169a

Thalassia testudinum Recovery in Boat Propeller Scars in Cockroach Bay, Florida.

Final Report: July 1, 1995 through 31 August, 1996.

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INTRODUCTION.

The present report covers the thirteen month grant extension from Hillsborough E.P.C. for 1 July 1995 to 31 August 1996. Detailed descriptions and studies of Cockroach Bay on the recovery of Thalassia testudinum (turtle grass) in propeller scars, begun in December 1992, are given in the Annual reports for 1993 and 1994, and the Extension report of 30 June 1995. This report includes information from the six month report (1 July through 31 December 1995) and summarizes the studies carried out by the University of South Florida and Hillsborough Community College based on our proposal of June, 1995.

A. Seagrass Community Assessment.

Proposed Study Sites: Two of the original 6 Recovery Area (RA) sites selected were 2C and 4. A third, new site (EXT) was established in Tampa Bay exterior to site 2C. Field work began in July but due to intense summer storms, the first growth studies could not be completed at the three sites until October. General sampling and growth studies were also carried out in December 1995 and February, April and June 1996. To aid in comparisons, data obtained in February and May, 1995 are also included in some of the tables.

1. Seagrass development studies

Above Ground: abiotic factors. The temperature and salinity graph (Fig. 1) demonstrates two important features of Cockroach Bay during the past three years. First, there is a strong seasonal cycle in both salinity and temperature. From September 1992 through June 1996 the lowest and highest water temperature observed was 12 °C (Feb. 1996) and 33 °C (Aug 1994, June 1995). The lowest and highest salinities observed were 16 ppt (July 1995) and 34 ppt (Apr. 1995). Second, salinities in the fall months of 1994 and 1995 were lower than measured in the previous 2 years (1992: 27 to 30 ppt; 1993: 31 to 33 ppt) because of a return to average rain fall in the Tampa Bay area. In spite of the low salinities in the fall of 1995, the spring regrowth of *Thalassia testudinum* in 1996 was as high as in previous springs.

Above Ground: short shoot density. The differences in ramet densities (Table 1; short shoot density) showed no pattern when the three sites are compared and Site 4 continued to show the highest short shoot densities. There was a general increase in biomass at all sites with spring growth and the increase was highly significant on a seasonal basis at Site 4. Again, we find no effect of the depressed salinities that occurred in the fall of 1995.

2. High altitude photographs

Above Ground: ground and aerial photographs. High altitude aerial photographs were taken in October, February and July of Cockroach Bay, Little Cockroach Bay and adjacent waters of Tampa Bay at a 1 to 2,400 scale. Enlargements were made of these images. The images were scanned into the computer and digitized. Scaling was accomplished by using known ground distances. Mangroves and seagrasses were outlined on the computer images in order to give us a computer map but also square footage of the grasses and mangroves. The following data were computed for the entire area:

Area	Square feet	Acreage
Seagrasses	35,700,000	819.56
Mangroves	57,800,000	1,326.91

3. Detailed photographs:

Aerial images of the site were taken in December, April, June and July at a scale of approximately 1 to 600. Of particular interest in the aerial photographs were the passes where boat traffic was most heavy. Our charge here was to determine if new prop scarring had occurred in any of the sites studied prior to July of 1995 and to make maps of prop scars in Little Cockroach Bay and in adjacent waters of Tampa Bay. The photographs were displayed on a poster board for viewing by the EPC staff.

The early photographs are very difficult to interpret. The images were taken at a low tide and at a low sun angle. The images are excellent, however, interpretation problems occur because the seagrasses have been "burned" back to mere stubs of their usual size. This creates images on the film that appear to be sand but are actually sparse and burned grasses. Some prop scars are clearly in sand but others may be through sparse seagrasses. Ground truthing has not helped much in this regard. In later photographs more details have emerged for interpretation.

One observation on the photographs is worth noting. In the "Hole-in-the-wall" area the sand has shifted to cover more seagrasses than previously noted. There appear to be new (or more powerful) currents moving through the area pushing sand and sediment up onto the grass beds. This observation is consistent with the increases in rainfall noted for 1995. In addition, some of the grasses along the "hole-in-the-wall" pass may have died due to cold temperatures and low salinities.

Seagrasses in Tampa Bay show numerous sites where sand embankments exist where seagrasses should be growing. These are probably caused by boats moving from the deeper waters of Tampa Bay at a high speed toward the shallows. The boats run aground and damage seagrasses. This is especially prevalent in the seagrass beds in Tampa Bay in front of the entrances to Little Cockroach Bay. Over time nothing is left in these areas but sand. We believe that proper marking of the grass beds with buoys would prevent a lot of this type of scarring. In addition, boaters could be encouraged to enter Little Cockroach Bay from the northern side via the Little Manatee River on the east side of Sand Key. This entrance already has a channel. If boaters would routinely enter Little Cockroach Bay from this site, less damage would occur in the seagrasses in Tampa Bay in front of Little Cockroach bay.

One important site is area number 1. This site is located south of the channel leading from the Cockroach Bay boat ramp out to Tampa Bay. This site has had very sparse populations of <u>Halodule wrightii</u>, drifting sand and a few scattered shoots of <u>Thalassia testudinum</u>. During the three year study period little change has been noted in this area until 1996. In the spring months of 1996 an explosive growth of <u>Halodule wrightii</u> took place. The grass grew to cover the entire site in just a few months. The estimated amount of new growth of seagrasses is about 3.4 acres. This will be a prime site to follow in the next few years to see if succession takes place with <u>Thalassia</u> taking over for <u>Halodule</u> as successional theory would indicate.

The recovery sites 2, 3, and 4 sustained very little damage during the past twelve months. Only one prop scar was noted in area 4. The seagrasses in these protected zones have not yet shown dramatic recovery as did the seagrasses in area #1. Of particular interest are the seagrasses inside of entrances C, D and E. These are the three entrances to Cockroach Bay from Tampa Bay. In the years 1993 to 1995 these entrances sustained continuous prop scar damage which was especially heavy inside of entrance E, the southern most entrance. We reported in 1993 that 145,488 square feet of seagrasses had been destroyed in entrances D and E. Not enough time has elapsed for the seagrasses to recover. Perhaps, if these sites are left alone for a few more years, the seagrasses could recover much like those in site #1.

Prop scar damage: a detailed analysis of prop scar damage at Cockroach Bay, Little Cockroach Bay and Tampa Bay was conducted during the time period of this project. Very little new prop scar damage was noted during this time period. During the first three years of observations in Cockroach Bay, prop scar damage had occurred on a regular basis, declining somewhat in 1994 from pervious years. However, in the time period of July 1995 to August of 1996 very little scarring was observed. The following data were compiled from aerial photographs and ground truthing (some of the linear feet data of new scars are estimates based upon field observations of scars that appeared to be new):

Location	Linear feet of old scars	Linear feet of new scars
Cockroach Bay	48,747	6
Little Cockroach Bay Plus Tampa Bay	21,682	2,000
Tampa Bay in front of C.R.B.	4,029	700

The total linear feet of prop scars in the aquatic preserve is 77,164 linear feet or about 1.8 acres.

The data clearly indicate that the rate of prop scar damage has dramatically declined, especially in Cockroach Bay where most of the signs are posted to warn boaters of the presence of seagrasses. This decline in prop scar damage to the seagrasses may be attributed to:

1. The Cockroach Bay Users Group (CBUG): This group has been very active in posting signs and educating boaters of the need to protect seagrasses. Apparently their educational efforts have been paying off.

2. The commercial fishing net ban that went into effect in 1994 may have reduced the number of fishing boats using the bay. We have noted in several aerial photographs in prior years, circular prop scar damage in the shallows of Cockroach Bay. This damage was most likely done by commercial net fishermen as they

encircled a school of fish. No damage of this type has been seen since the net ban went into place.

The next step in protecting seagrasses must come with the placement of markers in Tampa Bay to warn boaters that they are approaching shallow water and seagrass beds. With the placement of these markers, less damage should occur in Tampa Bay.

4. Seagrass blade studies

Above Ground: blade characteristics. Blade number, width, and length of Thalassia testudinum are compared for February, May, October and December 1995 in Table 2A and for February, April and June in Table 2B. Leaf areas are compared in Tables 3A and 3B. Significant differences in blade width and length were present but there was no real pattern within a site indicating that a prop cut does not affect blade development. What is evident is the much longer blades at all sites in June 1996 (Table 2B).

Leaf areas were significantly different ($P < 0.001$) within the Ext site in October (Table 3A), at 2C and 4 in February, and at Exterior and 2C in April (Table 3B). However there was no pattern and in June leaf areas were not significantly different within any site when samples from two prop cuts and reference areas are compared. Again, this indicates that a prop cut does not affect blade development.

Above Ground: blade growth. Blade production, expressed as percent new blade d^{-1} were surprisingly high throughout the winter (October through April) and then showed a major drop in June 1996 (Table 4A, 4B) for all three sites. The lower growth response in June is due to the large amount of old blade material that remained on the plant (growth = new/old blade tissue). What is most interesting is that the exterior site showed no greater response than the interior ones indicating that Cockroach Bay environment supports healthy seagrass communities similar to Tampa Bay.

A second method of studying blade growth is shown in Table 5 where the amount of blade produced per day per plant or per m^2 is given. This data takes into account only the amount of new blade growth and does not rely on old blade material. These data show high growth rates in June because the old blade material is not considered. What is also interesting is that the Ext plants showed higher dry wt production d^{-1} than plants at 2C and 4 in all periods except April. This suggests that there may be less stress in the Tampa Bay (Ext) site than in the Cockroach Bay sites. However Thalassia testudinum within Cockroach Bay also showed high production at site 2C and moderate growth at site 4 in June.

Below Ground. As proposed, quarterly core sampling were taken at the three sites in October and December 1995 and February, April and June 1996 (Tables 6A, 6B). The above and below ground biomass did not differ significantly between sites at any date due to the large standard deviations. This reflects the self-imposed limit of 3 samples per site to reduce damage to the beds. What is important in this data is the lack of any pattern in biomass differences between sites showing that the communities within and outside of Cockroach Bay are similar. The effect of depressed salinities in the fall of 1995 was not evident at site 4 in the spring.

Tables 6A and 6B also show the importance that short shoots and rhizomes play in the below ground biomass and that the ratio of above to below is about 1 to 3 or 1 to 4. There were no major differences in rhizome growth in the three sites in this last year of study.

A. Seagrass epiphyte load.

The epiphyte load on blades of turtle grass did not show a higher biomass in February of 1996 when compared to previous winters of 1993, 1994 and 1995 (Table 7A, 7B). Normally the epiphyte biomass increases with a drop in turbidity, rain fall, and increase in water column nutrients in the winter. We did not see this in 1996 and this might reflect the increased rainfall during the winter months but we do not know. In general, epiphyte load was low throughout the spring of 1996. Also, there was no pattern in epiphyte load between blades collected along prop cuts and within seagrass beds.

B. Macroalgal biomass.

Drift Macroalgal biomass was also much lower in February 1996 than in previous years (1993, 1994, 1995) and remained low at all three sites into June. The winter rise in Macroalgal biomass occurred earlier (December 1995) this winter and then declined. It does appear that the macroalgae replace the phytoplankton as nutrient "scrubbers" in the ecosystem. Because of the patchy nature of the drift algal biomass the percent cover was deleted from Table 8. Organic content of the macroalgae ranged from 10 to 17% and showed no seasonal pattern.

6. Restoration Experiments

This part of the study is divided into three components: stimulation of in situ rhizomes, tank and field nurseries, and transplantation into propeller cuts.

1. Stimulation of in situ rhizomes. In addition to the studies carried out at HCC, the USF group is using combinations of nutrients and plant growth regulators in the Field Nursery studies and the Transplantation studies described below.

Tank nurseries. The first problem to overcome in the laboratory experiments was to establish stable marine aquaria. In the past we had difficulty keeping environmental conditions constant, therefore, the experiments were not successful. We set up four 90 gallon salt water aquaria with a 250 watt halogen light sources. Heaters were placed in the water to stabilize the temperature and timers were placed on the lights for 14 hour days. The filtration system was a simple "bio-ball" filter with filter media superimposed in a 20 gallon aquarium. This system proved inadequate. We designed an "algae" filtration system in line with the other filter so that water trickled through the algae prior to going into the bio-ball filter. This worked very well. Next we added more light to each aquarium. The new lights were 40 watt fluorescent lights designed for marine aquaria plant growth. A water pump was added to each aquarium to create water movement in the tanks. Salinity has been kept fairly constant at 27 to 28 ppt. Temperature has been kept at 24 degrees C.

Experiment #1: The procedure involved procuring seagrasses from the bay and treating them with hormones and nutrients to attempt to stimulate growth. In paper cups we placed the following:

a. Nutrient agar.
b. Six drops of each hormone (Cytokinin, Auxin, and a gibberellin)
c. Three drops of DMSO
d. Five granules of ammonia

Plants were prepared by having their rhizomes cut so that each plant maintained its rhizome. The plants were placed in the solution and the agar was allowed to solidify around the rhizomes. After solidification, the cups were cut away from the plants and the plants were gently placed in the aquaria. The plants were left in the aquaria for 6 weeks. No new growth was noted. Speculation is that the agar solution held up the molecules from getting to the rhizomes. The plants, therefore, starved to death.

Experiment #2: In this experiment the seagrasses were soaked in solutions instead of using the agar. After soaking for two hours the plants were placed in the aquaria. In aquarium #2 the plants were left alone to grow. In aquarium #1 the plants have been injected with nutrients and hormones each week. Injections were as follows:

a. A dilute solution of Miracle Grow (15-30-15) in seawater.
b. Three granules of ammonia.
c. Three drops of hormone.

This experiment was begun in mid December. Results show that most of the plants in both aquaria sustained minimal life with little growth. No new apical meristems were noted. This experiment probably failed because of a lack of light in the system.

2. Tank and field nurseries.

2a. Tank nurseries.

Outdoor experiments: We obtained permission from the DEP marine fisheries lab located in the northern most portion of Manatee County near Cockroach Bay to set up outdoor experiments. The following were purchased:

a. Four crypts to grow plants in.
b. Water heaters
c. PVC pipes to connect the DEP. water system to our tanks.
d. Thermometers.
e. Heater regulators.

The tanks were set up with flow through water averaging salinity of 29 ppt. Thalassia testudinum was collected from Cockroach Bay and Tampa Bay at sites where the grass beds had been disturbed. The collected grasses were exposed above the surface and may not have remained alive if they were not collected. Experiments were conducted to determine if apical meristems could be stimulated in tanks with hormones. The plants were soaked in 1 % solutions of hormones in sea water with urea added as a nutrient source. Hormones used were an Auxin, a Gibberellin, and a Cytokinin. Combinations of hormones were also used. The following are the results of a two month study:

Control: 10 plants added with no survivors

Gibberellin: 15 plants started, 9 plants survived with 3 growing apical meristems

Cytokinin: 27 plants survived with 12 showing apical meristems

Auxin: 12 plants were added only 2 survived with no apical meristems

Gibberellin and Cytokinin: 10 plants with 2 apical meristems.

A later experiment was added to determine if a double shoot would more readily show a growth of an apical meristem. The following is the result of a 1 month experiment:

Gibberellin and Cytokinin: 5 double shoots with 4 growing apical meristems.

Conclusion: Cytokinin shows promise as a hormone that can stimulate apical meristem growth. In addition, when two shoots are used instead of one, the potential for apical meristem growth is accelerated.

2b. Field Nursery. A Thalassia testudinum field nursery was established in November 1995 in greater Cockroach Bay using single short shoots that were exposed to nutrients and growth regulators by placing paired agar blocks every 2 weeks next to each plant. The procedures have been described in our Six Month report with four treatments using controls (agar block only) nutrients (ammonia) and two hormones (NAA and, or kinetin). Two agar blocks were placed, one on each side of each short shoot every two weeks since 4 November. There were 12 replicates of each treatment resulting in a nursery of 48 single short shoots (Fig. 2, layout of nursery).

By the end of July (23 July 1996) 27% of the 48 short shoots remained regardless of treatment (Table 9). The 13 surviving plants were still single short shoots and equally distributed over the four treatments. There were two rhizome apices that developed from the short shoots, one from the NAA and the other from the NAA + Kinetin treatments. All of the survivors showed a development of long, fleshy roots from the short shoots, with no growth from the rhizome proper. The experiment demonstrated that the apical meristem of the short shoot is the site of new roots and rhizome meristems and that our plant growth regulator techniques are not correct.

3. Prop Cut Restorations.

Three experiments were carried out using existing propeller cuts and each will be described separately.

3a. Prop cut Restoration in Site 4 using Thalassia testudinum. This experiment began in February 1996 (Table 9). Single short shoots were used with the same treatments described for the nursery (Fig. 2 with four lines run continuously along prop cut) and the 48 plants were established along a propeller cut in Site 4.

By the end of July (23 July 1996) only 27% of the single short shoots remained regardless of treatment with about half of the survivors having only ammonium fertilization (Table 9). Again there were two rhizome meristems that had developed from the short shoots with the original rhizome being non-functional. Again the choice of plant growth regulators was not correct.

3b. Prop cut Restoration in greater Cockroach Bay using Thalassia testudinum. This experiment began in March 1996. Double short shoots were used in this experiment using the same treatments as described for the nursery (Fig. 2, with four lines run continuously along prop cut) and the 48 plants established in a propeller cut in greater Cockroach Bay. On 25 July 1996 all 48 double short shoot transplants were present and showing blade growth. The transplant studies (Nursery and Prop Cut Restorations 3a, 3b) support the earlier studies (Tomasko et al., 1989) in which we showed that survival of T. testudinum transplants increased to almost 100% if 2 or more short shoots are present. The experiment has not been disturbed so that it can be monitored through 1996-97.

3c. Prop cut restoration in greater Cockroach Bay using Halodule wrightii. This experiment began in April 1996 and used 10 plugs (15.2 cm diameter) placed in a propeller cut. No treatments were used and as of 31 July 9 of the 10 plugs have doubled their size. We will continue to monitor this experiment as well.

7. Prop scar nutrient enrichment experiments:

Experiments were conducted in prop scars to determine if Thalassia testudinum could be re-grown into prop scars with the use of nutrients. Two nutrients were used: fast-release urea in pellets and slow-release urea encapsulated with sulfur. Prop scars were selected in area 4 and in Tampa Bay in front of Little Cockroach Bay. Nutrients were added by hand every 7 to 10 days for a three month period (May through July). Each meter of a prop scar was marked with PVC pipe. One meter was enriched with urea, the next with sulphur coated urea, the third with both forms, and the fourth was a control. Each experiment was repeated four times at four locations. Once a month new shoots found in the scars were counted. The final summary counts are as follows:

Control: 13 new shoots, averaging 2.6 new shoots per meter.

Fast release Urea: 51 new shoots, averaging 10.2 new shoots per meter.

Sulphur coated slow release urea: 43 new shoots, averaging 8.6 new shoots per meter.

Combination: 40 new shoots, averaging 8.0 new shoots per meter.

Conclusion: nutrient enrichment of prop scars does stimulate new growth of shoots of Turtle grass into prop scars. Turtle grass has a growth period that begins sometime in the spring months. These experiments were begun several weeks after the initial growth spurt of the grasses. It is entirely possible that the results would be greater if enrichment was timed to coincide with the initial growth spurt. In addition, very little new growth of shoots was noted the further into the summer months the experiments were conducted. Therefore, further experiments of this type should be conducted earlier, perhaps in the months of April to June.

1696

Summary

Growth of Thalassia testudinum in Cockroach Bay during the spring of 1995 followed the same pattern as reported in the 1993 and 1994 Annual Reports in the interior RA (4) and exterior RA (2C). What is interesting is that the plants of the exterior site in Tampa Bay showed the same results. This demonstrates that the Cockroach Bay seagrass communities are as productive as are Tampa Bay populations. Further, the depressed salinities (11 ppt being common) again occurred as in 1994 yet there were no measurable effects when the turtle grass communities were compared (Ext vs 2C and 4). Establishment of the external site now has demonstrated that the Cockroach Bay plants do as well as those in the exterior site.

Throughout our studies we have determined that there are no differences in turtle grass plants growing along a propeller cut with those in an undisturbed seagrass bed. In the 1993-1994 reports we found sediment, nutrients and other abiotic factors were not critically different and in 1995 and now 1996 we reported that seagrass growth, biomass, standing stock, and blade features do not differ between plants of prop cuts and reference beds.

Our attempts at creating a field nursery were not effective. We used single short shoots of Thalassia testudinum because we knew the survival of a single ramet is low (ca 20%; Tomasko et al., 1989) and thus we could experiment with use of nutrients and plant growth regulators. Using 2 or more ramets per rhizome results in discarding at least three of every four plants dug up from a donor bed. This means severe destruction of donor beds to achieve high rates of survival (as in Restoration experiment 3b).

If restoration, mitigation, or creation of turtle grass beds are to succeed, techniques inducing growth of the short shoot (not the severed rhizome) must be developed. These techniques must include plant growth regulators. This is an area that is very critical and should be studied in the next few years. The experiments (Nursery, Prop restoration 3a, 3b) indicate that the short shoot is the site of root and rhizome meristem initiation. Thus, this portion of the plant should be exposed to combinations of growth regulators. This is an area of study that should prove valuable in the development of nursery techniques to produce transplants for mitigation of Thalassia testudinum beds.

Tank and field experiments using urea and hormones have shown two positive results:

1. Some Thalassia can be re-grown into prop scars using urea (ammonia).

2. Cytokinins and Gibberellins used in combination with double shoots of Turtle grass can initiate apical meristem growth in a one month period.

These results are encouraging for future experimentation of seagrass growth. The next step should be to inject urea and hormones into large sections of prop scars in the field to see if new growth can be further enhanced.

Prop scar damage to the seagrass beds has been reduced. Very little new scarring has been observed during the time period of this study in all of the Cockroach Bay aquatic preserve. Approximately 3.4 new acres of Halodule wrightii have grown into area #1, while some seagrasses have been lost in areas 3 and 4 due to cold temperatures, lowered salinities and shifting currents. Seagrasses are being lost to boats in the shallows of Tampa Bay as boats motor from deep waters into shallow waters. They simply run aground in the seagrass beds because the shallow waters are not marked with warning signs or buoys.

Recommendations

As a result of this study we are making the following recommendations:

1. That all of the present markers be kept in place with the same restrictions.

2. That the Cockroach Bay Users Group (CBUG) continue their active role in educating the boaters of Cockroach Bay on safe boating practices and methods to protect the seagrasses.

3. That numerous markers be placed in front of the seagrass beds in Tampa Bay to warn boaters of the shallow conditions and the presence of seagrasses.

4. That aerial photography be continued for three more years to monitor the status of the grass beds. Future monitoring of the seagrasses will only need to be done once a year.

5. That more research be conducted on seagrass re-growth in prop scars and hormone stimulation of rhizomes. Some progress was noted during this study. Perhaps it is time to stimulate re-growth on a grander scale.

Acknowledgments. The U.S.F. study was carried out with the help of a number of undergraduate (Manuel Merello, Dorothy Stevens, Katherine Sair) and graduate (John Andorfer, Brian Teasdale) students. Mr. Andorfer was the Research Assistant on this project and his help has been invaluable. The HCC studies were assisted by Catherine Scott who conducted the seagrass counts in the tanks. Lyle Kelley converted the picture images to computer images. James Wysong was the pilot and photographer for the detailed images.

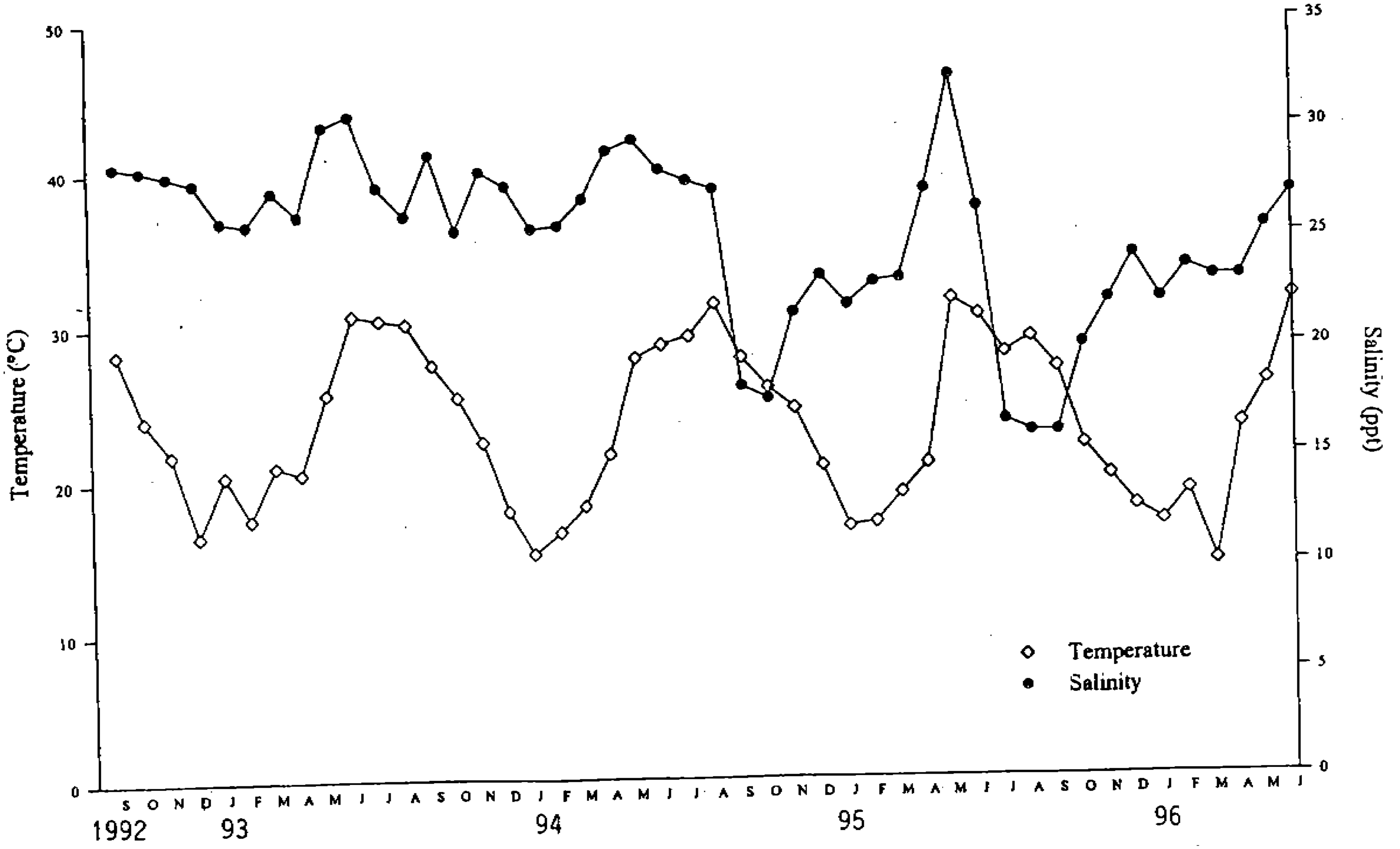


Figure 1. Temperature and Salinity graph of Cockroach Bay begining in September 1992 and ending in June 1996.

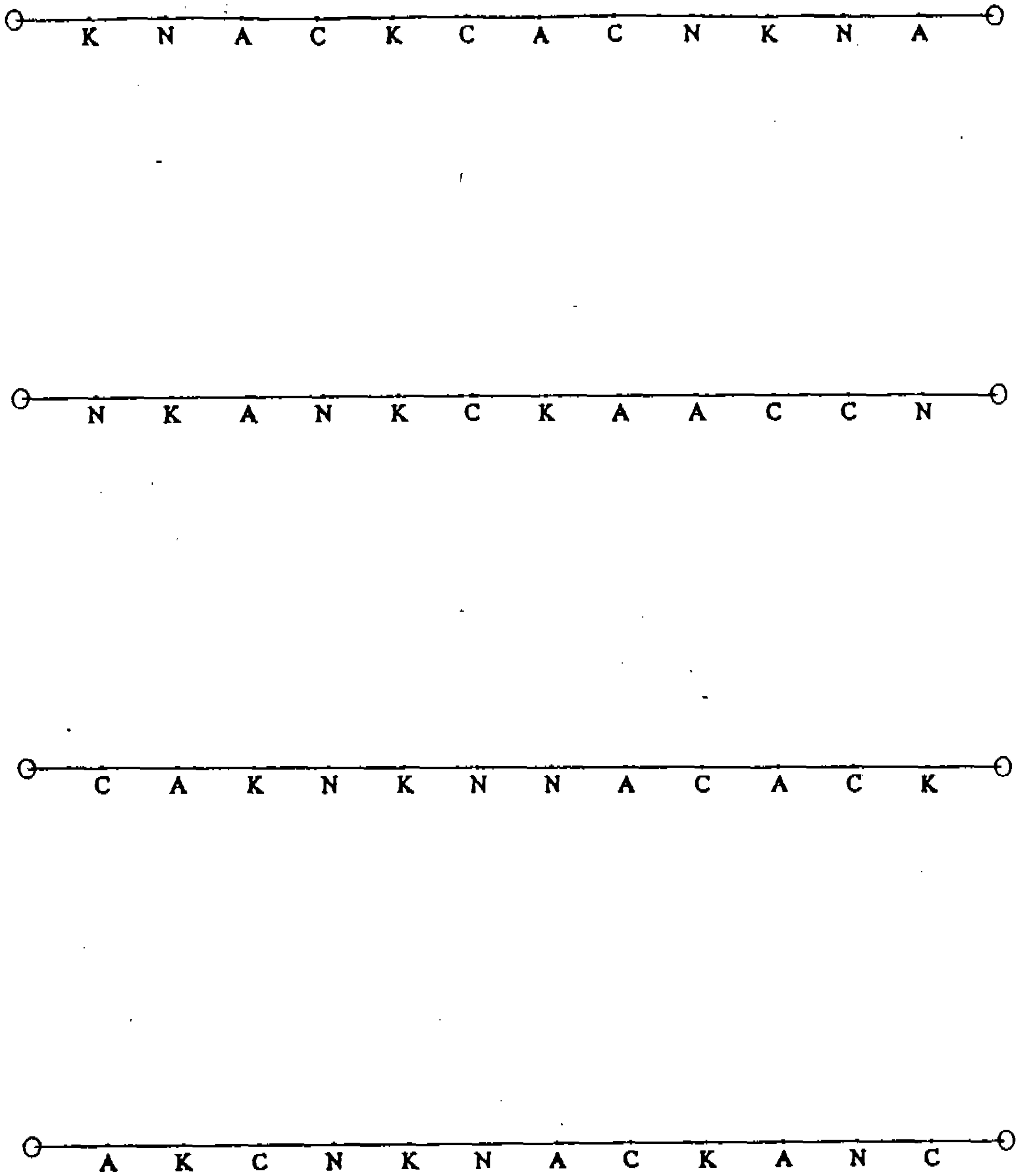


Figure 2. Experimental design of the *Thalassia testudinum* nursery in Greater Cockroach Bay, Tampa Bay, Florida

KEY

C = CONTROL

A = $NH4^+$

N = $NH4^+$ & NAA

K = $NH4^+$, NAA, & KINETIN

BAR = 20 cm ——

Table 1. Ramet densities in $1m^2$ of a *Thalassia testudinum* bed from 3 sites in Cockroach Bay, estimated from 15 haphazard chosen 25cm quadrats. Values are means ± S.D.'s.

Date	Ramet Density		
	Exterior site	Site 2c	Site 4
Oct. 95	139.73 ± 61.22	114.13 ± 40.96	152.53 ± 39.59
Dec. 95	176.00 ±50.98	80.00 ±33.12	231.47 ±57.65
Feb. 96	141.87 ± 61.63^a	108.80 ± 44.93^a	190.93 ± 56.88^b
Apr. 96	166.40 ± 65.64^a	109.87 ± 37.70^b	115.20 ± 51.38^b
Jun. 96	150.40 ± 70.21^a	113.07 ± 23.78^b	278.40 ± 45.58^c

Table 2A. Blade characteristics of *Thalassia testudinum* sampled from within and along the edges of boat propeller cuts (Prop cut), and within adjacent *T. testudinum* grassbeds (Seagrass) from 3 sites in Cockroach Bay, 1995. Values are means (± S.D.); sample sizes vary between 14 and 15. Superscripts denote significant differences between sampling areas, within each site ($P < 0.05$; Student's t-test and Mann Whitney Rank Sum Test).

	February			May			October			December		
	No.	Width (cm)	Length (cm)	No.	Width (cm)	Length (cm)	No.	Width (cm)	Length (cm)	No.	Width (cm)	Length (cm)
Exterior	-	-	-	-	-	-						
Seagrass							3.80[A] (0.56)	0.77[A] (0.09)	16.08 (2.51)	3.07 (0.80)	0.62 (0.06)	10.30 (2.34)
Prop cut 1							3.93[A] (0.70)	0.78[A] (0.09)	16.39 (3.89)	3.50 (0.76)	0.78 (0.10)	9.24 (2.02)
Prop cut 2							4.80[B] (1.37)	0.89[B] (0.08)	15.48 (3.29)	3.33 (0.72)	0.76 (0.10)	9.74 (2.07)
Site 2c												
Seagrass	2.27 (0.47)	0.62 (0.11)	11.70 (2.45)	3.83 (0.72)	0.70 (0.07)	15.72 (3.41)	3.67 (0.72)	0.67 (0.08)	14.95 (4.68)	3.13 (0.64)	0.63 (0.07)	10.43 (1.94)
Prop cut 1	2.69 (0.85)	0.66 (0.09)	10.52 (2.33)	4.67 (1.11)	0.71 (0.10)	15.12 (4.15)	3.14 (0.86)	0.59 (0.09)	14.45 (2.85)	3.00 (0.58)	0.56 (0.07)	7.17 (1.21)
Prop cut 2	-	-	-	-	-	-	3.73 (0.70)	0.63 (0.11)	13.74 (3.47)	2.71 (0.61)	0.59 (0.08)	8.87 (1.92)
Site 4												
Seagrass	2.67 (0.71)	0.63 (0.10)	7.81 (1.93)	4.50 (0.92)	0.68 (0.10)	15.08 (2.99)	3.4 (0.83)	0.56 (0.09)	8.22 (1.19)	2.93 (0.59)	0.49 (0.08)	7.32 (1.22)
Prop cut 1	2.93 (0.47)	0.61 (0.14)	7.63 (1.13)	4.73 (0.88)	0.68 (0.09)	15.33 (3.58)	3.79 (1.12)	0.56 (0.08)	6.96 (1.52)	2.80 (0.68)	0.52 (0.08)	6.27 (1.30)
Prop cut 2	-	-	-	-	-	-	3.20 (0.94)	0.59 (0.09)	7.67 (2.18)	3.00 (0.53)	0.51 (0.07)	5.20 (1.08)

Table 2B. Blade characteristics of *Thalassia testudinum* sampled from within and along the edges of boat propeller cuts (Prop cut), and within adjacent *T. testudinum* grassbeds (Seagrass) from 3 sites in Cockroach Bay, 1996. Values are means (± S.D.); sample sizes vary between 14 and 15. Superscripts denote significant differences between sampling areas, within each site ($P < 0.05$; Student's t-test and Mann Whitney Rank Sum Test).

	February			April			June		
	No.	Width (cm)	Length (cm)	No.	Width (cm)	Length (cm)	No.	Width (cm)	Length (cm)
Exterior									
Seagrass	3.00 (0.47)	0.77 (0.08)	2.34 (0.55)	3.00^{a} (0.67)	0.66^{ab} (0.07)	7.95^{a} (1.51)	4.33 (0.52)	0.81^{a} (0.07)	19.74 (3.16)
Prop cut 1	2.70 (0.48)	0.72 (0.06)	1.85 (0.47)	2.90^{a} (0.57)	0.61^{a} (0.05)	10.38^{b} (2.22)	3.57 (0.79)	0.72^{b} (0.06)	18.51 (3.48)
Prop cut 2	3.3 (0.67)	0.77 (0.08)	1.80 (0.60)	5.00^{b} (0.76)	0.70^{a} (0.05)	8.50^{ab} (2.11)	4.00 (1.00)	0.85^{a} (0.06)	17.69 (3.03)
Site 2c									
Seagrass	2.40 (0.52)	0.61 (0.05)	2.28^{a} (0.75)	2.90 (0.63)	0.52 (0.05)	8.53 (2.1)	4.87 (1.13)	0.77 (0.09)	20.48^{a} (3.05)
Prop cut 1	2.60 (0.52)	0.59 (0.10)	2.36^{a} (0.78)	3.80 (0.63)	0.59 (0.07)	9.11 (1.65)	5.43 (0.98)	0.68 (0.05)	16.58^{b} (3.00)
Prop cut 2	2.78 (0.97)	0.59 (0.07)	5.71^{b} (2.68)	3.70 (0.95)	0.55 (0.05)	10.30 (1.99)	5.50 (1.05)	0.68 (0.09)	15.36^{b} (2.73)
Site 4									
Seagrass	1.80 (0.42)	0.54 (0.07)	0.79^{a} (0.21)	2.78 (0.67)	0.63^{a} (0.03)	8.36^{ab} (1.33)	4.50 (0.84)	0.56 (0.08)	15.49 (2.31)
Prop cut 1	2.22 (0.44)	0.53 (0.04)	1.63^{b} (0.54)	3.20 (0.84)	0.57^{ab} (0.06)	9.70^{a} (2.46)	4.86 (0.69)	0.64 (0.04)	17.48 (2.35)
Prop cut 2	2.00 (0.71)	0.51 (0.07)	1.31^{b} (0.21)	3.60 (0.55)	0.55^{b} (0.06)	5.95^{b} (0.84)	4.20 (0.45)	0.56 (0.07)	16.04 (2.99)

Table 3A. Leaf areas of individual *Thalassia testudinum* ramets sampled from within and along the edges of boat propeller cuts (Prop cut), and within adjacent *T. testudinum* grassbeds (Seagrass) from 3 sites in Cockroach Bay, 1995. Values are means ± S.D.; sample sizes vary between 14 and 15. Superscripts denote significant differences between sampling areas, within each site ($P < 0.05$; Student's t-test and Mann Whitney Rank Sum Test).

	February	May	October	December
Exterior	-	-		
Seagrass			47.51 ± 11.65^{A}	18.90 ± 4.33
Prop cut 1			49.71 ± 15.74^{A}	25.00 ± 7.87
Prop cut 2			64.39 ± 20.18^{B}	24.75 ± 8.69
Site 2c				
Seagrass	16.49 ± 6.85	41.61 ± 15.90	30.32 ± 12.84	20.23 ± 4.63
Prop cut 1	18.37 ± 7.24	50.58 ± 20.94	27.36 ± 10.54	12.39 ± 4.20
Prop cut 2	-	-	32.36 ± 12.24	14.73 ± 6.13
Site 4				
Seagrass	12.77 ± 5.40	48.58 ± 20.26	15.52 ± 4.61	10.39 ± 2.91
Prop cut 1	13.95 ± 5.22	50.46 ± 22.26	14.74 ± 5.42	9.27 ± 3.51
Prop cut 2	-	-	14.34 ± 5.90	7.93 ± 2.73

Table 3B. Leaf areas of individual *Thalassia testudinum* ramets sampled from within and along the edges of boat propeller cuts (Prop cut), and within adjacent *T. testudinum* grassbeds (Seagrass) from 3 sites in Cockroach Bay, 1996. Values are means ± S.D.; sample sizes vary between 14 and 15. Superscripts denote significant differences between sampling areas, within each site ($P < 0.05$; Student's t-test and Mann Whitney Rank Sum Test)

	February	April	June
Exterior			
Seagrass	5.27 ± 1.71	16.61 ± 4.69^{a}	69.74 ± 15.93
Prop cut 1	3.57 ± 1.18	18.12 ± 2.81^{a}	47.63 ± 13.40
Prop cut 2	4.33 ± 1.48	29.87 ± 6.84^{b}	61.37 ± 22.99
Site 2c			
Seagrass	3.34 ± 1.52^{a}	12.96 ± 3.80^{a}	74.92 ± 17.51
Prop cut 1	3.41 ± 0.95^{a}	21.18 ± 7.54^{b}	57.51± 6.60
Prop cut 2	8.65 ± 3.31^{b}	21.51 ± 3.66^{b}	58.33 ± 19.23
Site 4			
Seagrass	0.83 ± 0.40^{a}	15.25 ± 4.02	40.02 ± 15.05
Prop cut 1	2.04 ±0.86^{b}	17.26 ± 3.71	55.11 ± 15.53
Prop cut 2	1.26 ± 0.85^{a}	12.03 ± 2.24	37.74 ± 10.62

Table 4A. Blade production (% d^{-1}) of *Thalassia testudinum* sampled from within and along the edges of boat propeller cuts (Prop cut), and within adjacent *T. testudinum* grassbeds (Seagrass) from 3 sites in Cockroach Bay, 1995. Values are means ± S.D.; sample sizes vary between 14 and 15. Superscripts denote significant differences between study areas within each site ($P < 0.05$; Student's t-test and the Mann Whitney Rank Sum Test).

	February	May	October	December
Exterioir	-	-		
Seagrass			3.18 ± 1.53	4.65 ± 2.51
Prop cut 1			2.72 ± 1.08	4.57 ± 2.68
Prop cut 2			3.12 ± 1.31	4.26 ± 1.44
Site 2c				
Seagrass	2.12 ± 1.60	4.44 ± 2.19	5.55 ± 1.59^{a}	4.94 ± 1.49
Prop cut 1	1.58 ± 0.85	3.98 ± 2.20	7.95 ± 2.70^{b}	6.01 ± 2.36
Prop cut 2	-	-	8.32 ± 3.89^{b}	5.89 ± 2.38
Site 4				
Seagrass	2.41 ± 1.18	3.87 ± 1.33	7.84 ± 3.52	5.11 ± 0.99
Prop cut 1	1.90 ± 0.76	3.54 ± 1.26	7.46 ± 3.60	4.36 ± 1.68
Prop cut 2	-	-	7.79 ± 3.25	6.73 ± 2.73

Table 4B.. Blade production (% d^{-1}) of ***Thalassia testudinum*** sampled from within and along the edges of boat propeller cuts (Prop cut), and within adjacent *T. testudinum* grassbeds (Seagrass) from 3 sites in Cockroach Bay, 1996. Values are means ± S.D.; sample sizes vary between 6 and 10. Superscripts denote significant differences between study areas within each site ($P < 0.05$; Student's t-test and the Mann Whitney Rank Sum Test).

	Febuary	April	June
Exterioir			
Seagrass	4.51 ± 1.44[a]	7.36 ± 2.42	1.39 ± 0.29
Prop cut 1	2.54 ± 0.79[b]	5.95 ± 2.41	1.69 ± 0.48
Prop cut 2	2.83 ± 1.53[b]	4.81 ± 1.33	1.62 ± 0.57
Site 2c			
Seagrass	5.29 ± 1.47[a]	5.95 ± 2.41	1.27 ± 0.65
Prop cut 1	4.99 ± 1..75[a]	5.55 ± 1.56	1.36 ± 0.28
Prop cut 2	3.32 ± 1.35[b]	6.35 ± 1.72	1.17 ± 0.24
Site 4			
Seagrass	5.63 ± 3.97	5.29 ± 1.57	1.12 ± 0.23
Prop cut 1	6.65 ± 1.19	5.19 ± 1.71	1.07 ± 0.18
Prop cut 2	5.60 ± 2.35	6.13 ± 1.48	0.91 ± 0.56

Table 5 . The amount of plant material produced per day (gdwt) for individual plants and for $1m^2$ of a *Thalassia testudinum* bed from 3 sites in Cockroach Bay. Values are means ± S.D.'s; (n=15).

Date	Site	g/day/plant	g/day/$1m^2$
Oct. 95	Ext	0.006 ± 0.003^{a}	0.787 ± 0.493^{a}
	2c	0.003 ± 0.001^{b}	0.378 ± 0.108^{b}
	4	0.002 ± 0.001^{c}	0.312 ± 0.171^{c}
Dec. 95	Ext	0.006 ± 0.016^{a}	1.112 ± 2.810^{a}
	2c	0.002 ± 0.001^{a}	0.188 ± 0.084^{b}
	4	0.001 ± 0.000^{b}	0.339 ± 0.101a
Feb. 96	Ext	0.0011 ± 0.0005^{a}	0.156 ± 0.071^{a}
	2c	0.0007 ± 0.0003^{a}	0.076 ± 0.033^{b}
	4	0.0002 ± 0.0003^{b}	0.038 ± 0.057^{b}
Apr. 96	Ext	0.0032 ± 0.0016	0.532 ± 0.269
	2c	0.0030 ± 0.0012	0.507 ± 0.195
	4	0.0019 ± 0.0007	0.324 ± 0.117
Jun. 96	Ext	0.0084 ± 0.0015^{a}	1.268 ± 0.227
	2c	0.0085 ± 0.0055^{a}	0.957 ± 0.618
	4	0.0033 ± 0.0017^{b}	0.923 ± 0.467

Table 6A. Dry weight biomass allocation (g) and above and below ground biomasses in $1m^2$ of a *Thalassia testudinum* bed from 3 sites in Cockroach Bay. Values are means ± S.D.'s; (n=3). The percent of the total biomass for each plant part is given in the ().

		Dry Weight Biomass Allocations (g)				Biomass (g)	
Date	Site	Blades	Short Shoots	Rhizomes	Roots	Above-ground	Below-ground
Oct. 95	Ext	103.27±27.18 (34.58)	105.95±38.32 (34.75)	66.24±4.77 (22.40)	24.89±5.32 (8.27)	103.27±27.18	197.08±46.93
	2c	75.88±24.39 (18.43)	128.50±17.81 (32.57)	171.79±75.23 (41.03)	33.01±15.17 (7.97)	75.88±24.39	333.31±97.28
	4	70.54±36.69 (16.72)	171.61±97.36 (39.61)	116.43±84.37 (24.13)	100.70±97.65 (19.55)	70.54±36.69	388.73±275.6
Dec. 95	Ext	81.39±14.31 (37.88)	51.51±6.49 (20.90)	66.88±25.11 (30.85)	15.79±6.43 (7.40)	81.39±14.31	130.05±31.27
	2c	73.81±35.48 (31.92)	53.14±43.76 (23.86)	88.80±25.74 (40.37)	14.82±3.59 (6.80)	73.81±35.48	156.77±67.59
	4	83.29±15.34 (24.23)	100.59±32.02 (28.85)	107.82±46.00 (30.82)	51.64±37.95 (16.10)	83.29±15.34	134.19±23.60
Feb. 96	Ext	32.33±19.06 (21.97)	38.43±36.04 (26.11)	54.98±20.83 (37.36)	21.41±8.04 (14.55)	32.33±19.06	114.82±53.25
	2c	38.80±10.10 (20.37)	47.38±25.93 (52.49)	87.22±28.96 (45.78)	17.10±7.37 (8.98)	38.80±10.10	151.70±30.77
	4	47.81±8.37 (15.13)	84.33±15.97 (26.69)	147.04±16.21 (46.53)	36.81±5.00 (11.65)	47.81±8.37	268.18±30.36

Table 6B . Dry weight biomass allocation (g) and above and below ground biomasses in 1m² of a *Thalassia testudinum* bed from 3 sites in Cockroach Bay. Values are means ± S.D.'s; (n=3). The percent of the total biomass for each plant part is given in the ().

		Dry Weight Biomass Allocations (g)				Biomass (g)	
Date	Site	Blades	Short Shoots	Rhizomes	Roots	Above-ground	Below-ground
Apr. 96	Ext	65.55±48.55 (13.91)	218.50±139.59 (46.37)	134.71±83.91 (28.59)	52.43±43.97 (11.13)	65.55±48.55	405.64±263.6
	2c	42.03±16.66 (18.14)	74.71±40.00 (32.25)	98.52±43.50 (42.52)	16.42±8.08 (7.09)	42.03±16.66	189.65± 84.19
	4	58.58±12.40 (14.61)	124.63±38.73 (31.07)	129.63±34.55 (32.32)	88.81±2.13 (22.14)	58.58±12.40	342.49 ±70.29
Jun. 96	Ext	79.54± 60.07 (28.95)	64.11± 50.00 (23.34)	87.99± 70.51 (32.03)	42.43± 17.32 (15.45)	79.54± 60.07	194.53±134.7
	2c	82.66±34.31 (24.42)	90.75±25.60 (26.80)	83.21±14.61 (24.58)	81.93±49.33 (24.20)	82.66±34.31	255.89±79.14
	4	185.72±73.55 (41.15)	110.23±78.31 (24.42)	82.11±9.92 (18.19)	73.29±65.24 (16.24)	185.72±73.55	265.62±148.7

Table 7A. Epiphyte load on short shoots of *Thalassia testudinum* sampled from within and along the edges of boat propeller cuts (Prop cut), and within adjacent *T. testudinum* grassbeds (Seagrass) from 3 sites in Cockroach Bay, 1995. Values are means ± S.D.; sample sizes vary between 14 and 15. Superscripts denote significant differences between study areas within each site ($P < 0.05$; Student's t-test and the Mann Whitney Rank Sum Test).

	February	May	October	December
Exterior	-	-		
Seagrass			0.07 ± 0.03^{a}	0.07 ± 0.06
Prop cut 1			0.06 ± 0.02^{a}	0.04 ± 0.03
Prop cut 2			0.16 ± 0.10^{b}	0.01 ± 0.01
Site 2c				
Seagrass	0.67 ± 0.54	0.10 ± 0.06	0.06 ± 0.03	0.02 ± 0.02
Prop cut 1	0.30 ± 0.18	0.14 ± 0.09	0.02 ± 0.02	0.04 ± 0.03
Prop cut 2	-	-	0.06 ± 0.04	0.03 ± 0.03
Site 4				
Seagrass	0.09 ± 0.26	0.06 ± 0.04	0.04 ± 0.03^{a}	0.03 ± 0.03
Prop cut 1	0.08 ± 0.06	0.11 ± 0.06	0.04 ± 0.02^{a}	0.01 ± 0.01
Prop cut 2	-	-	0.10 ± 0.04^{b}	0.04 ± 0.03

Table 7B. Epiphyte load on short shoots of *Thalassia testudinum* sampled from within and along the edges of boat propeller cuts (Prop cut), and within adjacent *T. testudinum* grassbeds (Seagrass) from 3 sites in Cockroach Bay, 1996. Values are means ± S.D.; sample sizes vary between 6 and 10. Superscripts denote significant differences between study areas within each site ($P < 0.05$; Student's t-test and the Mann Whitney Rank Sum Test).

	February	April	June
Exterior			
Seagrass	0.005 ± 0.002	0.005 ± 0.008[a]	0.05 ± 0.03
Prop cut 1	0.006 ± 0.007	0.001 ± 0.002[a]	0.06 ± 0.05
Prop cut 2	0.008 ± 0.012	0.012 ± 0.016[b]	0.07 ± 0.06
Site 2c			
Seagrass	0.006 ± 0.006[a]	0.001 ± 0.002[a]	0.07 ± 0.04
Prop cut 1	0.009 ± 0.009[a]	0.057 ± 0.036[b]	0.08 ± 0.06
Prop cut 2	0.023 ± 0.011[b]	0.066 ± 0.029[b]	0.11 ± 0.06
Site 4			
Seagrass	none	0.104 ± 0.060	0.06 ± 0.03
Prop cut 1	0.006 ± 0.002	0.131 ± 0.077	0.25 ± 0.09
Prop cut 2	0.001 ± 0.001	0.056 ± 0.078	0.13 ± 0.10

Table 8. Biomass of macroalgae (gdwt m^{-2}) and species diversity at 3 sites in Cockroach Bay. Values are means ± S.D., n = 15.

Date	Site	Biomass (gdwt m^{2})	Species Present
Feb. 95	2c	39.02 ± 32.29	8,10,11,17,19
	4	29.74 ± 38.40	8,11,17,19,21
May 95		NO MACRO ALGAE BIOMASS FOUND	
Oct. 95	Ext	13.16 ± 12.64[a]	1,10,18,19
	2c	2.99 ± 3.66[b]	1,10,19
	4	0	
Dec. 95	Ext	46.96 ± 27.38	1,5,6,7,11,20
	2c	13.48 ± 11.99	1,5,6,7,11,20
	4	1.75 ± 3.34	1,5,6,7,11,20
Feb. 96	Ext	0.36 ± 0.39	5,6,12,16,20
	2c	0.44 ± 0.46	5,6,12,16,20
	4	0	NA
Apr. 96	Ext	0.82 ± 0.84[a]	1,6,7,17
	2c	0.63 ± 0.53[a]	1,6,7,17
	4	1.89 ± 1.61[b]	1,6,7,17
Jun. 96	Ext	3.58 ± 1.71[a]	1,5,6,7,10,11
	2c	1.05 ± 1.24[b]	1,5,6,7,10,11
	4	2.05 ± 1.93[b]	1,5,6,7,10,11

Legend to Table 8

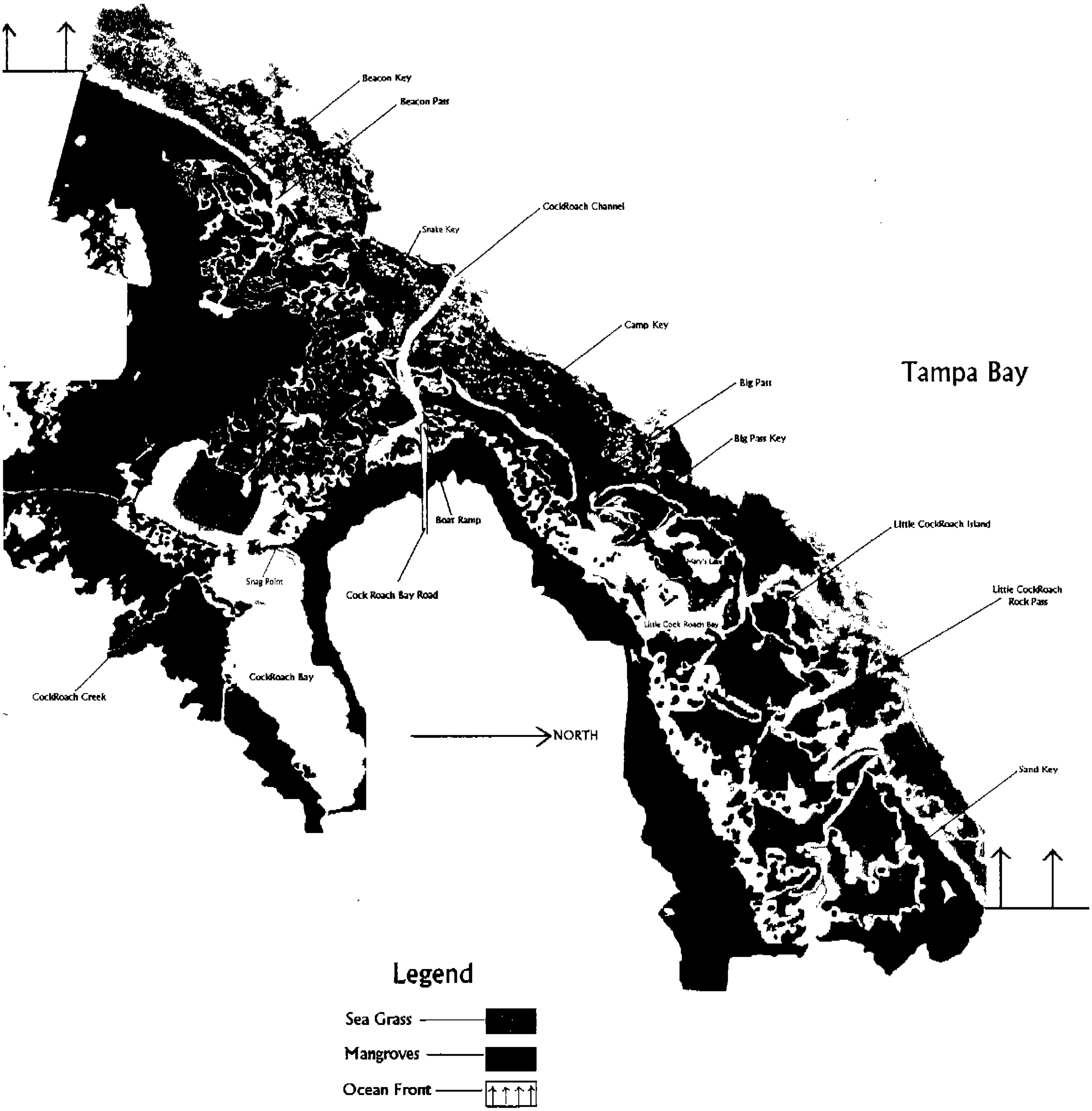
1. *Acanthophora spicifera*
2. *Centroceras clavulatum*
3. *Chondria cnicophylla*
4. *Gracilaria sjoestedtii*
5. *G. tikvahiae*
6. *G. verrucosa*
7. *Hypnea musciformis*
8. *Laurencia poitei*
9. *Lyngbya majescula*
10. *Spyridia filamentosa*
11. *Ulva lactuca*
12. *Solaria filiformis*
13. *Lomentaria baileyiena*
14. *Chondria sedifolia*
15. *Caulerpa sertularioides*
16. *C. prolifera*
17. *Enteromorpha intestinalis*
18. *Agardhiella tenera*
19. *Gracilaria foliifera var angustissima*
20. *Champia parvula*
21. *Chondria tenuissima*

Table 9. Biomass and productivity of *Thalassia testudinum* transplants harvested July, 1996. Single short shoots were transplanted into the nursery site in Oct. 1995, the prop scar site was established in Feb. 1996. 48 plants were placed in each site and assigned to 1 of 4 treatments. C = control, A = Ammonium, N = Napthalene acetic acid, K = Kinetin.

Type	Treatment	Blades	Short Shoots	Rhizomes	Roots	Survival	g/plant/day	# Apicals
Prop scar	C	0.29 ± 0.07	0.35 ± 0.08	0.06 ± 0.08	0.05 ± 0.03	3/12	0.007 ± 0.003	0
	A	0.28 ± 0.15	0.28 ± 0.17	0.08 ± 0.08	0.07 ± 0.04	4/12	0.005 ± 0.003	0
	N	0.27 ± 0.20	0.25 ± 0.17	0.21± 0.09	0.06 ± 0.05	4/12	0.006 ± 0.005	1
	K	0.34 ± 0.23	0.14 ± 0.016	0.14 ± 0.06	0.10 ± 0.13	3/12	0.006 ± 0.001	1
Nursery	C	0.43 ± 0.09	0.28 ± 0.03	0.17 ± 0.06	0.06 ± 0.02	3/12	0.004 ± 0.002	0
	A	0.35 ± 0.09	0.34 ± 0.19	0.15 ± 0.14	0.09 ± 0.02	6/12	0.006 ± 0.001	1
	N	0.43	0.31	0.22	0.05	1/12	0.005	0
	K	0.21 ± 0.05	0.23 ± 0.12	0.12 ± 0.04	0.04 ± 0.01	3/12	0.004 ± 0.001	1

Computer Drawings

The computer drawings on the following pages are representative sites where prop scar damage was most extensive. To locate a particular site, use the first drawing. Find the grid coordinates across the top and along the vertical scale. Use the coordinates to show the location of the drawing.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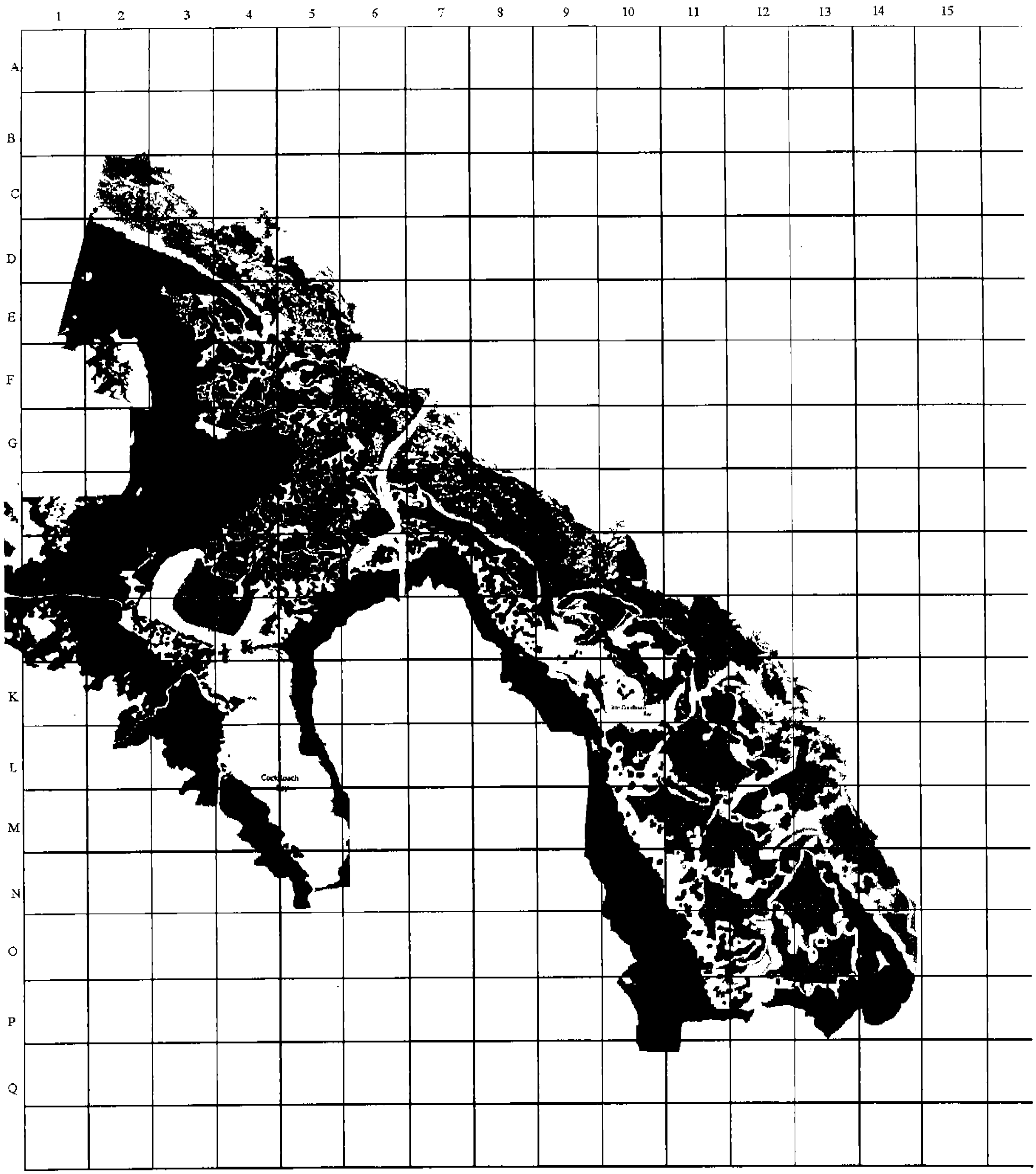
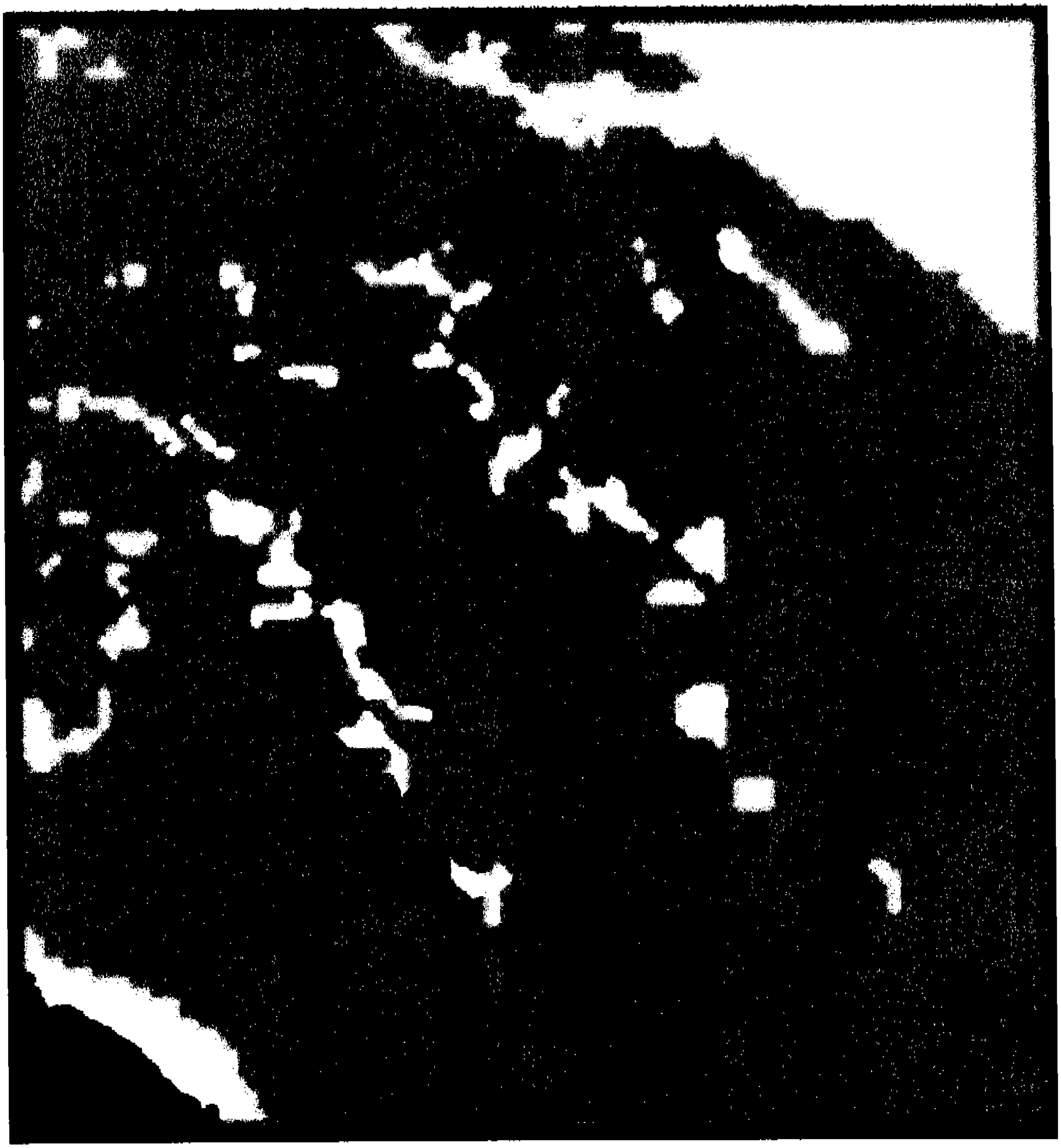
Beacon Pass
CockRoach Channel
Snake Key
Camp Key
Tampa Bay
Big Pass
Big Pass Key
Boat Ramp
Little CockRoach Island
Snag Point
Cock Roach Bay Road
Little Cock Roach Bay
Little CockRoach
Rock Pass
CockRoach Bay
CockRoach Creek
NORTH
Sand Key
Legend
Sea Grass
Mangroves
Ocean Front



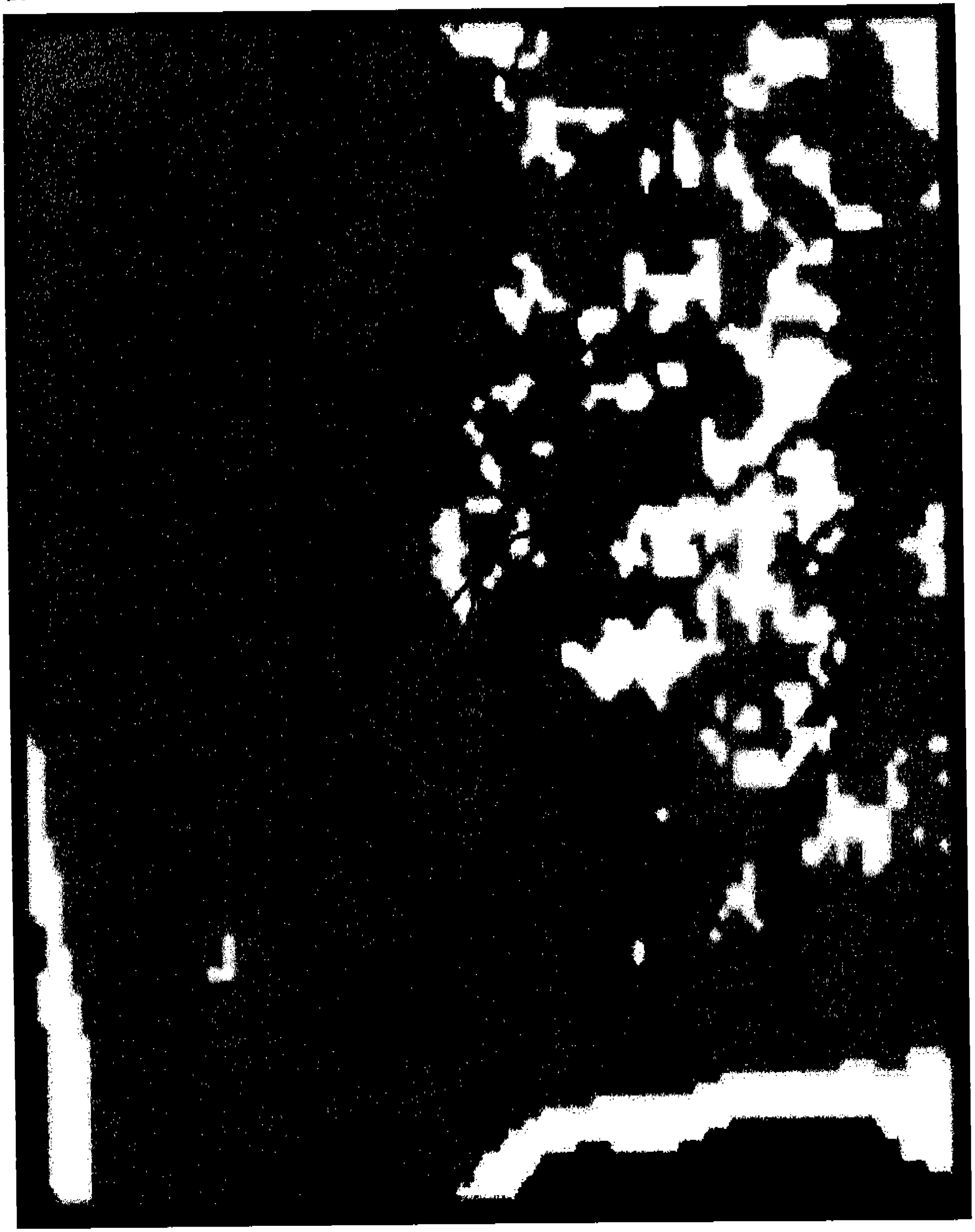
P691

H7

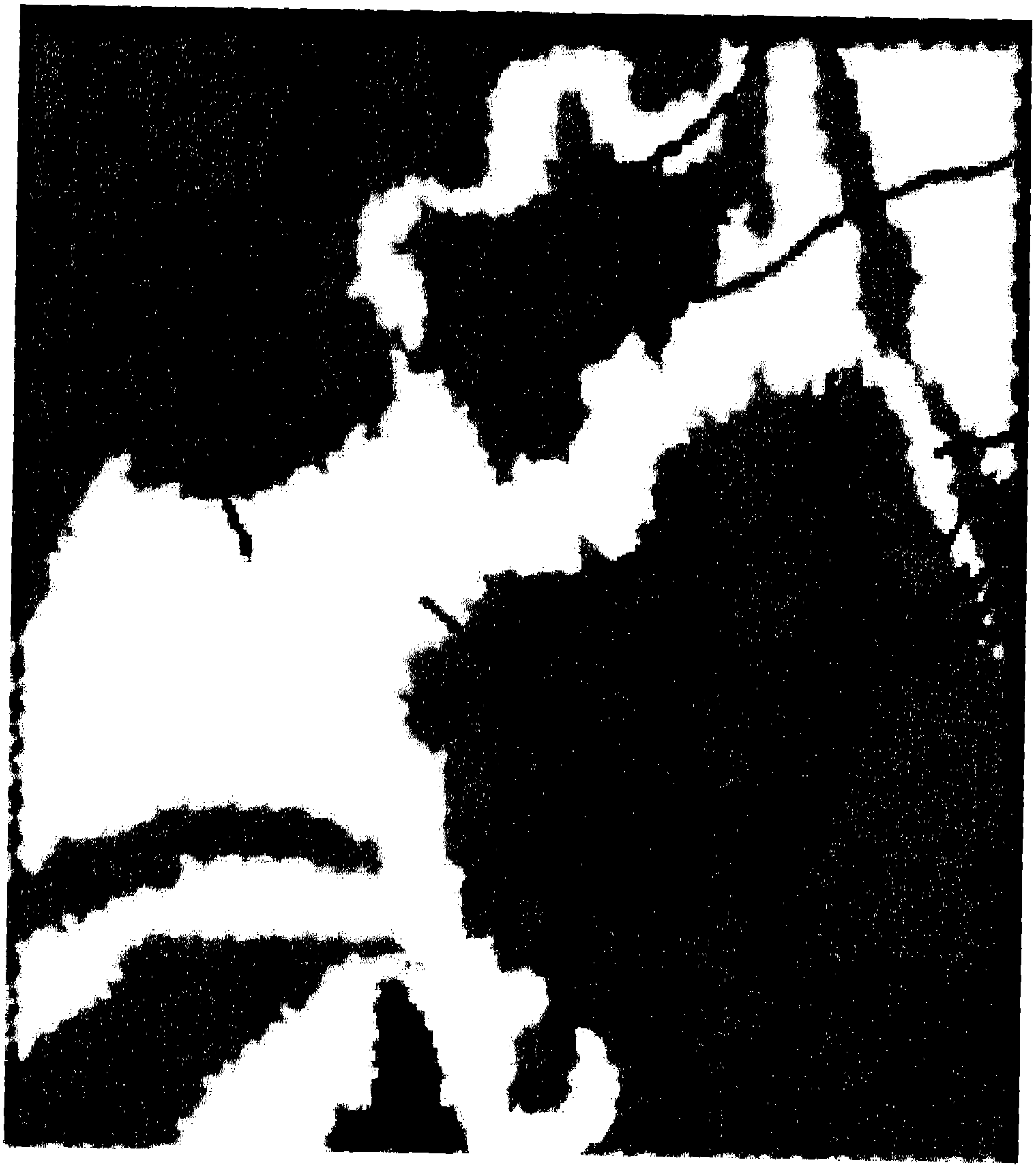
H 8



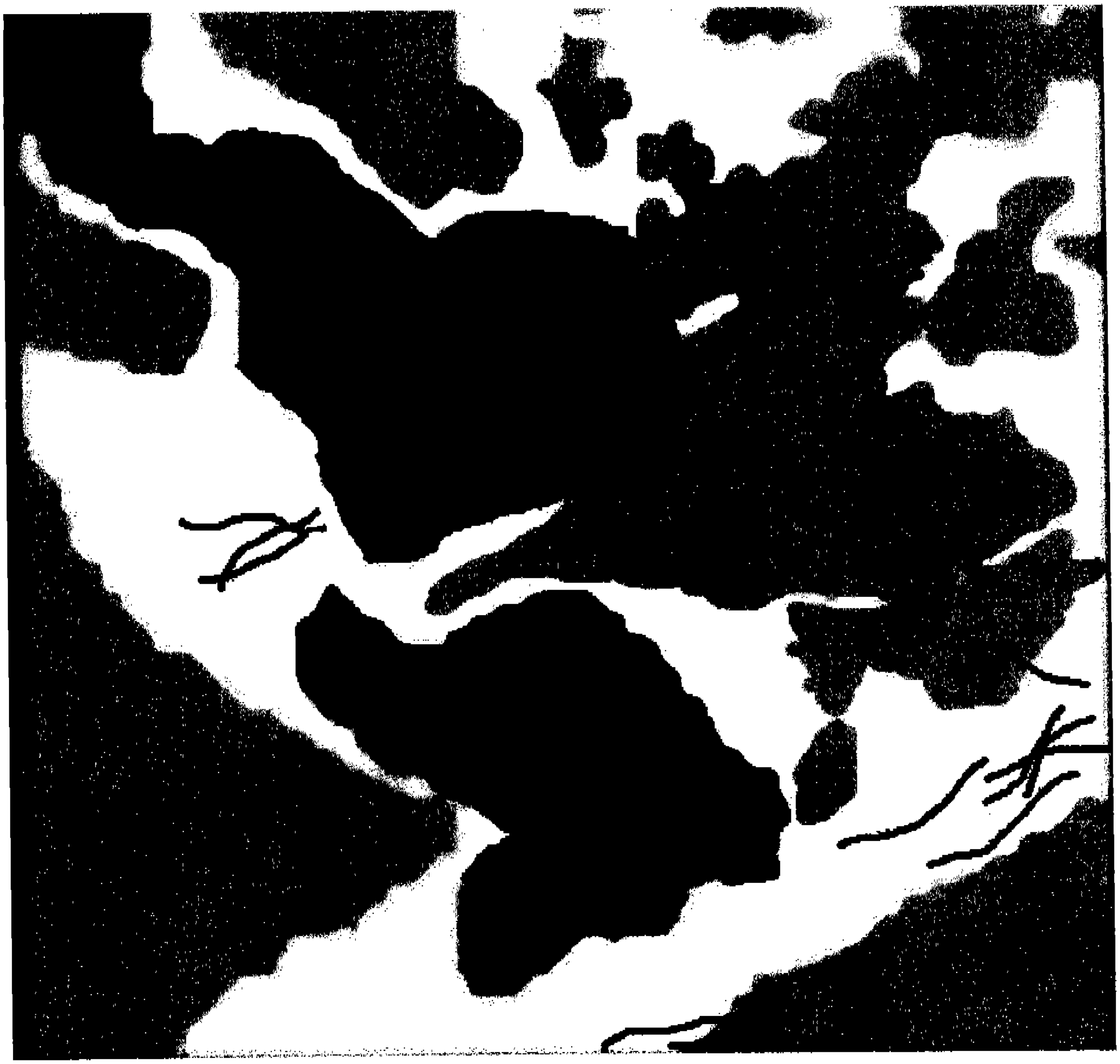
I9



L 13



L 12



M 12

M 13

N 13