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SEAGRASS RECOVERY FROM PROPELLER CUTS IN COCKROACH BAY, FLORIDA

First year report
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Introduction.

The project began in December, 1992 and is concerned with the recovery of turtle grass beds from propeller cuts by power boats in the mangal estuary, Cockroach Bay, a preserve of Hillsborough County, Florida. Four recovery areas were established in Cockroach Bay by the Hillsborough County Environmental Protection Commission (EPC) in November 1992. A two year research grant was awarded to us in January, 1993 to determine the extent of damage and rate of recovery of turtle grass communities. The report is divided into aerial photographic and in situ studies carried out by each of our laboratories.

HCC Report.

The primary role of HCC in the study of seagrasses in Cockroach Bay has been to obtain aerial photographs, digitize the photographs on computer images, measure the prop scars in the field and monitor the site for damage to the seagrasses. Each one of these roles will be discussed.

Aerial photography: There were two types of aerial photographs proposed for this study. One set of photographs was to be taken at a 1 to 2,400 scale as recommended by a FDNR study from 1992. The second type of photographs was to be a lower level series of photographs that would show more details of the terrain and the scars. The large scale photographs have not been taken since the first photos from last year. This was discussed in the last report.

Detailed Photographs: Detailed aerial photographs of all of the sites were taken by Jim Wysong in the following months: December (3 flights), January, April, June, July, September and December. This method of photography brought the scale down to 1 to 400 up to 1 to 1000. Photographs were enlarged and pasted together in a mosaic of each study site so that the seagrasses could be measured and the scars counted and measured. This level of photography was found to be quite sufficient for counting scars and was also less expensive than the higher altitude pictures. The flights do not follow the exact dates as proposed primarily because of weather. Flights have to occur when the weather is clear, little wind is in the atmosphere, and a minimum of smoke is in the air from the TECO plant which is nearby. Also, during the summer months low tides offer better visibility into the water column. There were several times in February and March in which flights could not take accurate photos because of the smoke. The results of these flights will be discussed below.

Computer Digitization: All of the flight information has been recorded in the computer and has been analyzed. The computerized information indicates that there are 2,140,803 square feet of seagrasses in recovery areas 1, 3, and 4, as well as the entrances to area 2. The center portion of area 2 did not show any scars in the seagrasses until the December flights of 1993. Analysis of the computerized data will follow below.

Field Measurements: Field measurements were made at all of the sites monthly and sometimes twice a month for the whole year. We (Ehringer and student assistants April Kiraly, Pete Chipman , Jeff York, David Kocher and Terri Forrest) have measured all of the prop scars in the study sites as well as the scars in the entrances to site 2 in Cockroach Bay.

Summary of Prop Scar Measurements

This report is a brief summary of the data collected on prop scars in Cockroach Bay from December of 1992 to December of 1993. Two charts of the data are attached. The charts indicate the square footage of seagrasses, the linear feet of prop scars, the sand areas present, and the percentage of damage done to the grasses at each site. (refer to tables 16 and 17).

The first observation is that of the linear feet of scarring occurring in the bay. The scar damage increased from 26,662 feet to 31,747 feet, an increase of 5,085 linear feet in twelve months, almost a mile of scars. This number, however, does not reflect the entire amount of damage occurring in the bay. This statement needs clarification. On several occasions we observed scar damage on photographs that could not be found in the field. Our first impression was that perhaps the scars were abnormalities of film processing, or that they were drift lines in the sediment. Further study of these occurrences have given us another idea. Perhaps the disappearing scars are real, but they are scars that are appearing in sediment that covers over rather quickly with the movement of the currents in and out of the bay. Our December 1993 photographs of Entrance "E" to Area 2 showed an area with a large amount of scars. Boat traffic was very heavy in this entrance where no serious traffic or damage had been noted before. A comparison of pervious photos of this site showed that no damage had been done in the past, therefore, the damage was new. In the field we could not find the scars to the extent that can be seen on the photographs. Only a few were visible. Currents during the month of December are very strong due to extreme high and low tides. It is entirely possible that the currents have erased, or covered over, most of the scars. Damage of this type to Entrance "E" has turned a seagrass community to sand. This particular entrance, which is the north side of Entrance "E", has lost 68,152 square feet of sparse grasses to sand.

Having observed damage of this type first hand has taken us on another path of categorizing scar damage to the bay. We have been looking at the areas of the bay that have sand bottoms to attempt to determine if the sites were created by natural events or by prop scars to the site over a period of time. Some sand areas close to mangrove islands are probably caused by fresh water runoff from the islands or by shade from the mangroves (or both). There are a number of sites like this in the bay and we have designated them as such on the computer images. Other sand areas are clearly in the path of commonly used passages that boats use to move from one part of the bay to another. Along these paths it appears as if scarring has been heavy enough to cause the same effect that we witnessed in Entrance "E". Damage of this type is apparent at one other part of Entrance "E" (the south part) and in Entrance "D". We have now computed the square footage of these areas as being prop scar damage to the bay as follows:

Entrance "D" lost 29,553 square feet of sparse grasses.
Entrance "E", south, lost 42,698 square feet of sparse grasses.
Entrance "E", north, lost 68,152 square feet of sparse grasses.

Our data show that in December of 1992 about 11.21% of the grasses in Cockroach Bay had been damaged by prop scars. In December of 1993 the figure rose to 13.27%. This is an increase of 2.06% (actually a 2.06% loss of seagrasses in one year). Some of the sites in the bay have no new damage occurring during the first year of the study, while other areas have received considerable damage. The sites receiving the most new damage were Area #4, and the middle part of Area #2 which includes the site just inside of Entrance "E" that scarred up in December of 1993. Recovery Area #1 shows the least amount of grass and the most amount of sand. This area was covered with algae for most of the year so we could not get an accurate reading on the amount of grass present. As of December 1993 photos we have been able to determine that very little grass has been growing under the algae. This entire area has been damaged by boats, currents, drifting algae, and other unknown events that have left very little grass. Recovery in this area does not seem likely.

In 1994 we will continue to look at the scars in the bay and we will continue to measure them. However, we have some doubts about the damage being done that we will attempt to answer this year. As we look at the new damage to Entrance "E" we can see that some boat scars occur in sites that can cover over with currents and appear undamaged on aerial photographs if algae is present in the water. Only ground truthing can determine the extent of the damage. Suppose there are sites in the bay that routinely encounter scarring but leave enough seagrasses between the scars to appear as grass beds on the photos, especially when algae drifts in and out. Then, if currents cover over the scars, then how much damage has been done to the area? Is this something that we can quantify? Are there areas within Cockroach Bay that have been scarred to this extent that we have not been able to find? If such areas exist, then the damage to Cockroach Bay is more severe than we are recording. We will attempt to determine the answer to these questions this year.

In conclusion, it appears that heavy scarring is taking place at Entrances D and E, as well as Recovery area #4. Our computations indicate the total loss of 145,488 square feet of seagrasses in Cockroach Bay, representing a 2.06% total loss of seagrasses.

USF Report.

Introduction

Six study sites were selected in the four recovery areas (RAs) in Cockroach Bay based on studies carried out in 1992 (Dawes and Uranowski, 1993). We began our studies in December 1992 with the EPC grant starting on 7 January, 1993. Persons involved in this study were Dr. Clinton Dawes, Mr. Craig Rose, and Ms Christine Uranowski. A number of undergraduate students also worked with us during the summer (Ms Kim Dewitt, Ms linda Riley, Mr. Mathew Hauser) and fall semesters (Mr. Jason Miller, Mr. Carolos Cartaya).

The 1993 studies have been carried out as proposed with the addition of permanent quadrats, expansion of sediment analyses, and addition of blade growth and chemistry of the plants. We are proposing additional studies and modification of ongoing projects for 1994.

Methods and Results

The results of each experiment will be presented and summarized. The procedures will not be detailed if they were described in the original proposal or in the 6 month report.

Short shoot density of Thalassia testudinum

1. Standard line transects. Three line transects (5 m) were run through the reference and across artificial prop cuts in each of the six sites. Thirty 25 cm^2 quadrats were taken to determine short shoot density and percent cover (n = 30 for each reference and artificial propeller cut) in May/June and August/September. Additional samplings were also taken in March and April and the number of samplings were doubled because of the patchy nature of the grass beds.

Seasonally, short shoot density was highest in the summer and variability in short shoot density was high between and within sites (Table 1). There was a lower density of short shoots in the propeller cut transects. The data demonstrates the patchy nature of the turtle grass beds and thus we propose to stop these measurements in 1994 and concentrate on permanent quadrats.

In addition to short shoot density, percent cover was determined using the same 30 quadrats $site^{-1}$. Percent cover also showed large variations in density within each site (Table 2). Again there was no consistent pattern between reference (undamaged) and areas where a propeller cut existed. We propose to stop determining percent cover except in the permanent quadrats.

2. Permanent quadrat sampling. Because of the large variation (patchiness) of turtle grass beds we established four experimental monitorings of artificial and existing propeller cuts. The experiments were not part of the original proposal and consisted of permanently staked out quadrats to follow recovery.

2a. Strip quadrats (100 x 25 cm) were established in 17 locations along existing propeller cuts in all 6 RAs in August and October. Permanent stakes mark the strips along old cuts and the number of short shoots were partially counted in August, and in October. The data is too limited to analyze at this date.

2b. Large strip quadrats (5 x 1.25 m strips; Fig. 1) were located over existing and artificial propeller cuts with permanent stakes; one each in RAs 2c, 2d, 3, 4. The quadrats were sampled in June, August, and October when short shoot density was counted in 5 exterior, 5 interior and 5 center (prop cut) in randomly determined 25 cm^2 quadrats n = 20 for each zone).

Short shoot density increased in the exterior and interior quadrats from June through October (Table 3, Fig. 2). There appears to be an increase in the number of short shoots as well in the existing propeller cuts at 3 of the 4 sites.

2c. Nine permanent quadrats of 1.25 m^2 (Fig. 3) were established at site 4 and Thalassia testudinum removed from the center 25 cm^2 in July. The purpose of the experiment was to study the effects of fertilizer on the spread of turtle grass near and into a disturbed area. The nine quadrats were grouped into units of three, each having a control (no fertilizer), addition of four packets of 2.5 g urea + 2.5 g phosphate and for packets of 2 Jobe sticks (13% N, 4% P) every other week. Short shoot density was measured in July, August, October, and November, in 6 exterior, 6 interior, the disturbed center 25 cm^2 quadrat.

Short shoot density varied over the four months for the 6 exterior and 5 interior quadrats at site 4 and a large (+2.67 ss) increase only in the center quadrat fertilized with Jobe sticks (Table 4). We expect to see larger changes after spring growth begins in April-May.

2d. Nine permanent quadrats (1.25 m^2) were also established over existing propeller cuts at site 2c. The design and sampling regime were as described in 2c.

There was a small decrease in short shoot density in the control and Jobe stick fertilized quadrats for the exterior and interior areas as seen for Site 2c. However, the urea + phosphate fertilized interior quadrats and those along the existing propeller cut showed a small increase in short shoot density (Table 4).

Blade production and LAI.

Growth of Thalassia testudinum blades was added to the research program in order to determine the physiological status of the seagrass meadows at the 6 sites. Growth was measured in May/June, August/September, and in December by puncturing the blades with a hypodermic needle just above the leaf sheath bundle, tagging the short shoot and collecting them after 1 to 2 weeks. Blade weights were then used to determine new blade production (below the wound) and total blade material per short shoot. Leaf area index (LAI) was also determined by measuring the width and length of all the blades in each short shoot.

As can be seen from Tables 5a, new blade production increased significantly in Aug/Sept compared to May/June and was low in December for all 6 sites. There was no significant pattern in blade growth between sites (Table 5b). Also, there was no increase in LAI in Aug/Sept and this may indicate rapid growth but a high leaf loss during the summer. We intend to use blade growth as a monitor of short shoot response to the creation of artificial prop cuts made in March, before spring growth begins.

Above- and Below-ground (A/B) Biomass.

Three 0.019 m^2 cores were taken in the reference areas of each of the 6 sites in July and December. Blades (above-ground), short shoots, rhizomes, and roots (below-ground) were separated, dried and weighed. In addition, "Unit Plant" weights (n = 2 $site^{-1}$) were determined using a single short shoot and 4 cm of attached rhizome. Samplings have been limited to 2/year to avoid excessive damage to the sites.

The ratio of A/B for the 3 cores at each site shows a seasonal shift of blade growth in the summer and importance of the rhizome in the winter (Table 6, Fig. 4). The unit plant in July consisted of 0.27 (±0.13) leaves, 0.31 (±9,12) short shoot, 0.2 (±0.05) 4 cm of rhizome, and 0.04 (±0.04) roots with a A?:B ratio of 0.49. In December, the same unit plant had 0.15 (±0.1) blades, 0.6 (±0.39) short shoot, 0.17 (± 0.05) 4 cm of rhizome, and 0.06 (±0.04) roots with an A/B ratio of 0.18.

Thus, the A/B data from the cores and unit plant show an almost 3 fold decrease from summer to winter. This data along with the blade growth data indicates there is one primary growth period for Thalassia testudinum in Cockroach Bay, spring and summer. We will examine A/B ratios of short shoots adjacent to artificial and existing prop cuts during 1994.

Proximate constituents.

Proximate constituent analyses (ash, protein, soluble carbohydrate) and calculation of energetic values for different plant parts were carried out in February, May/June, and are being done on December samples. We originally proposed to do but one set a year, in May/June but with extra above and below ground material it is useful to have more seasonal data.

Table 7a shows the average levels of ash, protein and soluble carbohydrate of the blades, short shoot, rhizome, and root for all sites as there was no distinct pattern between recovery areas. Blade growth is higher in the summer, hence higher protein levels and lower soluble carbohydrate in the rhizome.

Table 7b shows the levels of kilocalories calculated for each organ. Energy levels are higher in summer than winter plants, even though ash (inorganic) content is lower as well.

Macroalgae.

Percent cover of the macroalgae was determined along with percent cover of Thalassia testudinum using 30 25 cm^2 quadrats. Macroalgal cover was highest in the May/June sampling and lowest in the Aug/Sept samplings (Table 8). However there was no pattern in macroalgal dominance in reference or propeller cut transects except in sites 1, 2a and 4 in the Aug/Sept samplings. This is probably due to the ability of the algal masses to drift into and out of Cockroach Bay.

Macroalgae biomass (gdwt m^2) decreased significantly in the Aug/Sept samplings (10 samplings 25 cm2 $site^{-1}$) although the dominant species remained the red alga Acanthophora spicifera (Table 9). The change in biomass shows the loss of water column nutrients and dropping of water transparency as the plankton increase in the summer (Fig. 5, see change in abscissa values).

Epiphytes.

We continued to sample blade epiphytes at each site. Species are identified, the epiphytes scraped off, dried and weighed (n = 15 $site^{-1}$). Epiphytism was lowest in Aug/Sept as expected with the increased water turbidity, increased plankton and warmer water (Table 10, Fig. 5). The dominant species also changed from Ceramium byssoideum to a mixture dominated by a colonial bryazoan. High levels of epiphyte biomass occurred at site 3 in May/June and at site 2c and 2d in Aug/Sept thus there appears to be no pattern for possible eutrophication. In our December collection there was a massive development of a colonial Tunicate forming large patches, particularly at site 2c as noted in the previous winters at Cockroach Bay.

Temperature and Salinity.

Both salinity and temperature showed typical seasonal changes during 1993 (Table 11, Fig. 6). We noted the largest variation in salinity during the winter (Fig. 6, largest S.D.'s) when fronts would move through and dilute the inner parts of Cockroach Bay. The salinity pattern indicates that Cockroach Bay is estuarine but approximating Tampa Bay due to the lack of freshwater input. Certainly the range is very supportive of Thalassia testudinum requirement for stable higher salinities and moderate subtropical temperatures.

Sediments.

1. Standard sediment samplings. Five replicate cores (10 cm depth) were taken in all 6 sites (120 samples) in February/March, June/July, and August/September in four regions (seagrass, artificial propeller cuts parallel and perpendicular to current; existing propeller cut). Samples were analyzed for particle size, calcium carbonate level, and organic content by site and then the data pooled to increase sample size (n = 30). The samples from the November samplings have been analyzed but is not yet statistically tested.

No distinctive patterns in particle size distribution were evident either with a site or after the data was pooled for all 6 sites in order to increase sample size (n = 30; Table 12; Fig. 7) for Feb/Mar or June/July. Organic content was significantly lower in June/July in the artificial propeller cuts, perhaps due to erosion (Table 13, Fig. 8). Calcium carbonate levels were not significantly different and did not change with season (Table 13, Fig. 9). Thus, the standard sediment sampling regime did not demonstrate a distribution between propeller cuts (existing or artificially made) and the reference seagrass beds.

2. Special sediment samplings. Twenty replicate cores were taken at sites 2a and 3 in July in order to determine if a larger sample size would show differences between areas. The special set of samplings were made in five areas, seagrass bed, bare sand, artificial propeller cuts parallel and perpendicular to current, and already existing propeller cuts. Analysis included particle size, organic, and calcium carbonate levels.

The bare sand site had significantly higher levels of 2.0+mm size particles at both sites (Table 14, Fig.10a, b). The artificial propeller cuts (parallel and perpendicular to current) did not differ in particle size distribution from existing (old) cuts or the reference area. Thus, although replicate size was increased 4 fold, there still were no significant differences between propeller cuts and seagrass beds with regard to particle size. The sediments appear to be well sorted regardless of area.

There were no obvious differences in total organics of the sediments between the five areas sampled in each site (Table 15, Fig. 11a, b). The only distinction for calcium carbonate for both sites was the bare sand region that showed significantly higher levels (Table 15, Fig. 12a, b).

COMMENTS

Recovery rates.

We proposed to follow recovery rates by Thalassia testudinum using random line transects and 25 cm^2 quadrats through undisturbed reference areas, existing and artificial propeller cuts. The patchy nature of the turtle grass beds in Cockroach Bay has prevented determination of increases or decreases in short shoot density in the beds. In June, we began to add permanent quadrats in order to assess recovery. However, these were added after the initial spring growth.

As shown in Fig. 13a-d, short shoot density showed no change or minor recovery over 4 months for existing propeller cuts and was similar to the mean density of the exterior 6 quadrats of the 5 m x 1.25m permanent quadrats. Figure 14 shows the linear regression models for short shoot density in existing prop cuts at site 2c and Figure 15 for in artificial 25 cm^2 made in site 4 using 1.25 m^2 permanent quadrats and fertilizers. Again, both studies showed mixed responses when short shoot density in the cut or cleared square as compared with the mean density of the 6 exterior quadrats for each treatment. All controls showed decreases in density (top rows, Fig. 14, 15) and only in a few cases did densities increase in fertilized quadrats compared to the exterior quadrats.

The limited responses in all of the permanent quadrat data suggests that as present rates of increasing short shoot density would require 2-3 years to reach densities found near by the damaged area. Spring growth that should occur in March-May, 1994 might demonstrate more rapid recovery. Further, the expanded set of permanent quadrats should improve our predictions on turtle grass recovery.

Modification of research program.

1. Continuing new projects. As noted in our results, we are carrying out a number of additional studies including blade growth, proximate constituent determination and use of permanent quadrats in determining short shoot density of Thalassia testudinum. We now have an extensive set of permanent quadrats that will be used to determine short shoot densities and to calculate recovery by turtle grass in propeller cuts.

The blade growth studies will be used to follow short shoot growth along existing and newly made prop cuts in areas 2a and 4. Our data from 1993 indicate that blade growth is uniform at all sites so that we can increase the sample size by reducing the number of sites. We hope to determine if short shoots along prop cuts show decreases in blade production when compared with undisturbed short shoots. We will also compare proximate constituents of unit plants along propeller cuts with undisturbed plants to follow shifts in nutrients in damaged plants.

2. Additional new projects. There are two other questions we wish to study during 1994. The first is patterns of rhizome regrowth after damage. We propose to excavate areas along existing and the artificial prop cuts made in February, 1993. This will be done at the end of the growth period in September. The goal is to identify rhizome growth patterns, the fundamental requirement for recovery of turtle grass in prop cuts. These studies will not damage the seagrasses, only the overlying sediments will be blown away to photograph rhizome patterns. Rhizome exposure will be done at the end of the project.

The second new project is determination of the redox potential and levels of nitrogen and phosphorous in seagrass and propeller cut sediments. We will extend our studies to aeration and pore water nutrients. These studies will also be done at sites 2a and 4 because they represent the "typical" conditions in Cockroach Bay.

3. Deletion of projects. Line transect determinations of short shoot density and percent cover estimates of Thalassia testudinum for the 6 sites should be terminated. No useful data being produced. As noted, we have a large number of permanent quadrats which are yielding more reliable data. The standard sediment studies should be limited to sites 2a and 4; there is no in particle size, organic or calcium carbonate levels between prop cuts, seagrass beds or bare sand.

4. Extension of research project. We request that the research project be extended for 6 months through the 1995 spring growth period to June 7. This will permit study of recovery in propeller cuts during a second spring growth and refine the predictions for recovery. We will submit a proposed budget for the extension at a later date.

Conclusion

After one year of studying seagrasses and prop scars at Cockroach Bay we have observed that Thalassia testudinum has a very slow recovery rate from damage in prop scar sites. Blade growth rates show their highest growth in the months of April to July, however, this does not conicide with rhizome growth. We need to complete the data for one full year with permanent quadrats for growth rates of rhizomes which are the fundamental basis for recovery. We have seen very little new growth of grasses in the bay, yet, at the same time, we are seeing continual destruction of seagrass beds due to boat props (a loss of 2.06% of seagrasses). The rate of destruction far exceeds the plants ability to recover and to heal from prop damage. In some areas the damage is so frequent that sparse seagrass beds that we observed a year ago, are now sand flats with scattered grasses and masses of algae. These areas will take a very long time to recover. If we took the rate of destruction that we have seen in 1993 and projected the same rate of destruction into the future, the bay would lose one fourth or more of its grasses within fifteen years. This rate of destruction is especially alarming when we consider the effort that is being made to protect the seagrasses. However, this is just the first year of a two year study.

It is possible that the rate of destruction will change. We will have one more year to see if the trend continues or not.

To repeat an earlier point, we are requesting an extension of the project from January of 1995 to June 7 of 1995. This small extension will allow us to complete the infield data that we have been gathering for a second growth season. The budget for this extension will be very small in comparison to prior budgets and will be submitted at a later date.

Table 1. Short shoot density of *Thalassia testudinum* sampled with thirty $25cm^2$ quadrats taken along three 5m transects through a reference area and a locale containing an artificial propeller cut at 6 sites in Cockroach Bay, Florida; 1993. Values are means ± S.D., n = 30. Superscripts denote statistical differences (P < 0.05; Student's t-test; Mann-Whitney Rank Sum Test).

Site		No. Short Shoots m^{-2}			
		March	April	May/June	August/September
1	Reference Area	200.32 ± 79.04	153.12 ± 62.72	241.60 ± 74.24[a]	304.00 ± 83.20
	Propeller Cut	204.48 ± 74.72	177.12 ± 61.44	195.20 ± 47.36[b]	307.20 ± 115.20
2a	Reference Area	90.08 ± 36.96[a]	182.40 ± 218.40	129.60 ± 67.84	193.60 ± 35.20[a]
	Propeller Cut	124.48 ± 48.00[b]	125.92 ± 52.80	95.52 ± 39.52	140.80 ± 64.00[b]
2c	Reference Area	110.24 ± 42.24	174.40 ± 44.80	102.40 ± 45.92[c]	337.60 ± 110.40[c]
	Propeller Cut	†	222.40 ± 72.96	188.80 ± 76.96[d]	243.20 ± 70.40[d]
2d	Reference Area	95.36 ± 38.24	169.60 ± 76.32	128.00 ± 45.60[e]	139.20 ± 52.80[e]
	Propeller Cut	87.04 ± 51.36	94.40 ± 42.88	73.60 ± 41.28[f]	80.00 ± 41.60[f]
3	Reference Area	89.44 ± 40.48[c]	155.20 ± 58.56	130.72 ± 62.40[g]	89.60 ± 52.80[g]
	Propeller Cut	138.08 ± 69.76[d]	142.88 ± 75.68	84.80 ± 46.56[h]	131.20 ± 67.20[h]
4	Reference Area	182.40 ± 75.20[e]	222.40 ± 91.84	171.20 ± 53.60[i]	328.00 ± 89.60[i]
	Propeller Cut	132.16 ± 50.88[f]	283.20 ± 81.76	214.40 ± 56.32[j]	227.20 ± 84.80[j]

† Artificial propeller cuts were not located.

Table 2. Percent cover of *Thalassia testudinum* sampled with thirty 25cm^2 quadrats taken along three 5m transects through a reference area and a locale containing an artificial propeller cut at 6 sites in Cockroach Bay, Florida; 1993*. Values are means ± S.D., n = 30. Superscripts denote statistical differences (P < 0.05; Student's t-test; Mann-Whitney Rank Sum Test).

Site		Percent Cover 25 cm^{-2}		
		April	May/June	August/September
1	Reference Area	16.83 ± 10.54	35.92 ± 22.07	79.33 ± 17.51
	Propeller Cut	22.67 ± 15.13	26.00 ± 11.40	67.50 ± 26.06
2a	Reference Area	12.42 ± 6.38	34.50 ± 18.77	37.00 ± 10.14
	Propeller Cut	12.58 ± 7.15	29.17 ± 18.48	31.75 ± 20.77
2c	Reference Area	28.17 ± 13.36	21.17 ± 10.88[a]	85.67 ± 18.09
	Propeller Cut	32.00 ± 17.35	47.50 ± 22.70[b]	83.50 ± 21.58
2d	Reference Area	18.83 ± 11.85[a]	31.50 ± 19.35[c]	39.17 ± 20.97[a]
	Propeller Cut	10.33 ± 6.75[b]	16.00 ± 11.85[d]	17.25 ± 12.22[b]
3	Reference Area	17.15 ± 8.98	17.00 ± 12.22	29.33 ± 20.57
	Propeller Cut	13.50 ± 10.16	23.67 ± 16.40	35.92 ± 24.37
4	Reference Area	22.67 ± 15.13	45.67 ± 14.78	86.50 ± 10.01[c]
	Propeller Cut	23.67 ± 10.82	42.00 ± 14.48	66.67 ± 26.37[d]

* Percent cover was not determined in March.

Table 3. Short shoot density of *Thalassia testudinum* in large permanent strip-quadrats (5 x 1.25m) sampled with 25cm^2 quadrats within and adjacent to an existing propeller cut at 4 sites in Cockroach Bay, Florida; 1993. Random 25 cm^2 quadrats were taken 25 cm from the propeller cut (Exterior), adjacent to the cut (Interior), and in the cut (Prop Cut). Values are means (±SD); n = 20, unless otherwise stated. Superscripts denote statistical differences within sites during the same sampling period ($P < 0.05$; Dunn's Method and Student-Newman-Keuls Method).

	June			August			October		
Site	Exterior	Interior	Prop Cut	Exterior	Interior	Prop Cut	Exterior	Interior	Prop Cut
2c•	8.15^{a} (3.05)	8.35^{a} (3.83)	3.00^{b} (1.75)	13.85^{c} (4.42)	12.30^{d} (4.38)	4.69^{e} (3.66)	14.05^{f} (3.28)	9.70^{g} (2.74)	4.94^{h} (3.07)
2d†	7.45^{i} (4.07)	8.90^{i} (2.43)	4.54^{j} (3.36)	10.10^{k} (6.12)	12.90^{l} (7.22)	4.69^{k} (3.77)	7.25^{m} (4.39)	7.85^{m} (3.86)	3.77^{n} (2.77)
3•	13.45^{o} (2.82)	11.35^{p} (3.73)	3.38^{q} (1.54)	12.56^{r} (5.55)	13.20^{r} (4.70)	2.56^{s} (1.21)	11.70^{t} (3.26)	9.35^{u} (3.54)	2.63^{v} (1.45)
4‡	13.65^{w} (4.87)	13.95^{w} (4.01)	3.20^{x} (1.74)	21.35^{y} (5.70)	20.60^{y} (4.57)	3.40^{z} (2.32)	19.15^{a} (5.82)	18.30^{a} (5.33)	5.80^{b} (2.60)

• n = 16 for prop cut.
† n = 13 for prop cut.
‡ n = 15 for prop cut.

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Table 4. Changes in short shoot densities of *Thalassia testudinum* in 6 exterior, 6 interior, and 1 center 25cm^2 quadrat in 2 sites within Cockroach Bay, Florida; during fertilization. Values are mean changes in short shoot densities (n = 18 for both the exterior and interior quadrats; n = 3 for the center quadrats). Statistical analyses could not be conducted at this time.

		July - October 1993		
Site	Treatment	Exterior	Interior	Center
2c: Existing Prop Cut	Control	-1.72	-1.61	-1.33
	Urea + Phosphate	-0.22	0.50	2.00
	Jobe's Sticks	-1.67	-1.94	-1.67
4: Artificially denuded 25cm^2 quadrat	Control	-2.39	-0.22	0.67
	Urea + Phosphate	1.00	0.56	0.67
	Jobe's Sticks	-0.67	-0.22	2.67

Table 5a. Blade production (% d^{-1}) and leaf area index (LAI) of *Thalassia testudinum* sampled from 6 sites in Cockroach Bay, Florida; 1993. Values are means ± S.D.; n = 15. Statistical analyses were conducted for blade production and LAI between sites for each date ($P < 0.05$; Dunn's Method; Student-Newman-Keuls Method).

	May/June		August/September		December	
Site	% Production d^{-1}	LAI (mm^{-2})	% Production d^{-1}	LAI (mm^{-2})	% Production d^{-1}	LAI (mm^{-2})
1	1.41 ± 0.41^{a}	45.19 ± 12.21^{a}	3.65 ± 1.34^{ab}	35.89 ± 8.29^{a}	0.87 ± 0.57^{a}	22.63 ± 5.57^{a}
2a	1.87 ± 0.63^{ab}	79.55 ± 14.20^{b}	3.84 ± 1.91^{ab}	55.78 ± 20.06^{b}	1.34 ± 2.45^{a}	18.93 ± 5.28^{a}
2c	2.24 ± 0.71^{b}	61.03 ± 21.36^{c}	3.83 ± 1.82^{ab}	54.17 ± 11.58^{b}	†	†
2d	1.92 ± 0.63^{ab}	63.57 ± 14.24^{c}	2.81 ± 0.93^{a}	70.80 ± 104.74^{c}	0.16 ± 0.24^{b}	32.63 ± 9.17^{b}
3	3.01 ± 1.17^{b}	29.49 ± 9.80^{d}	4.50 ± 1.13^{bc}	41.15 ± 13.21^{a}	0.51 ± 0.30^{c}	25.81 ± 6.42^{a}
4	2.45 ± 0.72^{b}	42.59 ± 12.71^{a}	5.68 ± 1.24^{c}	39.84 ± 13.57^{a}	0.36 ± 0.39^{d}	18.87 ± 7.49^{a}

† No samples collected.

Table 5b. Blade production (% d^{-1}) and leaf area index (LAI) of *Thalassia testudinum* sampled from 6 sites in Cockroach Bay, Florida; 1993. Values are means ± S.D.; n = 15. Statistical analyses were conducted for blade production and LAI between dates for each site ($P < 0.05$; Dunn's Method; Student-Newman-Keuls Method).

	May/June		August/September		December	
Site	% Production d^{-1}	LAI (mm^{-2})	% Production d^{-1}	LAI (mm^{-2})	% Production d^{-1}	LAI (mm^{-2})
1	1.41 ± 0.41^{a}	45.19 ± 12.21^{a}	3.65 ± 1.34^{b}	35.89 ± 8.29^{b}	0.87 ± 0.57^{a}	22.63 ± 5.57^{c}
2a	1.87 ± 0.63^{a}	79.55 ± 14.20^{a}	3.84 ± 1.91^{b}	55.78 ± 20.06^{b}	1.34 ± 2.45^{c}	18.93 ± 5.28^{c}
2c	2.24 ± 0.71^{a}	61.03 ± 21.36^{a}	3.83 ± 1.82^{a}	54.17 ± 11.58^{b}	†	†
2d	1.92 ± 0.63^{a}	63.57 ± 14.24^{a}	2.81 ± 0.93^{a}	70.80 ± 104.74^{a}	0.16 ± 0.24^{b}	32.63 ± 9.17^{b}
3	3.01 ± 1.17^{a}	29.49 ± 9.80^{a}	4.50 ± 1.13^{b}	41.15 ± 13.21^{b}	0.51 ± 0.30^{c}	25.81 ± 6.42^{a}
4	2.45 ± 0.72^{a}	42.59 ± 12.71^{a}	5.68 ± 1.24^{b}	39.84 ± 13.57^{a}	0.36 ± 0.39^{c}	18.87 ± 7.49^{b}

† No samples collected.

Table 6. Above ground and below ground biomass of *Thalassia testudinum* sampled from 6 sites in Cockroach Bay, Florida; 1993. Values are means ± S.D.

Site	July* Biomass (gdwt m^{-2})		July* Above:Below ground ratio	December† Biomass (gdwt m^{-2})		December† Above:Below ground ratio
	Above ground	Below ground		Above ground	Below ground	
1	3.51 ± 0.88	8.99 ± 2.93	0.39	0.63	4.23	0.15
2a	1.10 ± 0.36	2.53 ± 1.12	0.44	0.76	5.60	0.14
2c	2.94 ± 0.67	7.75 ± 1.32	0.38	0.85	8.21	0.10
2d	3.14 ± 1.11	7.77 ± 1.22	0.40	0.69	4.88	0.14
3	0.75 ± 0.58	3.16 ± 0.99	0.24	1.20	7.46	0.16
4	2.62 ± 0.96	7.20 ± 1.22	0.36	1.04	9.51	0.11

* n = 3.
† n = 1.

Table 7a. Proximate constituent allocation (% g dwt⁻¹) of *Thalassia testudinum* sampled from 6 sites in Cockroach Bay, Florida; 1993. Values are means ± S.D. (where applicable).

	February				July				December[1]			
	Protein	Ash	Soluble Carbohydrate	Lipid	Protein	Ash	Soluble Carbohydrate	Lipid[*]	Protein	Ash	Soluble Carbohydrate	Lipid
Blade	13.43 (1.78)	29.06 (4.94)	7.26 4.23)	1.92	19.80 (2.41)	26.93 (6.70)	6.66 (1.17)	2.00		32.14 (0.19)		
Short Shoot	6.93 (1.58)	40.74 (7.66)	12.16 (5.08)	0.77	15.22 (2.54)	39.57 (7.53)	10.38 (1.66)	2.00		46.23 (2.16)		
Rhizome	8.29 (2.39)	24.75 (1.64)	27.31 (9.73)	1.52	17.88 (2.71)	30.99 (11.50)	20.72 (3.60)	2.00		24.08 (0.41)		
Root	3.92 (1.28)	54.17 (12.26)	7.37 (5.60)	1.86	11.36 (4.83)	39.51 (15.46)	10.39 (3.60)	2.00		53.01 (0.46)		

[1] Samples are currently being processed.
[*] Estimated.

Table 7b. Mean energy content (kJ g dwt^{-1}) of *Thalassia testudinum* sampled from 6 sites in Cockroach Bay, Florida; 1993.

	February	July	December[1]
Blade	13.50	14.27	
Short Shoot	10.80	11.80	
Rhizome	13.80	13.45	
Root	8.54	11.57	

[1] Samples are currently being processed.

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Table 8. Percent cover of macroalgae sampled with thirty $25cm^2$ quadrats taken along three 5m transcts through a reference area and a locale containing an artificial propeller cut at 6 sites in Cockroach Bay, Florida; 1993*. Values are means ± S.D., n = 30. Superscripts denote statistical differences ($P < 0.05$; Student's t-test; Mann-Whitney Rank Sum Test).

Site		Percent Cover $25cm^{-2}$ April	May/June	August/September
1	Reference Area	22.17 ± 14.37	60.33 ± 34.06	6.42 ± 11.61[a]
	Propeller Cut	18.33 ± 16.31	66.00 ± 21.27	13.50 ± 16.33[b]
2a	Reference Area	91.67 ± 13.41[a]	58.33 ± 17.83	5.75 ± 6.95[c]
	Propeller Cut	70.00 ± 25.05[b]	42.83 ± 27.44	19.00 ± 15.56[d]
2c	Reference Area	43.50 ± 18.06	46.00 ± 23.58	8.33 ± 6.61
	Propeller Cut	46.17 ± 23.73	47.00 ± 28.55	9.25 ± 7.46
2d	Reference Area	62.33 ± 16.80	74.33 ± 24.87[a]	8.50 ± 8.11
	Propeller Cut	65.33 ± 21.97	39.17 ± 26.59[b]	5.92 ± 7.38
3	Reference Area	45.00 ± 20.60[c]	59.83 ± 30.41	6.92 ± 11.44
	Propeller Cut	8.83 ± 7.84[d]	56.67 ± 30.18	6.67 ± 11.91
4	Reference Area	33.17 ± 20.11[e]	91.00 ± 16.68[c]	0.17 ± 0.91[e]
	Propeller Cut	10.17 ± 12.00[f]	75.33 ± 22.70[d]	3.75 ± 5.03[f]

* Percent cover was not determined for March.

Table 9. Biomass of macroalgae (gdwt m^{-2}) and dominant species at 6 sites in Cockroach Bay, Florida; 1993. Values are means ± S.D., n = 10. Astericks denote dominant species.

Site	May/June		August/September		December	
	Biomass (gdwt m^{-2})	Species Present	Biomass (gdwt m^{-2})	Species Present	Biomass (gdwt m^{-2})	Species Present
1	50.14 ± 56.37	2,7,10*	6.26 ± 12.48	1*,3,7	6.54 ± 9.07	1,5,7,10,11,12, 13*, 14
2a	26.08 ± 20.80	1*,6,7	15.65 ± 20.47	1*	80.56 ± 26.12	1,7*,10,11,13*
2c	23.24 ± 29.60	2,7*	10.67 ± 16.67	8*	39.90 ± 33.59	1*,7,10,11*,12, 13*,15,16
2d	7.09 ± 12.06	6,7*,8,10	24.38 ± 28.84	1*,6,8	39.70 ± 26.66	1,5,7,10-13
3	69.33 ± 46.69	7*	0.35 ± 1.11	1*	5.49 ± 8.00	1*,7,10*,12,13
4	16.37 ± 14.92	1*,2,7	0.53 ± 1.23	1*,2-5,7	11.82 ± 13.41	1,11,12,

Legend:

1. *Acanthophora spicifera*
2. *Centroceras clavatum*
3. *Chondria cnicophylla*
4. *Gracilaria sjoestedtii*
5. *G. tikvahiae*
6. *G. verrucosa*
7. *Hypnea musciformis*
8. *Laurencia poitei*
9. *Lyngbya majescula*
10. *Spyridia filamentosa*
11. *Ulva lactuca*
12. *Solaria filiformis*
13. *Lomentaria baileyiena*
14. *Chondria sedifolia*
15. *Caulerpa sertularioides*
16. *Enteromorpha intestinalis*

Table 10. Epiphyte load on short shoots of *Thalassia testudinum* at 6 sites in Cockroach Bay, Florida; 1993. Values are means (± S.D.), n = 15. Astericks denote dominant species.

Site	May/June			August/September			December		
	Biomass			Biomass			Biomass		
	(gdwt ss⁻¹)	(gdwt m⁻²)	Species present	(gdwt ss⁻¹)	(gdwt m⁻²)	Species present	(gdwt ss⁻¹)	(gdwt m⁻²)	Species present
1	0.43 (0.22)	6.85 (3.52)	5*,7,12, 13,14	0.04 (0.02)	0.78 (0.34)	2,15,17, 18	0.24 (0.16)	4.31 (2.83)	4,5*,19
2a	0.19 (0.08)	3.06 (1.27)	5,18*	0.07 (0.04)	1.30 (0.72)	2,4*,10, 17	0.33 (0.19)	5.93 (3.35)	4,5*,18, 19
2c	0.33 (0.10)	5.33 (1.62)	5*,6	0.19 (0.12)	3.48 (2.27)	4,5,8*, 11,17,18*	†	†	†
2d	0.34 (0.20)	5.48 (3.22)	5*,7	0.13 (0.07)	2.35 (1.30)	2,5,8,15, 17	0.19 (0.10)	3.36 (1.77)	4,18,19*
3	0.51 (0.31)	8.22 (5.02)	5*,18	0.04 (0.03)	0.71 (0.58)	1,3,4,15	0.23 (0.13)	4.11 (2.35)	4,5*
4	0.28 (0.16)	4.52 (2.58)	5,6,13*, 18	0.07 (0.04)	1.37 (0.80)	5,9,15, 16	0.03 (0.02)	0.60 (0.43)	19*

† No samples collected.

Legend:

1. *Boodleopsis pusilla*
2. *Bryopsis hypnoides*
3. *Calothrix crustacea*
4. *Centroceras clavatum*
5. *Ceramium byssoideum*
6. *C. fastigiatum*
7. *Chondria leptacreamon*
8. *C. sedifolia*
9. *Enteromorpoha chaetomorphoides*
10. *E. spicifera*
11. *Goniotrichium alsidii*
12. *Griffithsia globulifera*
13. *Hypnea musciformis*
14. *Laurencia poitei*
15. *Lyngbya majescula*
16. *Myriotrichia subcorymbosa*
17. *Polysiphonia sublissima*
18. *Spyridia filamentosa*
19. Clonial bryzoan

Table 11. Temperature (°C) and salinity (‰) data at boat ramp and 6 sites in Cockroach Bay, Florida; 1993.

	B. Ramp		1		2a		2c		2d		3		4	
Date	°C	S‰	°C	S‰	°C	S‰	°C	S‰	°C	S‰	°C	S‰	°C	S‰
Dec 12											16	28		
Jan 23			22	24.4	22	24.4	23	25.3	23	25.3				
Feb 4											19	23	19	23
Feb 6			19	24	19	24								
Feb 18							17	28	17	29				
Mar 5			18	24	19.5	23	19	26	19	26	21	25	21.5	24
Mar 25				28		28		29		29		26		26
Mar 27			25	28	25	28	25	29	26	30	26	26	26	26
Apr 10			19	27	19.5	25	20	25	19	26	21	25	20.5	25
Apr 29	20	20.5					20.5	26						
May 13	24	29									25	29		
May 15	25	28									26	29	28	29
May 17			29	30										
May 27	25	30	25	30							25	29	24.5	30
Jun 5	32	31			28	31	30.5	30						
Jun 6									32	31				
Jun 15		30				30		31		31				
Jul 6			30	27.5	30	27	30	25.5	29	28	31	29	29	27

Table 11[cont.]. Temperature (°C) and salinity (‰) data at boat ramp and 6 sites in Cockroach Bay, Florida; 1993.

	B. Ramp		1		2a		2c		2d		3		4	
Date	°C	S‰	°C	S‰	°C	S‰	°C	S‰	°C	S‰	°C	S‰	°C	S‰
Jul 16	31	27					30	27					30	26.5
Jul 21	32	26					30	27.5					32	24.5
Aug 2	32.5	27									31.5	25	30	22
Aug 3	31	24	30	26.5	31	26.5								
Aug 10	31	25	29.5	24.5	29	26	31	26	32.5	29.5				
Aug 15	29	27												
Aug 17	28	27	28	25.5									28	24
Aug 18	31	27					28	27					30.5	27
Sep 10	27	25			26	25.5	27.5	24	27.5	25				
Sep 22	25	21			25	24	26	23	25	19				
Oct 1	26	20					23	20					26	19
Nov 5	28.5	30	28	30			25	23.5						
Nov 10		26						26						25
Dec 8			18	27	20	26	17.5	27	22.5	24	20	24	18	26.5

Table 13. Organic and calcium carbonate levels from sediment samples taken in a reference *Thalassia testudinum* bed (Reference Area), an existing propeller cut (Old Cut), and artificial propeller cuts made parallel (Parallel Cut) and perpendicular (Perpendicular Cut) to the tidal currents in Cockroach Bay, Florida; 1993. Data are pooled from 6 sites. Values are means ± S.D., n = 30. Superscripts denote statistical differences ($P < 0.05$; Student-Newman-Keuls Method).

Substrate Type	February/March		June/July		November	
	Organic (%)	$CaCO_3$ (%)	Organic (%)	$CaCO_3$ (%)	Organic (%)	$CaCO_3$ (%)
Reference Area	2.90 ± 2.18	5.46 ± 3.19	2.97 ± 1.25[a]	8.79 ± 7.30	2.50 ± 0.81	7.23 ± 6.71
Old Cut	2.18 ± 0.70	6.44 ± 3.90	2.96 ± 1.35[a]	7.80 ± 5.21	2.10 ± 0.63	8.35 ± 9.18
Parallel Cut	2.13 ± 1.03	7.49 ± 3.32	1.93 ± 0.88[bc]	8.16 ± 5.97	2.02 ± 1.00	8.04 ± 8.48
Perpendicular Cut	2.05 ± 0.84	4.91 ± 2.74	2.40 ± 0.92[ac]	9.09 ± 9.17	2.33 ± 0.88	9.60 ± 12.11

Table 14a-b. Percent of sediment particle size (mm dia) distribution from a reference *Thalassia testudinum* bed (Reference Area), an existing propeller cut (Old Cut), artificial propeller cuts made parallel (Parallel Cut) and perpendicular (Perpendicular Cut) to the tidal currents, and a bare area within 1 m of the inshore fringe of the *Thalassia* bed (Bare Sand), in sites 2a (14a) and 3 (14b) in Cockroach Bay, Florida; June 1993. Values are means ± S.D., n = 19. Superscripts denote statistical differences ($P < 0.05$; Dunn's method).

Substrate	Particle Size (%)						
	<0.063	0.063	0.125	0.25	0.50	1.0	2.0+
Reference Area	1.09 ± 1.83^{a}	4.68 ± 1.72^{a}	42.06 ± 16.39^{a}	39.82 ± 18.82^{a}	6.99 ± 2.23^{a}	2.64 ± 2.03^{a}	2.72 ± 1.65^{a}
Old Cut	1.48 ± 0.88^{b}	6.68 ± 3.41^{a}	51.94 ± 8.43^{ab}	28.78 ± 8.72^{a}	6.68 ± 1.73^{a}	2.88 ± 2.06^{a}	1.55 ± 1.09^{a}
Parallel Cut	1.24 ± 1.41^{a}	7.35 ± 3.56^{a}	44.92 ± 15.90^{a}	37.78 ± 16.73^{a}	6.19 ± 1.15^{a}	0.91 ± 0.40^{bc}	1.61 ± 2.21^{a}
Perpendicular Cut	0.91 ± 0.42^{a}	6.32 ± 2.64^{a}	50.55 ± 6.77^{ab}	29.19 ± 7.12^{a}	9.27 ± 4.61^{a}	2.13 ± 1.81^{ac}	1.63 ± 1.43^{a}
Bare Sand	1.46 ± 1.24^{b}	5.81 ± 2.20^{a}	38.68 ± 7.66^{ac}	15.27 ± 4.71^{b}	6.15 ± 1.09^{a}	6.43 ± 2.36^{d}	26.21 ± 5.65^{b}

(a) Site 2a

Substrate	Particle Size (%)						
	<0.063	0.063	0.125	0.25	0.50	1.0	2.0+
Reference Area	1.57 ± 0.65^{a}	8.37 ± 4.52^{a}	46.93 ± 17.77^{a}	25.91 ± 20.84^{a}	5.73 ± 0.94^{a}	3.84 ± 1.26^{a}	7.65 ± 2.11^{a}
Old Cut	1.47 ± 0.35^{a}	10.70 ± 2.13^{ab}	50.98 ± 9.63^{a}	16.36 ± 8.68^{a}	5.34 ± 0.80^{ab}	4.47 ± 1.41^{a}	10.68 ± 4.35^{a}
Parallel Cut	0.99 ± 0.20^{b}	7.89 ± 2.25^{ac}	58.95 ± 5.62^{a}	15.60 ± 3.38^{a}	4.44 ± 0.79^{b}	3.85 ± 1.66^{a}	8.28 ± 2.55^{a}
Perpendicular Cut	1.45 ± 0.24^{a}	10.91 ± 1.48^{ab}	56.41 ± 4.80^{a}	13.63 ± 3.96^{ab}	4.61 ± 0.80^{b}	3.44 ± 1.11^{a}	9.54 ± 3.19^{a}
Bare Sand	1.31 ± 0.37^{a}	8.73 ± 9.78^{ac}	38.68 ± 7.64^{b}	18.62 ± 3.98^{ac}	8.47 ± 1.99^{c}	6.53 ± 1.73^{b}	17.66 ± 5.24^{b}

(b) Site 3

Table 15a-b. Organic and calcium carbonate levels from sediment samples taken in a reference *Thalassia testudinum* bed (Reference Area), an existing propeller cut (Old Cut), artificial propeller cuts made parallel (Parallel Cut) and perpendicular (Perpendicular Cut) to the tidal currents, and a bare area within 1 m of the inshore fringe of the *Thalassia* bed (Bare Sand), in sites 2a (16a) and 3 (16b) in Cockroach Bay, Florida; June 1993. Values are means ± S.D.; n = 19. Superscripts denote statistical differences ($P < 0.05$; Dunn's method).

Substrate	Organic (%)	$CaCO_3$ (%)
Reference Area	3.36 ± 0.85^{a}	6.80 ± 2.53^{a}
Old Cut	4.50 ± 0.97^{b}	6.95 ± 1.73^{a}
Parallel Cut	2.66 ± 0.64^{ac}	5.92 ± 2.42^{a}
Perpendicular Cut	4.38 ± 2.07^{ab}	6.15 ± 1.25^{a}
Bare Sand	3.99 ± 0.89^{ab}	35.70 ± 10.59^{b}

(a) Site 2a

Substrate	Organic (%)	$CaCO_3$ (%)
Reference Area	3.56 ± 0.65^{a}	24.30 ± 8.89^{a}
Old Cut	3.76 ± 1.01^{a}	24.73 ± 6.64^{a}
Parallel Cut	1.88 ± 0.77^{b}	19.63 ± 6.21^{ab}
Perpendicular Cut	2.18 ± 0.94^{b}	24.82 ± 8.34^{a}
Bare Sand	4.01 ± 0.75^{a}	30.73 ± 8.05^{ac}

(b) Site 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	9	12			9		6	10				10	9	7		8		16		
B	16	12			9		7	7				4	9	9		12		8		
C	6	6		5	4	5	4	2	2	2	2	1	1	1		3		2	2	
D	7	6			5		6	6				11	6	6		18		3		
E	12	8			6		7	4				6	4	10		6		4		

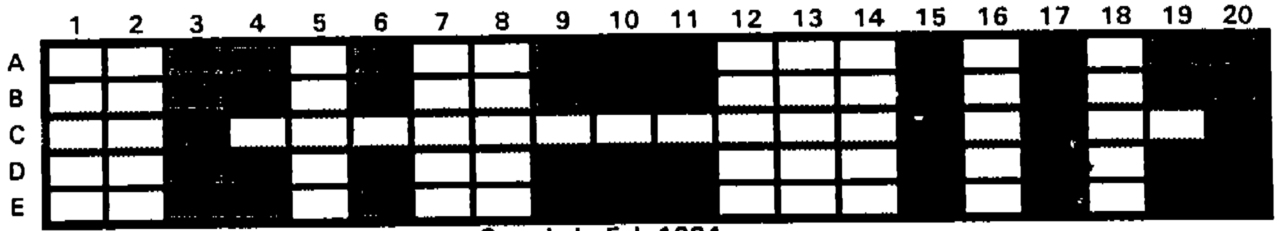
Sampled: June 1993

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	16	19			17		10	14				13	14	10		19		22		
B	17	17			16		8	5				12	10	15		12		11		
C	11	13		6	7	9	5	3	1	2	3	5	2	1		3		1	3	
D	13	11			10		17	11				19	6	14		18		4		
E	20	15			16		10	11				10	14	12		12		3		

Sampled: Aug 1993

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	14	9			18		10	11				16	12	14		15		20		
B	11	6			10		8	6				6	9	8		11		12		
C	6	11		4	7	6	8	7	1	3	0	7	2	8		5		2	2	
D	11	9			7		14	13				13	7	9		15		9		
E	11	14			15		13	17				10	18	19		15		10		

Sampled: Oct 1993



Sampled: Feb 1994

Figure 1. A schematic time-series for the large permanent strip-quadrat (5 x 1.25m) at Site 2c. Values are the number of short shoots per quadrat (25 x 25cm).

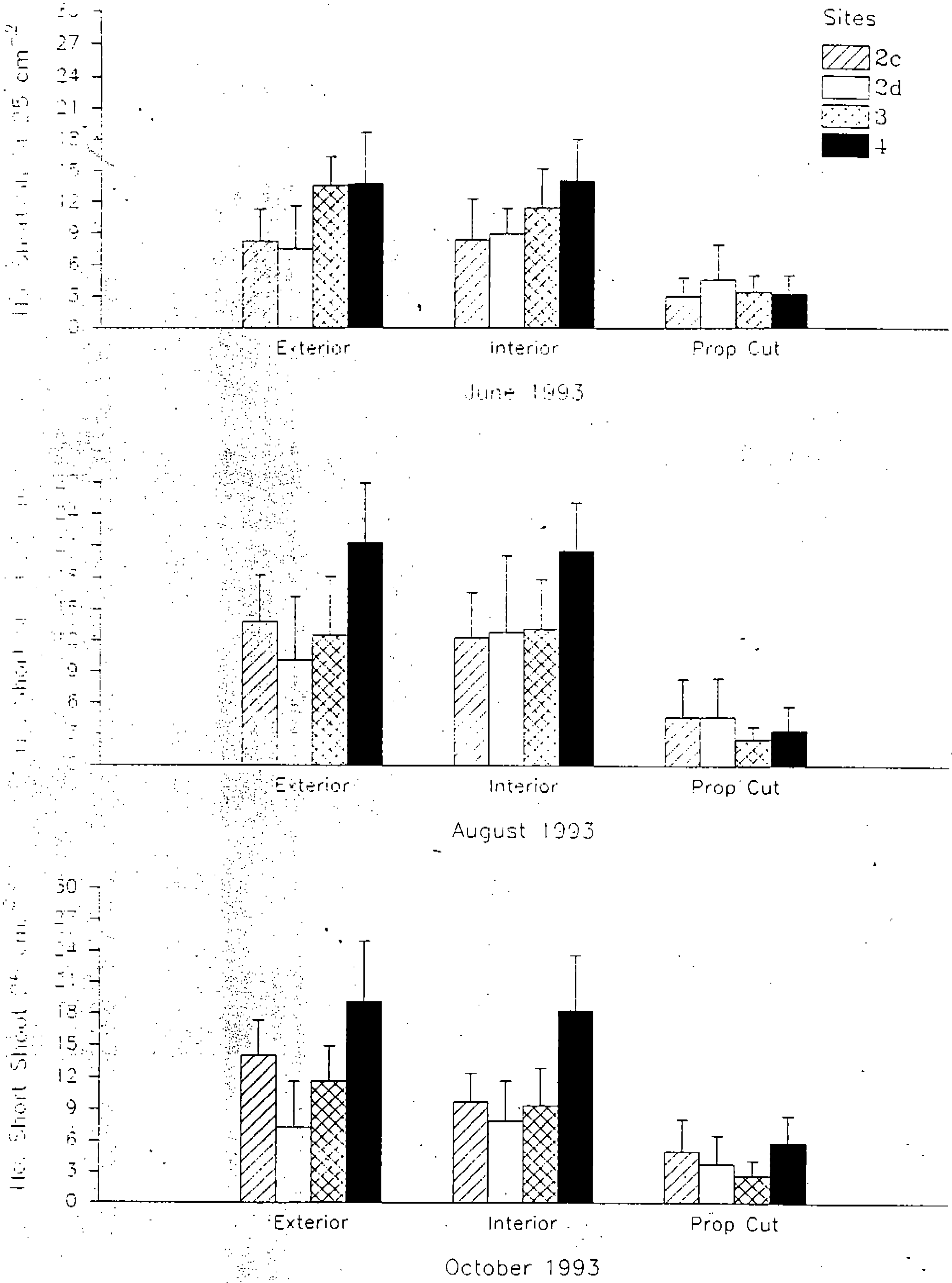


Figure 2. Short shoot density of *Thalassia testudinum* within and adjacent to existing propeller cuts at 4 sites in Cockroach Bay, Florida.

Sampled: 16 July 1993

Control

	1	2	3	4	5
A		6		10	
B	5	8	2		
C	7	5	0	5	
D	9	6	3		10
E					

Jobe's Sticks

	1	2	3	4	5
A			4		
B	3	3	6	6	6
C		8	0		
D	3	0		2	
E	9			3	

Urea + Phosphate

	1	2	3	4	5
A				5	
B		4	4	4	
C	4	3	0		5
D		2		3	2
E				6	3

Sampled: 18 August 1993

Control

	1	2	3	4	5
A		4		8	
B	4	6	3		
C	5	6	0	5	
D	0	3	5		10
E					

Jobe's Sticks

	1	2	3	4	5
A			5		
B	3	7	5	5	0
C		7	6		
D	2	2		2	
E	8			5	

Urea + Phosphate

	1	2	3	4	5
A				4	
B		5	4	7	
C	3	2	0		7
D		5		4	2
E				7	2

Sampled: 1 October 1993

Control

	1	2	3	4	5
A		4		5	
B	7	6	3		
C	4	5	1	4	
D	0	3	5		10
E					

Jobe's Sticks

	1	2	3	4	5
A			1		
B	3	4	2	4	0
C		10	3		
D	4	2		1	
E	5			5	

Urea + Phosphate

	1	2	3	4	5
A				6	
B		4	4	4	
C	2	3	0		8
D		2		2	3
E				6	1

Sampled: 28 November 1993

Control

	1	2	3	4	5
A		4		4	
B	9	8	1		
C	5	7	1	5	
D	2	3	3		7
E					

Jobe's Sticks

	1	2	3	4	5
A			4		
B	3	4	5	5	1
C		9	3		
D	6	0		1	
E	4			4	

Urea + Phosphate

	1	2	3	4	5
A				5	
B		4	2	3	
C	4	3	0		6
D		4		1	2
E				7	2

Sampled: 23 January 1994

Control

	1	2	3	4	5
A		4		3	
B	6	6	0		
C	4	4	1	3	
D	0	3	1		4
E					

Jobe's Sticks

	1	2	3	4	5
A			2		
B	2	3	1	3	0
C		11	1		
D	4	0		1	
E	5			5	

Urea + Phosphate

	1	2	3	4	5
A				5	
B		4	1	4	
C	4	1	0		7
D		5		0	1
E				4	0

Figure 3. Schematic time-series for 1 group of permanent quadrats (1.25 x 1.25m) at Site 4. Two treatments (Jobe's Sticks and Urea + Phosphate) and a control are shown Values are the number of short shoots per quadrat (25 x 25cm).

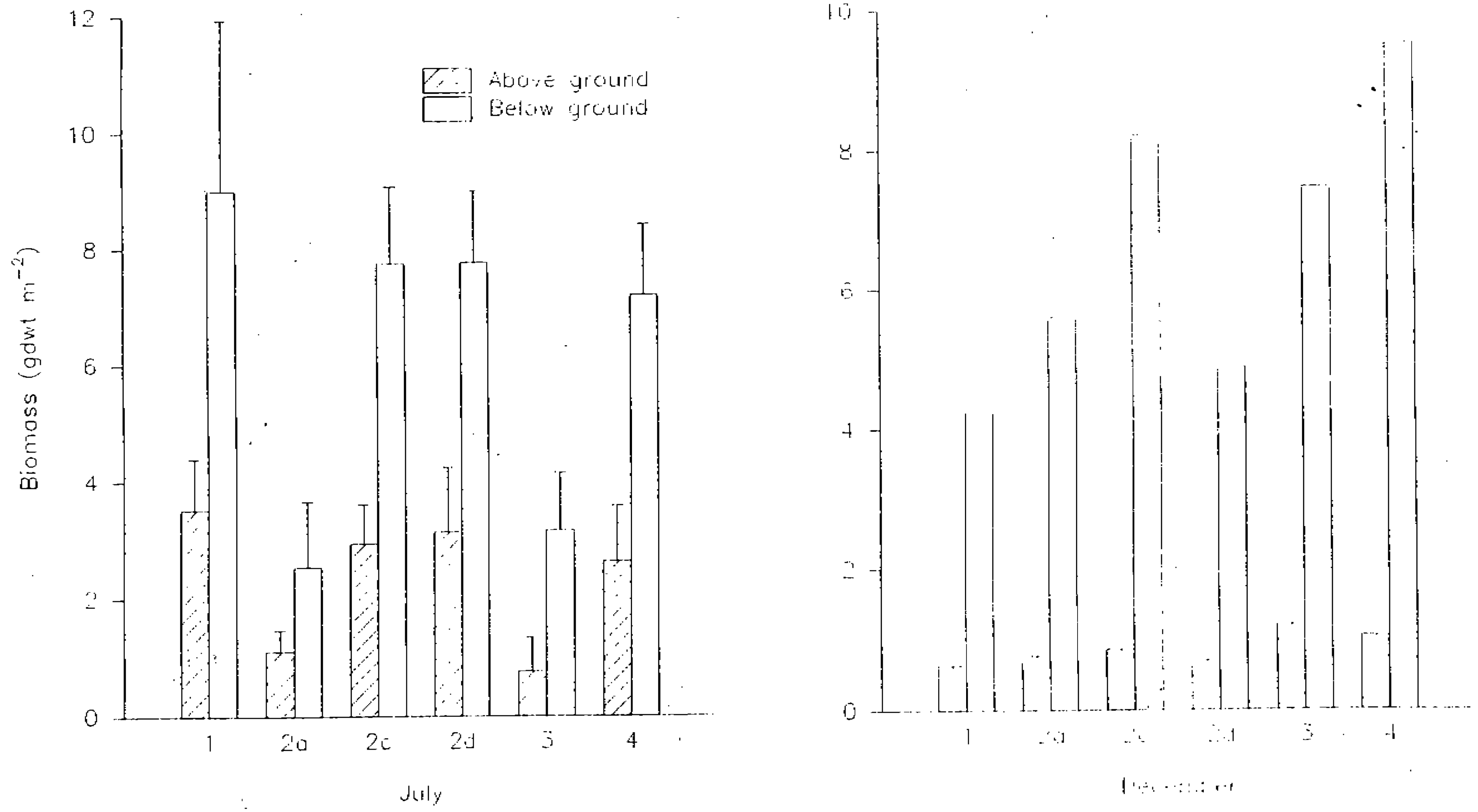


Figure 4. Above ground and below ground biomass of *Thalassia testudinum* at [illegible] sites in [illegible] Bay, [illegible] 1993 (July, n = 3; December, n = 1).

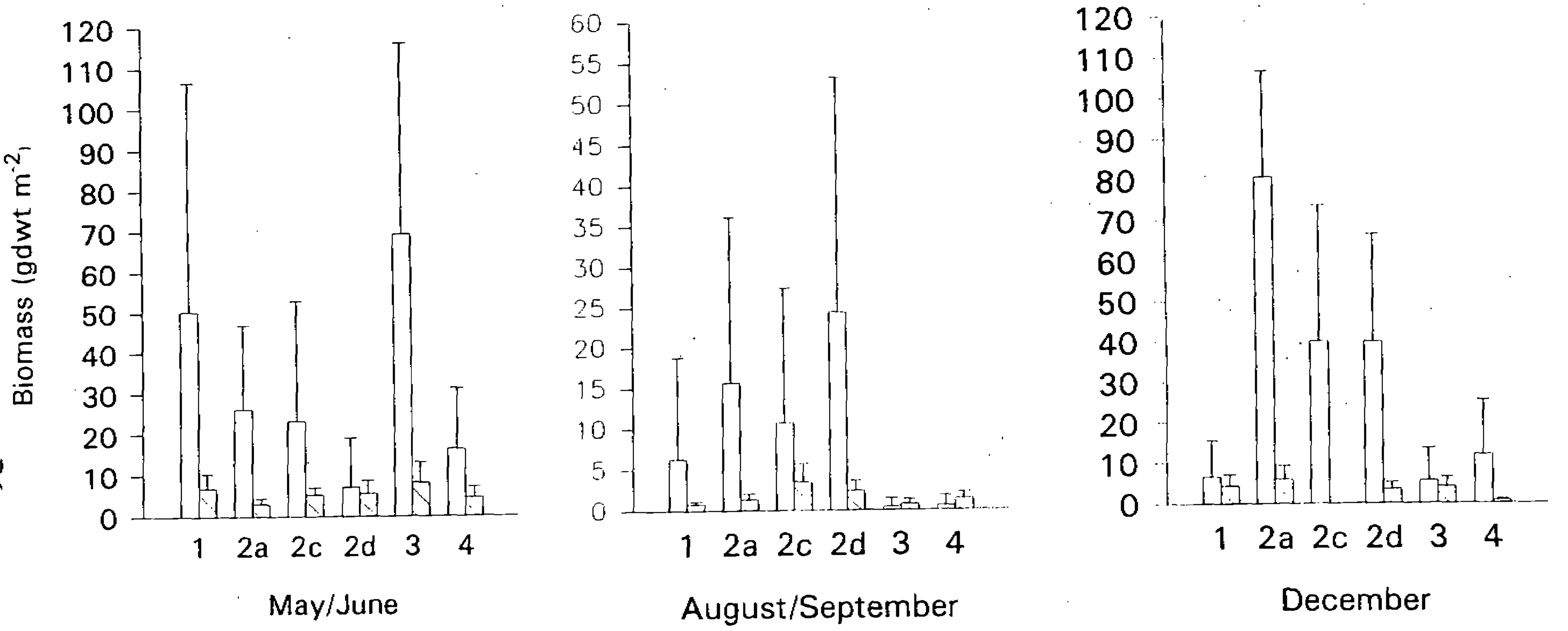


Figure 5. Algal biomass (▭ Macrophytes and ▨ Epiphytes) at 6 sites in Cockroach Bay, Florida; 1993.

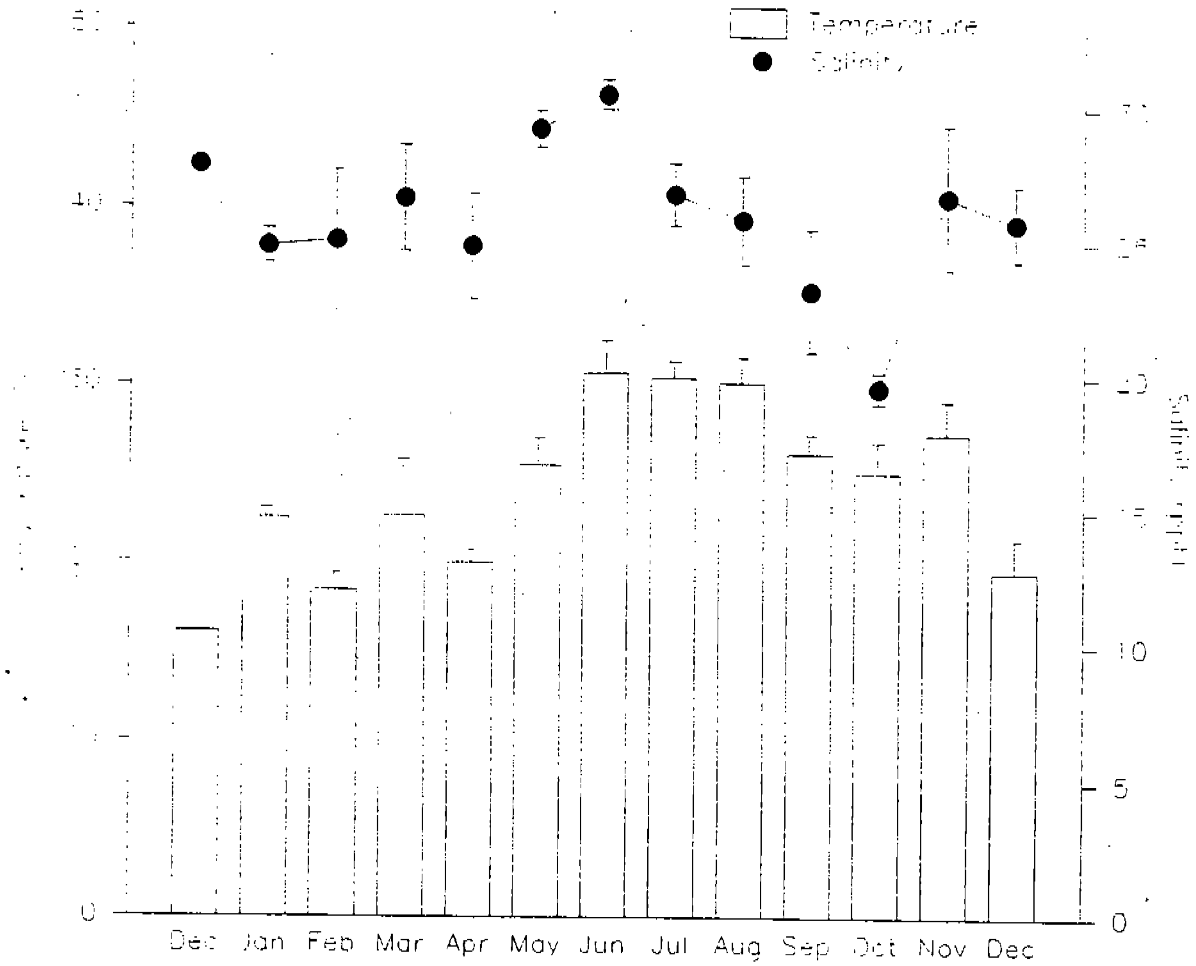


Figure 8. Mean temperature and salinity for all sites in Cockroach Bay, Florida; December 1992 - December 1993.

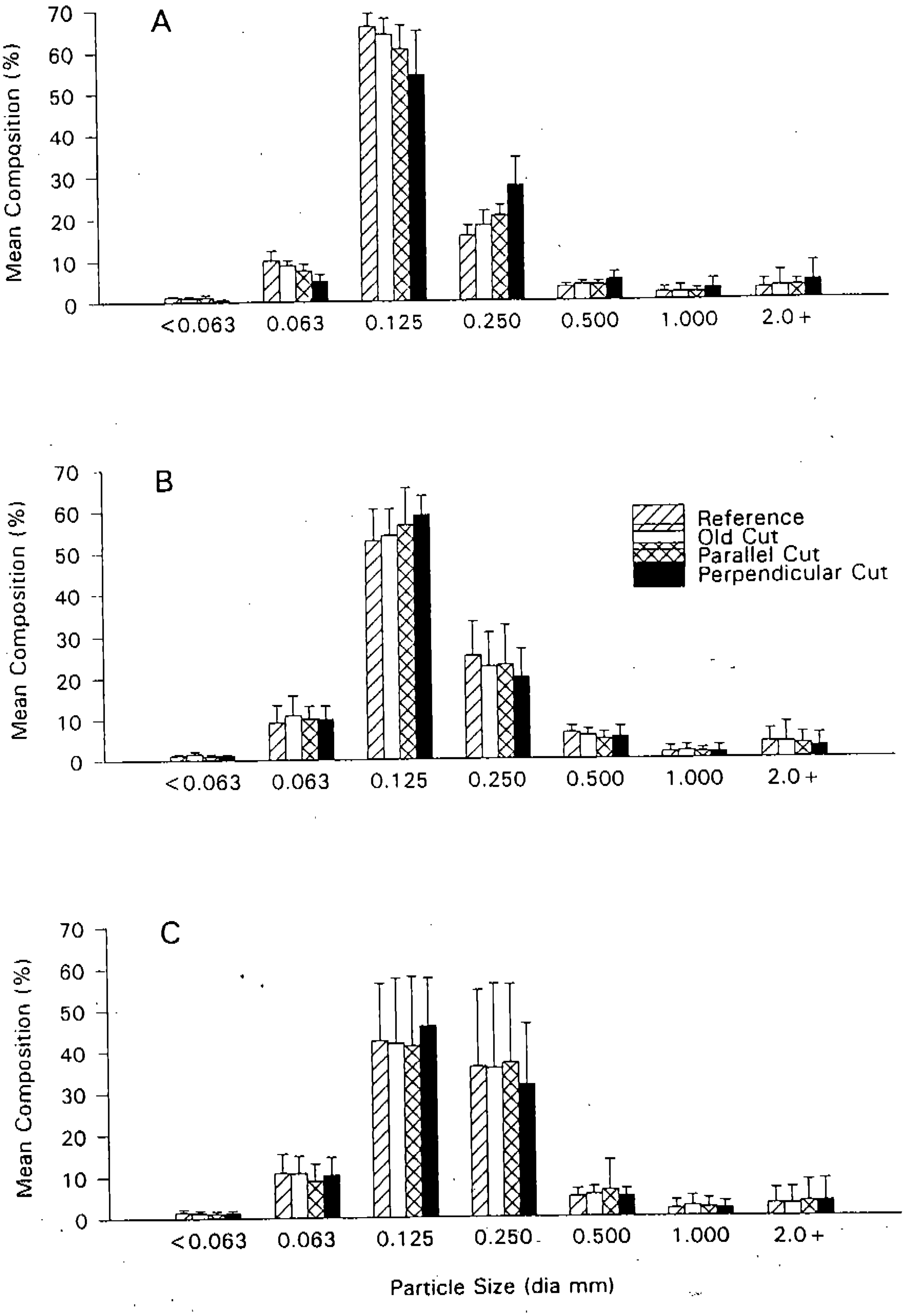


Figure 7a-c. Particle size distribution of sediments from 6 sites in Cockroach Bay, Florida; 1993. (A) February/March, (B) June/July, and (C) November.

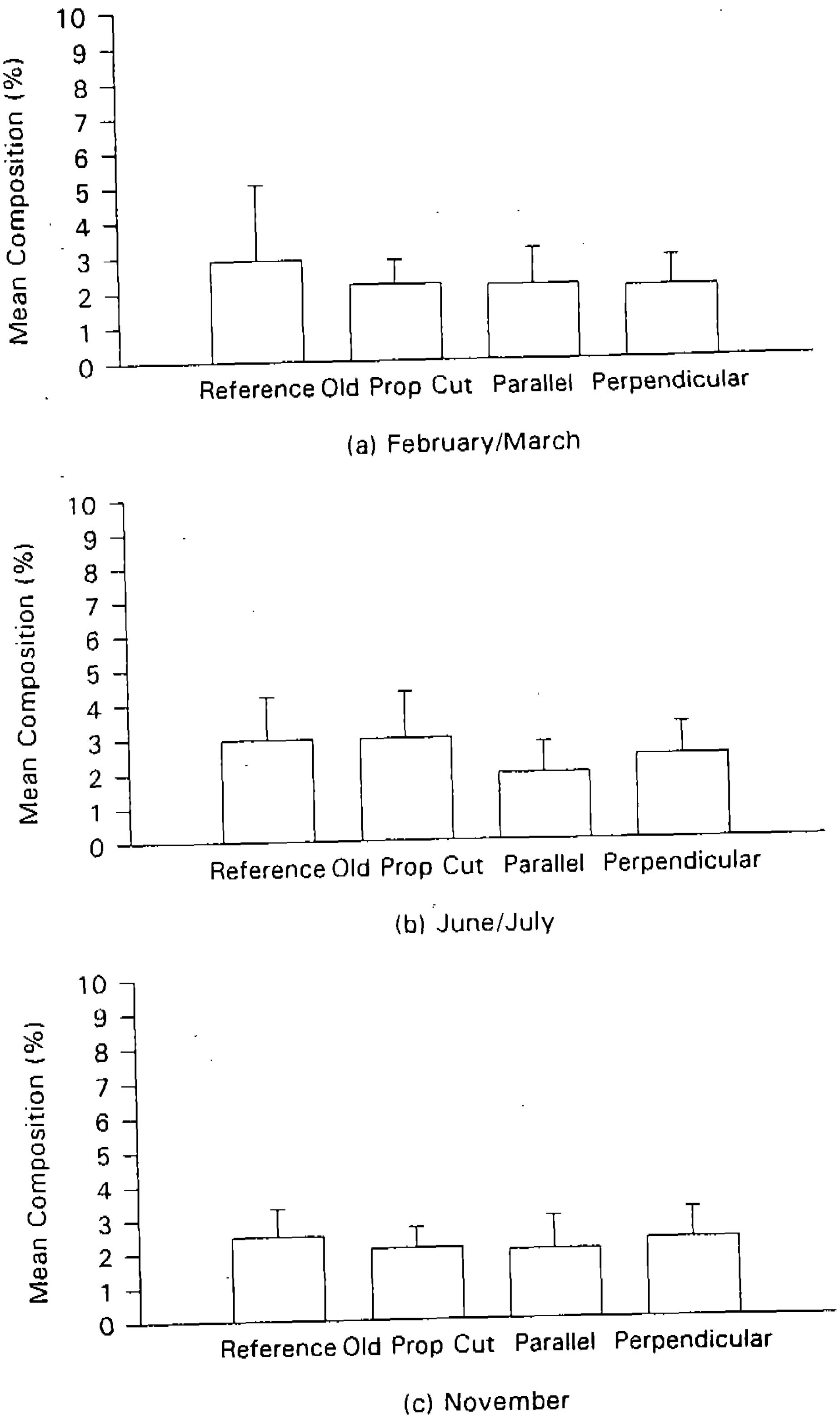
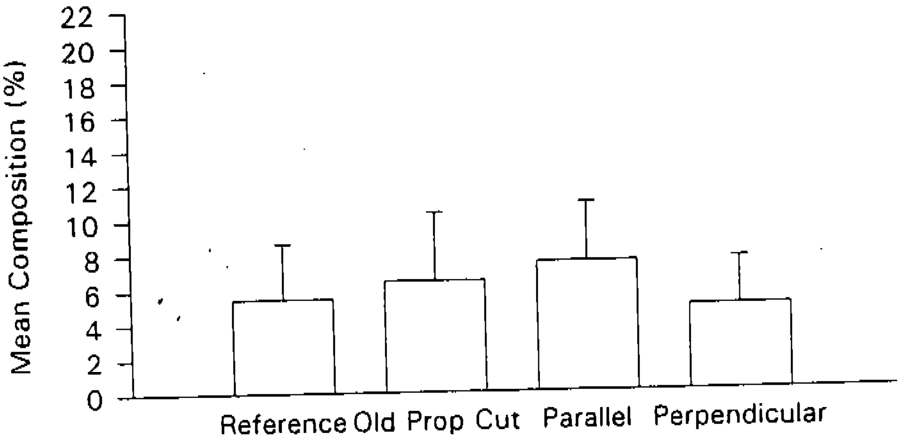
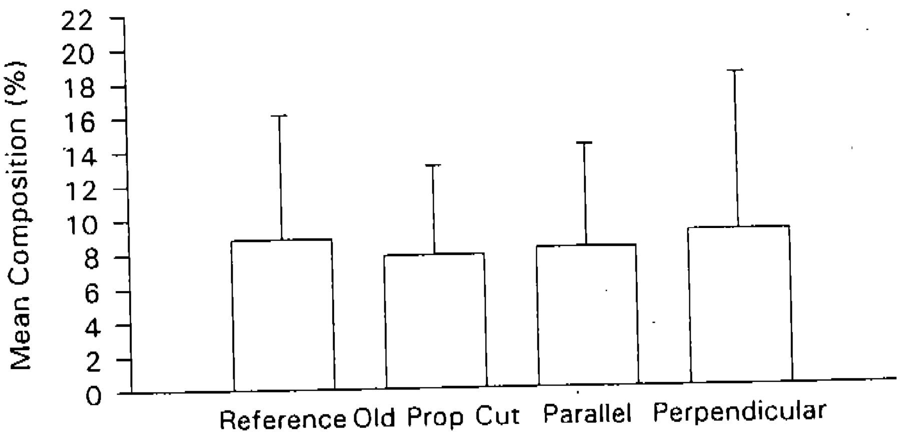


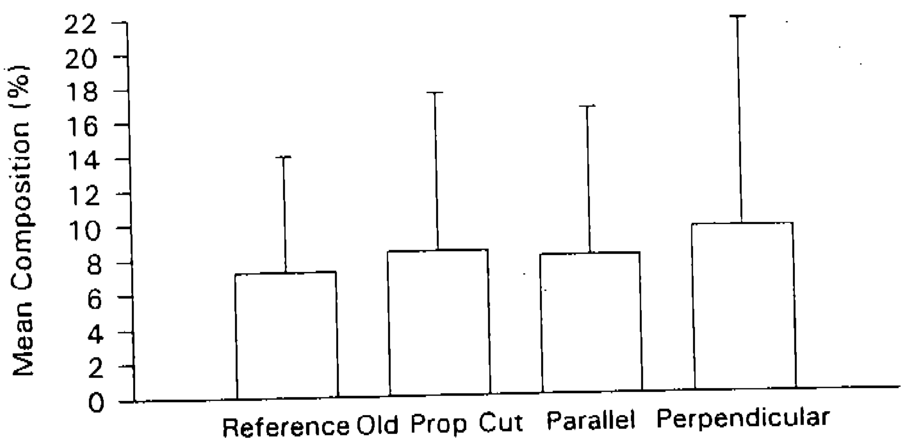
Figure 8a-c. Total organics in sediments from 6 sites in Cockroach Bay, Florida; 1993.



(a) February/March



(b) June/July



(c) November

Figure 9a-c. Calcium carbonate n sediments from 6 sites in Cockroach Bay, Florida; 1993.

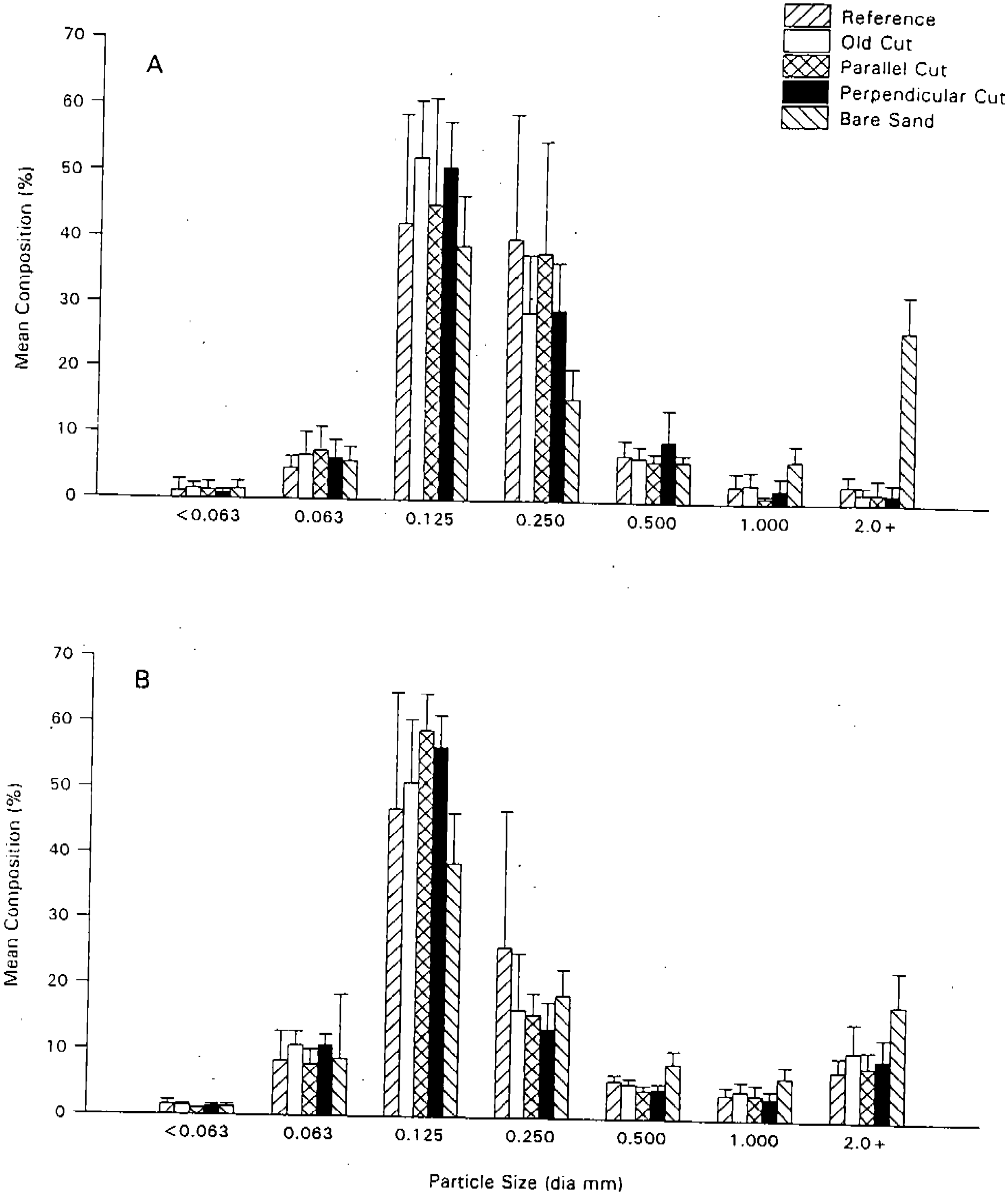
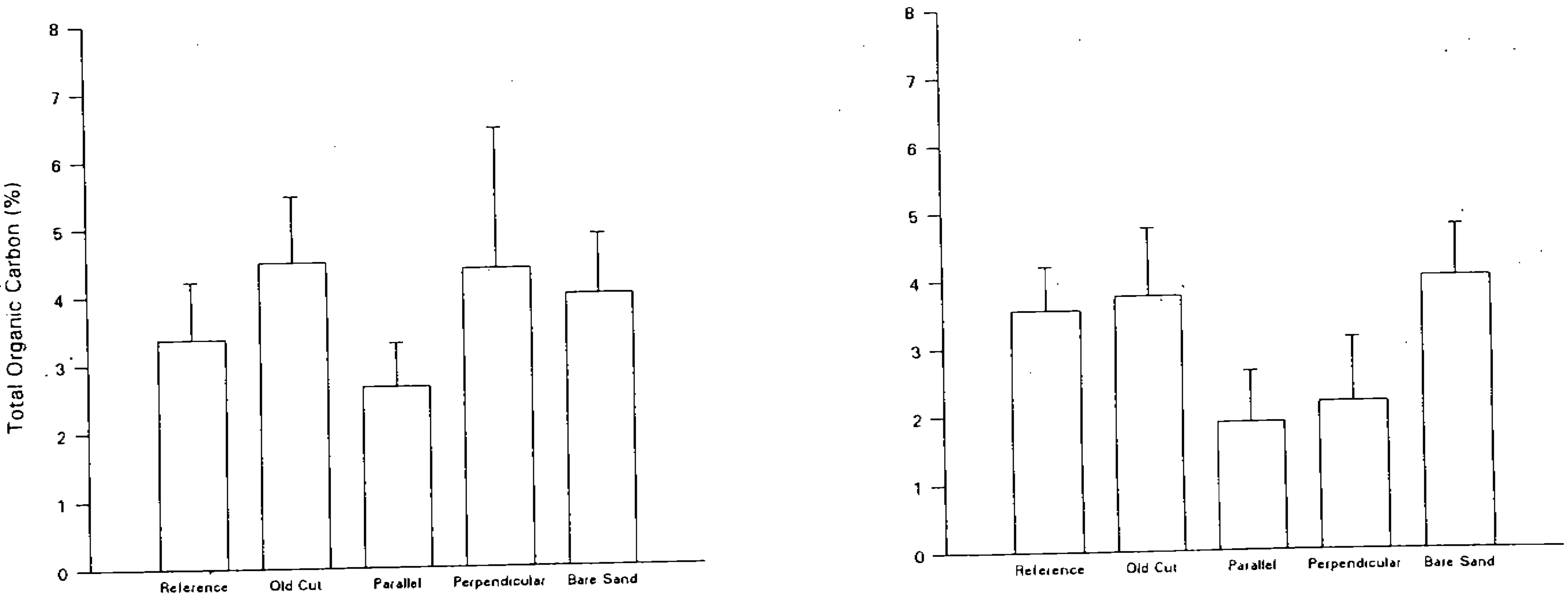


Figure 10a-b. Particle size distribution of sediments from (a) Site 2a and (b) Site 3 in Cockroach Bay, Florida; June 1993.



(a) Site 2a

(b) Site 3

Figure 11a-b. Total organic carbon of sediments collected from (a) Site 2a and (b) Site 3 in Cockroach Bay, Florida; June 1993.

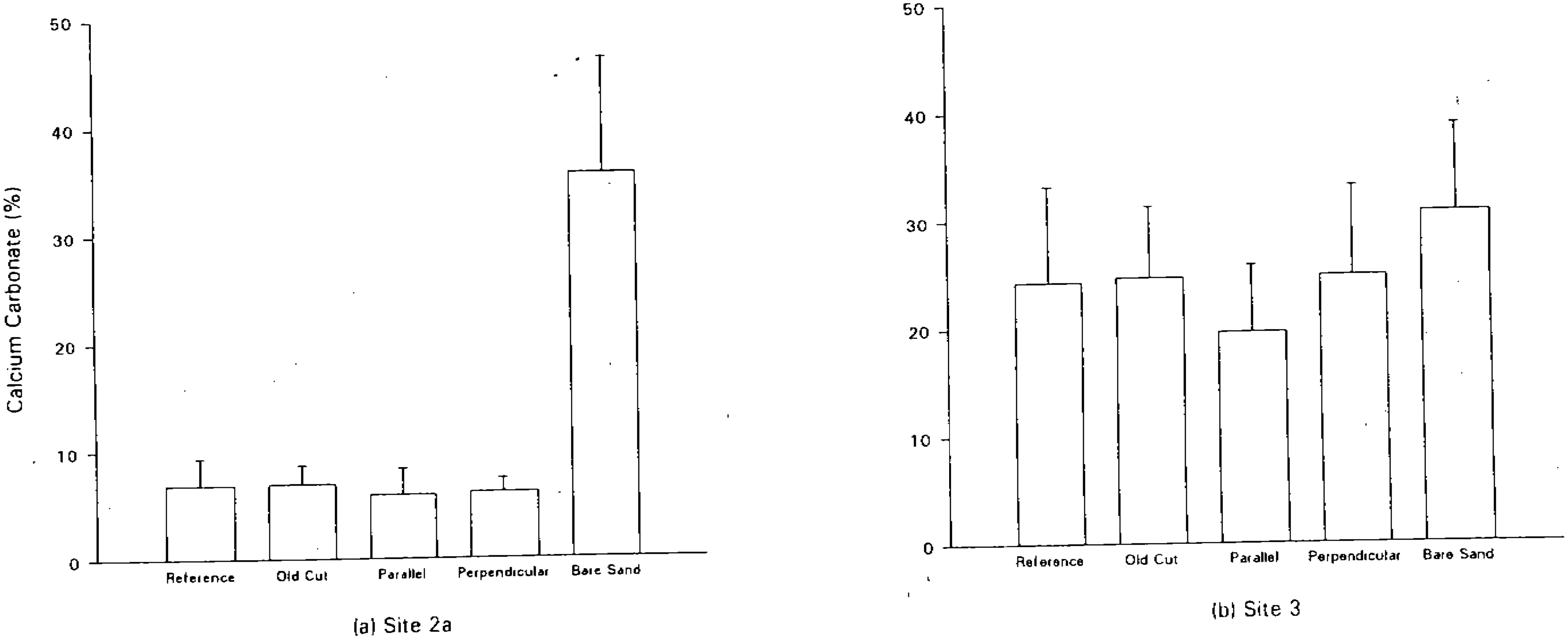


Figure 12a-b. Calcium carbonate content of sediments collected from (a) Site 2a and (b) Site 3 in Cockroach Bay, Florida; June 1993.

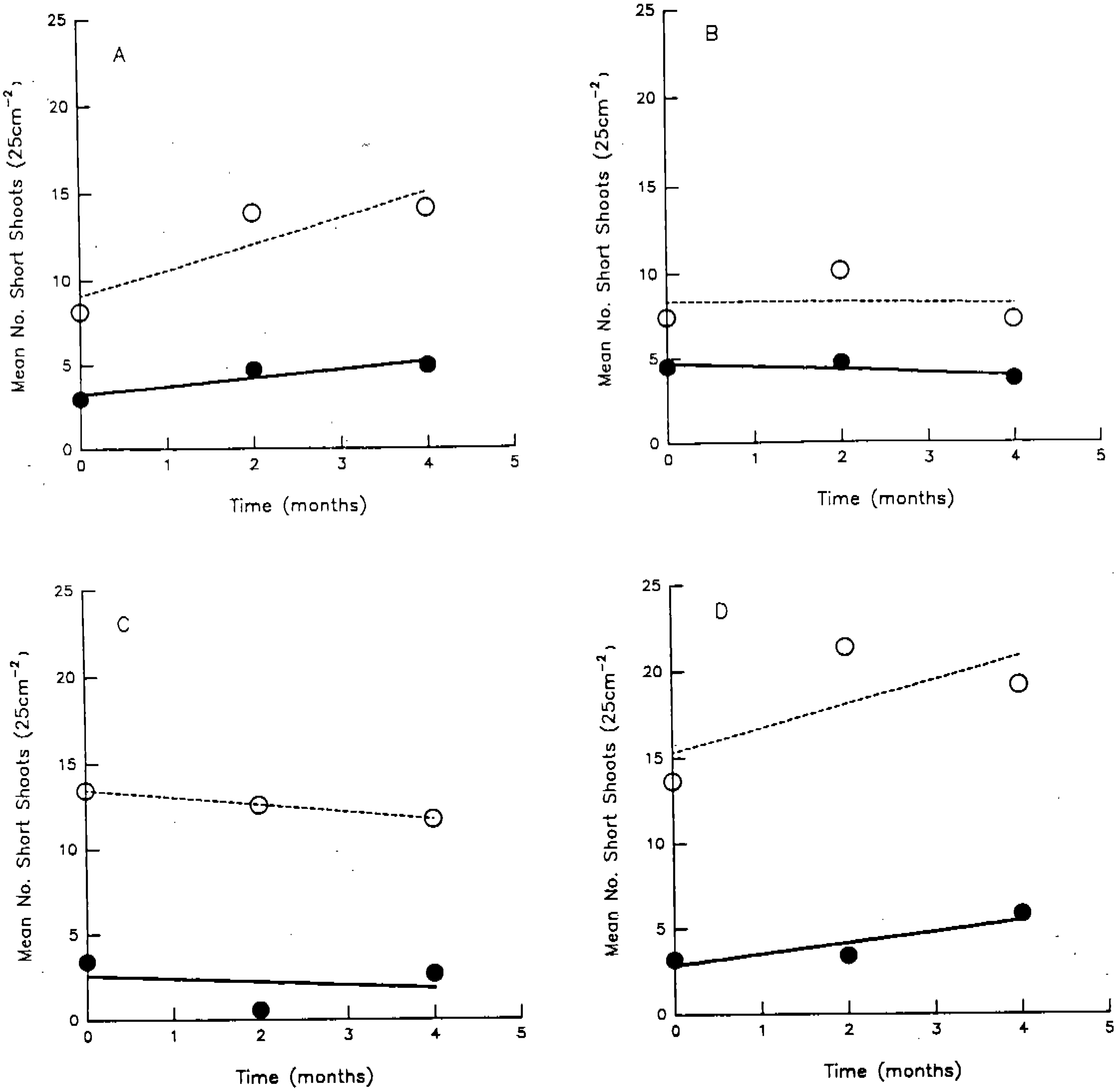


Figure 13a–d. Linear regression models predicting the recolonization of turtlegrass in existing propeller cuts at (a) Site 2c, (b) Site 2d, (c) Site 3, and (d) Site 4, in Cockroach Bay, Florida; 1993. Study was initiated in June 1993.

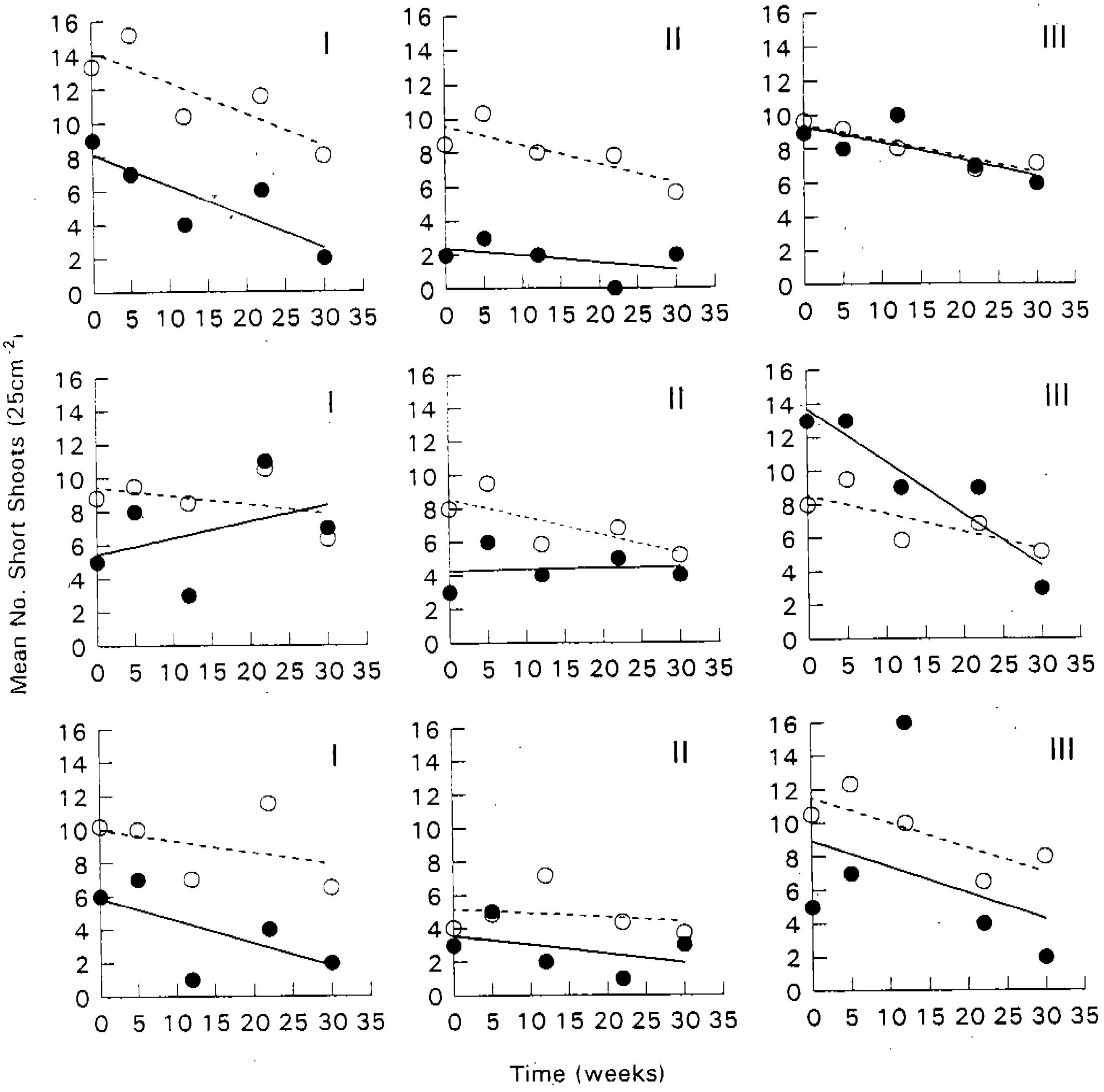


Figure 14. Linear regression models for short shoot density in nine 1.25m^2 quadrats located at Site 2c in Cockroach Bay, Florida. Three subsets (I, II, and III) consisted of 3 treatments: Control, (top row), Jobe's Sticks (middle row), and Urea + Phosphate (bottom row). Solid lines and circles represent mean densities of the center quadrat (25cm^2; n = 1), and the dotted line with hollow circles represents the mean densities of the quadrats in the exterior row (n = 6). Study was initiated on 16 July 1993.

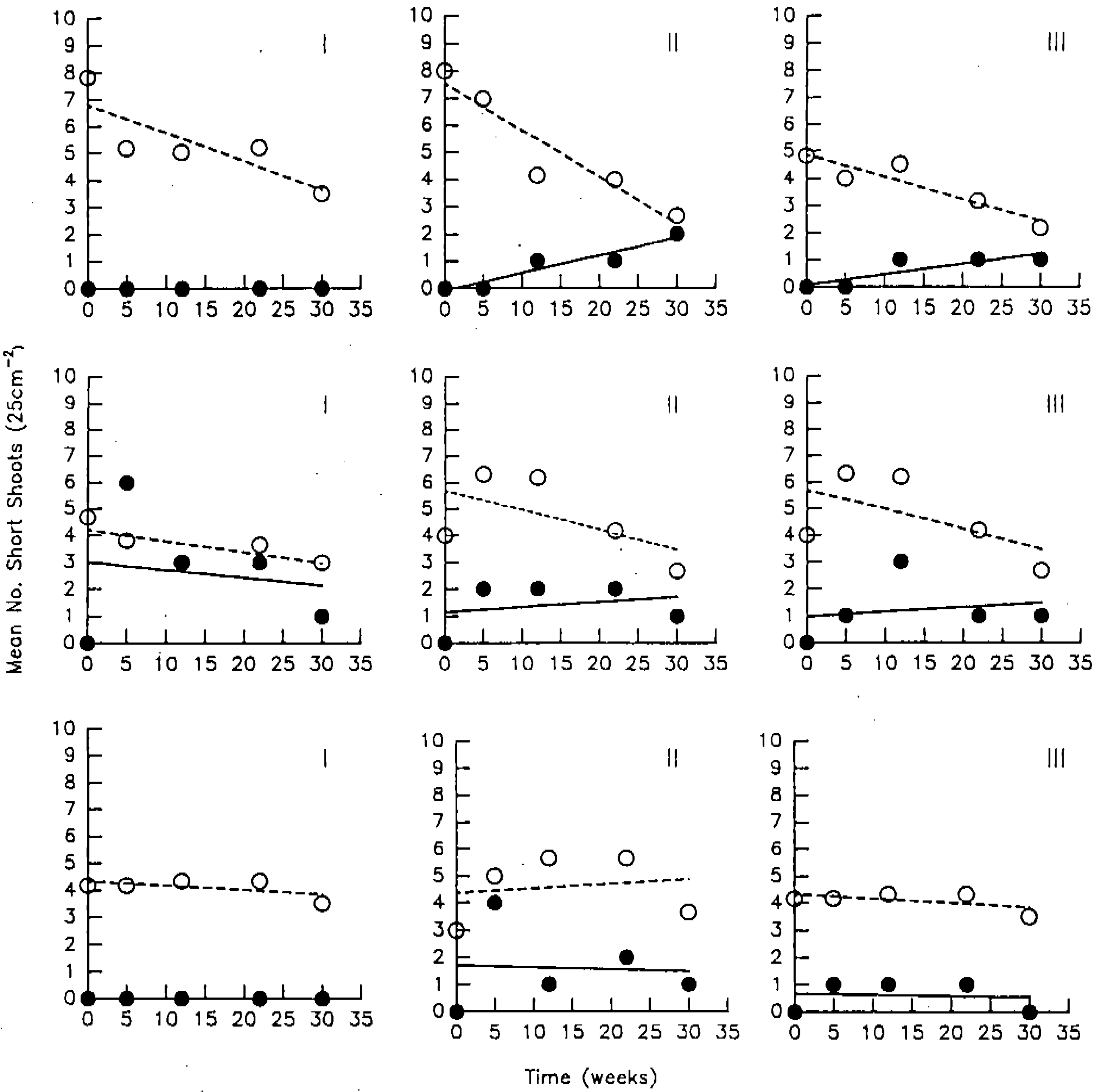


Figure 15. Linear regression models for short shoot density in nine $1.25m^2$ quadrats located at Site 4 in Cockroach Bay, Florida. Three subsets (I, II, and III) consisted of 3 treatments: Control (top row), Jobe's Sticks (middle row), and Urea ± Phosphate (bottom row). Solid lines and circles represent mean densities of the center quadrat ($25cm^2$; n=1), and the dotted line with hollow circles represents the mean densities of the quadrats in the exterior row (n=6). Study was initiated on 16 July 1993.