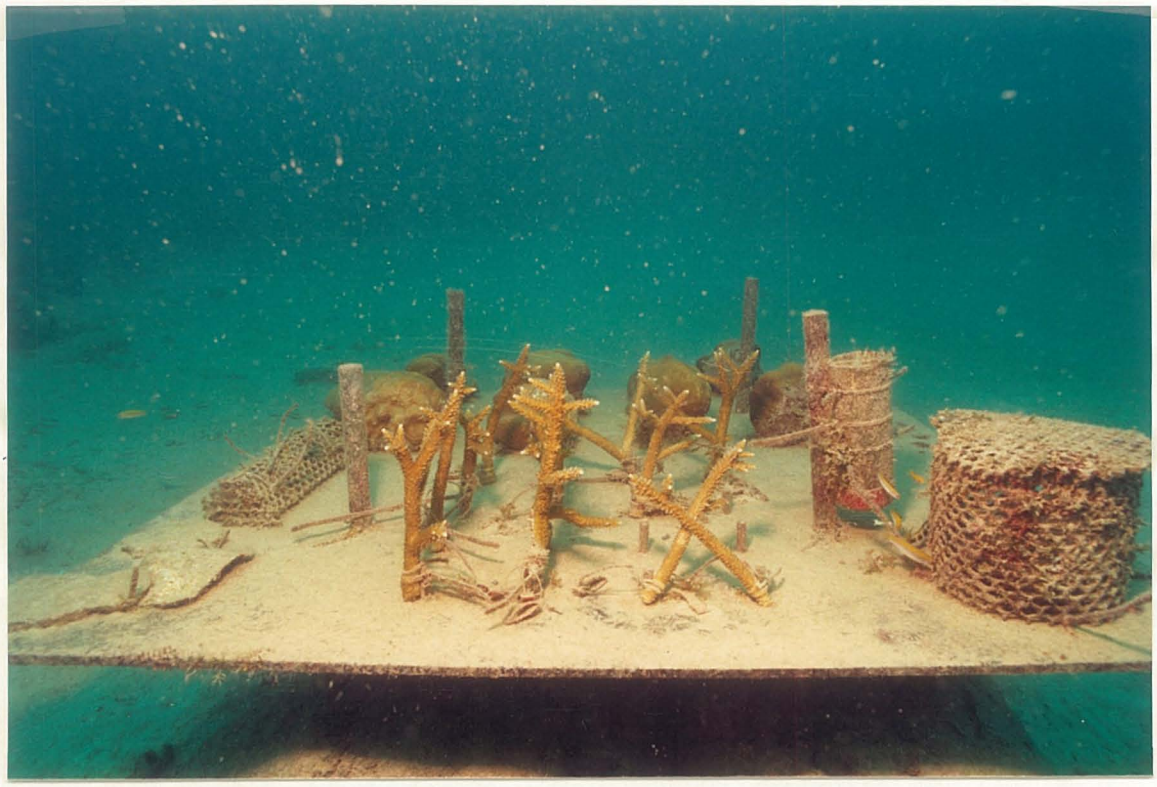
PLATFORM #2. Taken September 26, 1987 (DAY 90)

PLATFORM 2. Taken September 26, 1987 (DAY 90)

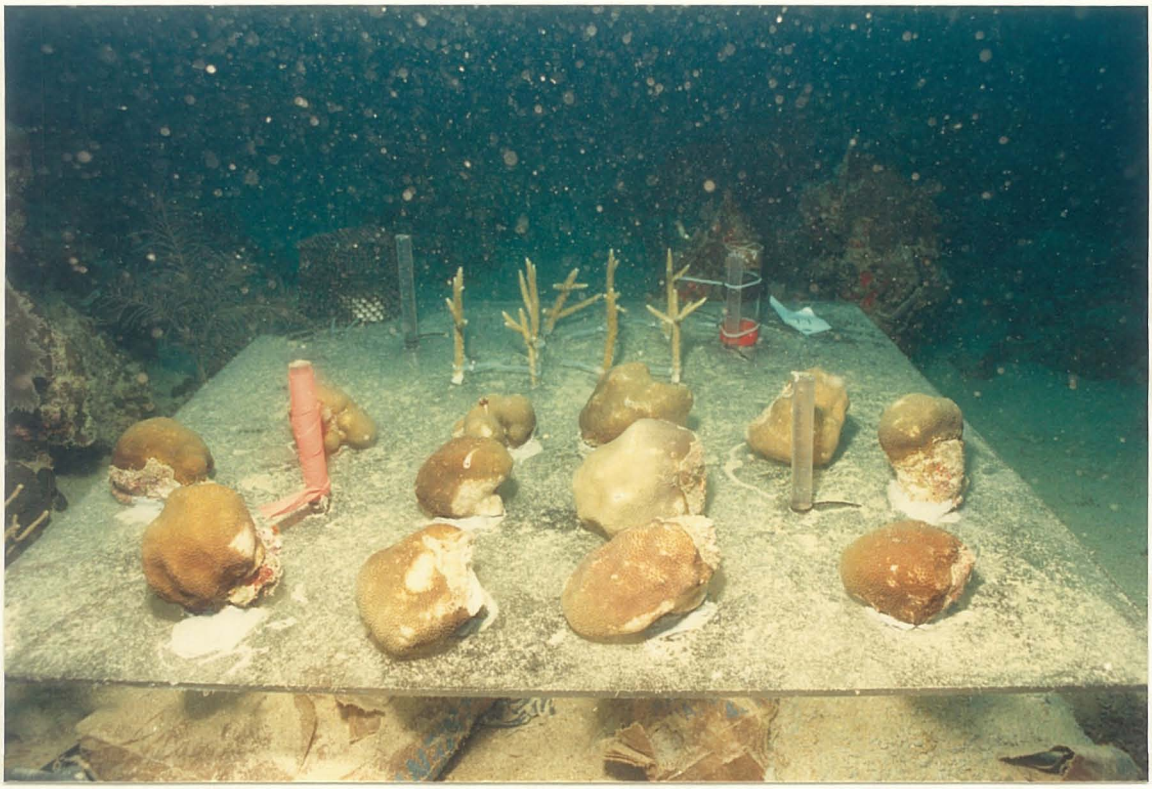


PLATFORM #3. Taken June 29, 1987 (DAY 1)

PLATFORM #3. Taken September 26, 1987 (DAY 90)



PLATFORM 3. Taken September 26, 1987 (DAY 90)

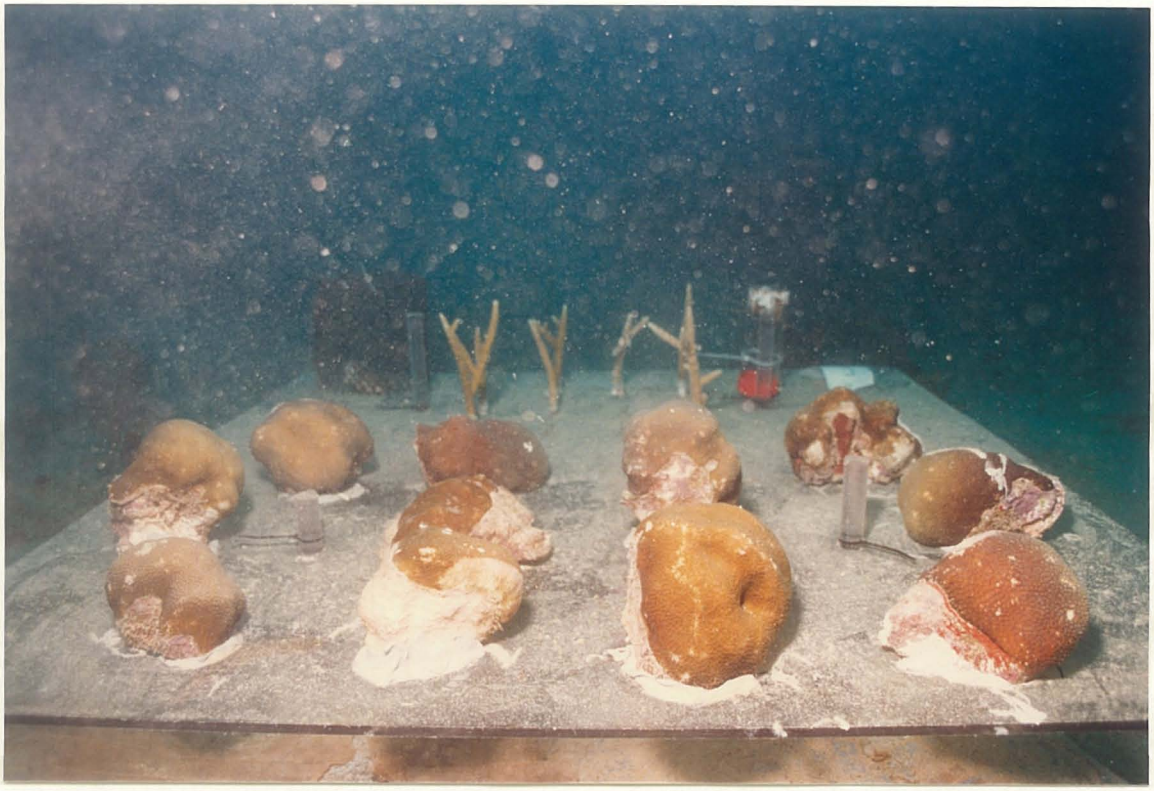


PLATFORM #4. Taken June 29, 1987 (DAY 1)

PLATFORM #4. Taken September 26, 1987 (DAY 90)

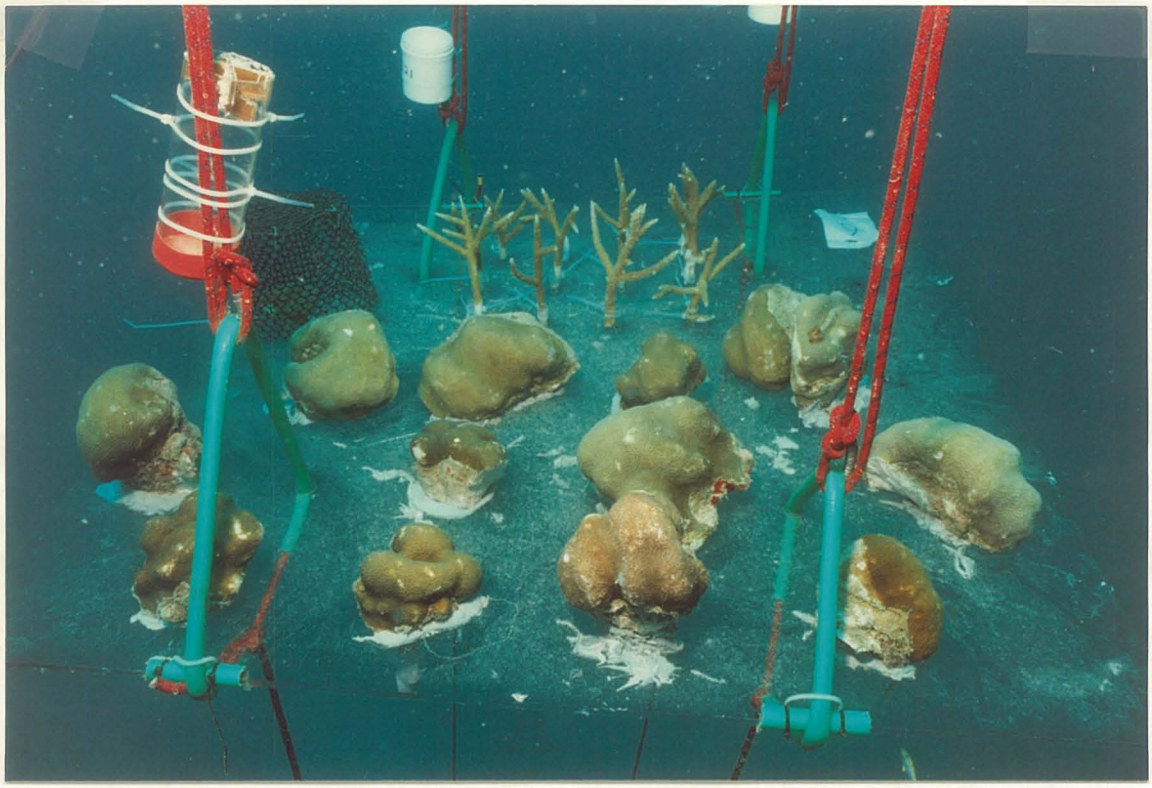
PLATFORM 4. Taken September 26, 1987 (DAY 90)

PLATFORM 5. Taken September 26, 1987 (DAY 90)



PLATFORM #5. Taken June 29, 1987 (DAY 1)

PLATFORM #5. Taken September 26, 1987 (DAY 90)



PLATFORM #6. Taken June 29, 1987 (DAY 1)

PLATFORM #6. Taken September 26, 1987 (DAY 90)

PLATFORM #6. Taken September 26, 1987 (DAY 90)

PLATFORM #6. Taken September 26, 1987 (DAY 90)

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