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PLANTINGS OF RED MANGROVES (*Rhizophora Mangle L.*) FOR STABILIZATION OF MARL SHORELINES IN THE FLORIDA KEYS

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NAVAL OCEAN SYSTEMS CENTER
SAN DIEGO, CALIFORNIA 92152

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ADMINISTRATIVE INFORMATION

Work reported herein was performed during the period July 1977 to May 1979. Project initiation and development was a joint effort of NOSC and the Florida Keys Community College of Key West, Florida where Mr. Goforth was an instructor.

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Shoreline stabilization using mangrove plantings offers an environmentally and economically superior alternative to the construction of seawalls, riprap, etc. Three developmental stages of red mangroves (i.e., propagules, seedlings and small trees) were planted to provide erosion protection along three separate sections of marl shoreline at Key West, Florida.

Mangrove propagules ("beans") which were carefully removed from mature fruits or collected from shoreline debris exhibited the greatest vertical growth. However, survival of this stage ranged from 86–14% ($\bar{x}$ = 45%) and was inversely related to the degree of shoreline exposure. Seedlings (approximately 1 year old)

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did not exhibit a significantly greater survival rate ($\bar{x} = 48\%$) or vertical growth than propagules. Transplants of small mangrove trees (i.e., approximately 2-3 years old) were highly successful on all three shorelines exhibiting an average survival of 98% after 23 months. Degree of exposure to erosion and/or burial proved more important in determining seedling survival than either of the organic amendments or tidal heights tested. Using a power auger to bore holes and seagrass wrack as mulch proved to be an effective and economical method of planting all three developmental stages of red mangroves along organically deficient marl shorelines. However, marl shorelines exposed to moderate wave, tidal, or wind action are best planted with small mangrove trees to insure transplant survival and erosion protection.

SUMMARY

Shoreline stabilization using mangrove plantings offers an environmentally and economically superior alternative to the construction of seawalls, riprap, etc. Three developmental stages of red mangroves (i.e., propagules, seedlings and small trees) were planted to provide erosion protection along three separate sections of marl shoreline at Key West, Florida.

Mangrove propagules ("beans") which were carefully removed from mature fruits or collected from shoreline debris exhibited the greatest vertical growth. However, survival of this stage ranged from 86–14% ($\bar{x}$ = 45%) and was inversely related to the degree of shoreline exposure. Seedlings (approximately 1 year old) did not exhibit a significantly greater survival rate ($\bar{x}$ = 48%) or vertical growth than propagules. Transplants of small mangrove trees (i.e., approximately 2–3 years old) were highly successful on all three shorelines exhibiting an average survival of 98% after 23 months. Degree of exposure to erosion and/or burial proved more important in determining seedling survival than either of the organic amendments or tidal heights tested. Using a power auger to bore holes and seagrass wrack as mulch proved to be an effective and economical method of planting all three developmental stages of red mangroves along organically deficient marl shorelines. However, marl shorelines exposed to moderate wave, tidal, or wind action are best planted with small mangrove trees to insure transplant survival and erosion protection.

CONTENTS

INTRODUCTION

Three species of mangroves (*Avicennia germinans, Laguncularia racemosa,* and *Rhizophora mangle*) grow throughout the Florida Keys and provide a natural barrier to erosion forces along undisturbed shorelines. Mangroves are acknowledged as significant contributors to nature's land building process (Davis, 1940; Savage, 1972; Carlton, 1974) even though their role in this process may have been previously overemphasized (Thom, 1967). Nature's land building pace however, has often been too slow for modern man who has often resorted to land fill operations to "reclaim and develop" wetlands in southern Florida (Passavant and Jefferson, 1976; Teas, et al., 1976). Seawalls and riprap are typically used as substitutes for mangroves to stabilize the shorelines of these newly created plots of land. Unfortunately, seawalls and riprap cannot substitute for mangroves in their diverse biological role as a source of detritus and habitat for a variety of animals (Heald and Odum, 1969; Teas, 1976). In recognition of this fact, a number of studies have been conducted in recent years to develop transplanting techniques for all three species of Florida mangroves (Savage, 1972 and 1978; Hannan, 1975; Pulver, 1975 and 1976; Teas, et al., 1975 and 1978; Lewis and Dunstan, 1976; Evans, 1977; Teas, 1977). These studies reveal the primary determinants of transplant survival and optimal growth to be: (a) tidal elevation, (b) wave energy, (c) salinity and organic content of the substrate, and (d) human interference.* Savage (1972) concluded that the black mangrove (*Avicennia germinans*) offered greater potential for statewide shoreline rehabilitation projects due to its extensive pneumataphore development and wider geographical distribution. In southern Florida however, the red mangrove (*Rhizophora mangle*) is frequently used for shoreline transplant projects because of its local dominance and the ready availability of transplant stock.

This transplant project was conducted to satisfy a mitigation requirement for the loss of 70 meters of red mangrove shoreline resulting from a construction project at the Florida Keys Community College (FKCC), Stock Island, Key West, Florida. Since the primary goal of this project was to re-establish a red mangrove shoreline, the study was designed to employ techniques which would increase the probability of transplant success. Additionally, a secondary goal was to test these techniques under several experimental conditions. Within this context the study was designed to determine the relative success of: (a) three developmental stages of red mangrove transplant stock, (b) two tidal heights, (c) two organic amendments, and (d) three degrees of exposure to erosion forces.

AREA DESCRIPTION

The transplant sites for this study were located on the campus of Florida Keys Community College (FKCC) at Stock Island, Key West, Florida. Figure 1 shows the three marl shorelines (Sites A, B and C) which were utilized as transplant sites in this study. The three shorelines had experienced varying degrees of erosion and only limited natural recruitment of mangroves during the ten years since placement of the marl fill. Figure 1 also shows the average annual wind velocity and frequency for Key West over a 25-year period (Boylan, 1974). Site A faced south and was "protected" on three sides by adjacent land masses and

*Add to this unidentified mangrove-eating animals as reported for St. Croix, Virgin Islands (Lewis, 1979, elsewhere in this publication).

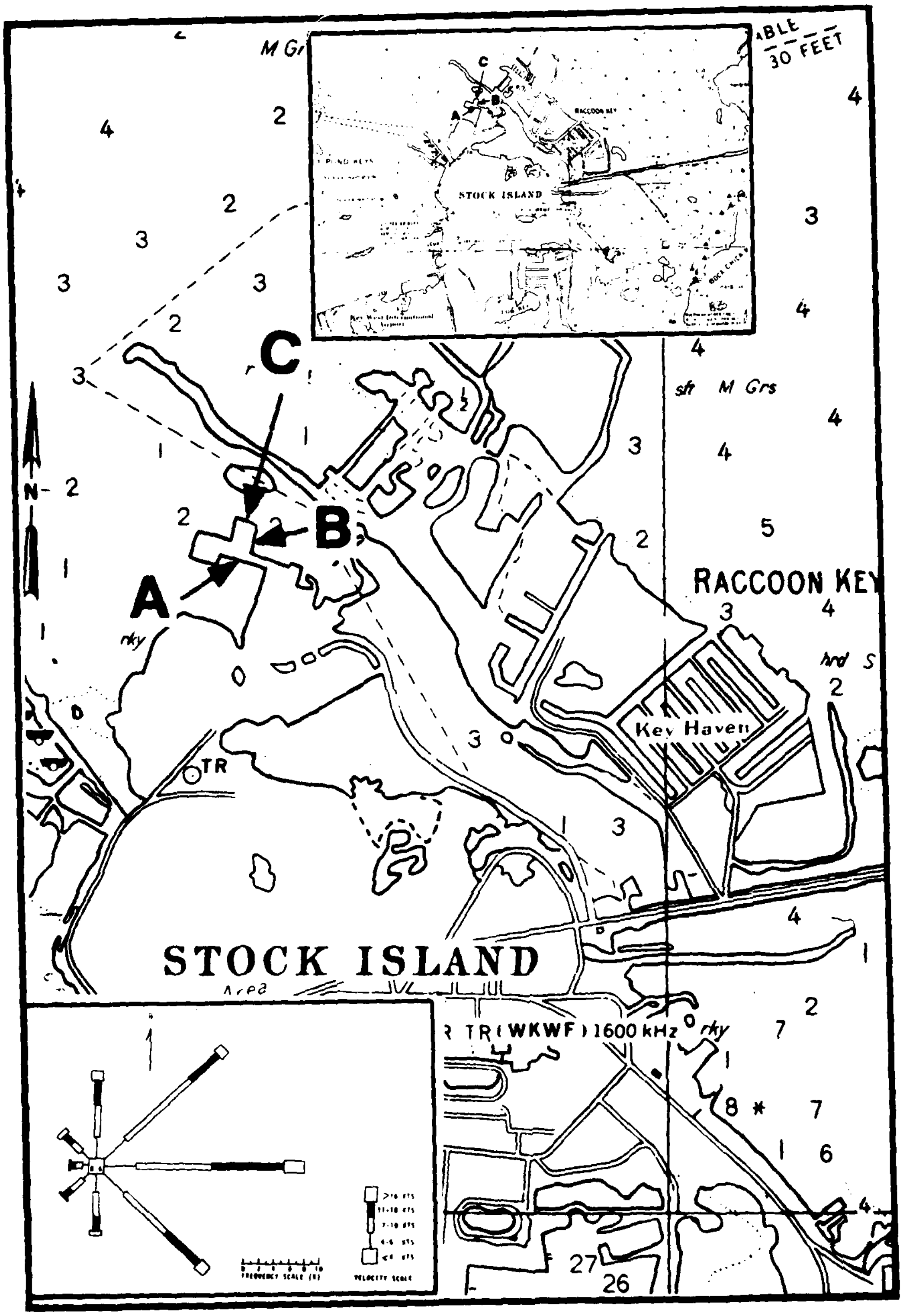

Figure 1. Location of mangrove transplant sites at Key West, Florida.

received only limited wind wave action. Site B faced east and was "exposed" to the greatest wind wave action and as a result was eroding more rapidly than either of the other two shorelines. Site C faced north and was "partially protected" from wind wave action by a small mangrove island located approximately 25 m to the north. The physical characteristics of the three transplant sites were quite similar except for their distinctly different exposures to wind wave action.

MATERIALS AND METHODS

COLLECTION AND SELECTION OF MANGROVE PLANTS

TYPE A. Mangrove propagules were picked from mature fruits on trees in an established mangrove stand or collected from shoreline debris windrows. Only propagules that could be extracted from a mature fruit with a gentle steady force were collected from trees. Propagules collected from the shoreline debris were required to satisfy the following criteria: (1) presence of an undamaged green terminal growth bud; (2) absence of evidence of dehydration (e.g., brown wrinkled appearance); (3) absence of developing roots and leaves; (4) absence of insect (*Poecilips rhizophorae*) or isopod (*Sphaeroma terebrans*) damage; and (5) possess the general characteristics of a propagule recently released from a mature fruit. Approximately half of the 42 propagules were collected by each method. Propagules were then pooled, wrapped in moist newspaper for 12–48 hours, and later selected by chance for planting at one of the three sites. No attempt was made to determine the relative success of propagules collected by these two methods.

TYPE B. Small mangrove seedlings (approximately 12–18 months old) were collected from a nearby natural mangrove nursery on Raccoon Key (Figure 1). Military folding shovels were used to dig up the seedlings along with a 0.2 m deep × 0.2 m diameter root ball. Seedlings were 0.2–0.5 m tall ($\bar{x}$ = 0.33 m), had 4–10 leaves ($\bar{x}$ = 6.6), and were collected within the 0.0 m to +0.3 m (MLW) tidal elevation range. Seedlings were placed in 0.2 m diameter nursery pots to facilitate handling and to protect the root ball complex. Potted seedlings were then transported to the transplant site in the bed of an open truck.

TYPE C. Small mangrove trees possessing aerial prop roots (approximately 2–3 years old) were collected at the same location and in the same manner as Type B plants but with minor differences. Type C plants were removed with a root ball diameter corresponding to the leaf drip line and were transported to the transplant site without the use of nursery pots. The Type C mangrove trees were 0.4–0.8 m tall ($\bar{x}$ = 0.56), had 1–7 aerial prop roots ($\bar{x}$ = 3.3), and root ball diameters that ranged from 25–50 percent of the tree height (Figure 2).

PLANTING PROCEDURE

Two organic amendments were utilized in this study to enhance growth and survival of mangroves planted on organically deficient marl shorelines (Figure 3). Commercially available peat (Genuine Canadian Sphagnum – Beaver Brand – Berwick, Nova Scotia) was obtained from a local nursery and staged along the transplant sites. Seagrass wrack in various stages of decay was collected from local beaches using standard gardening tools and transported to the transplant sites.

Figure 2. Typical small mangrove tree (Type C) used as transplant stock.

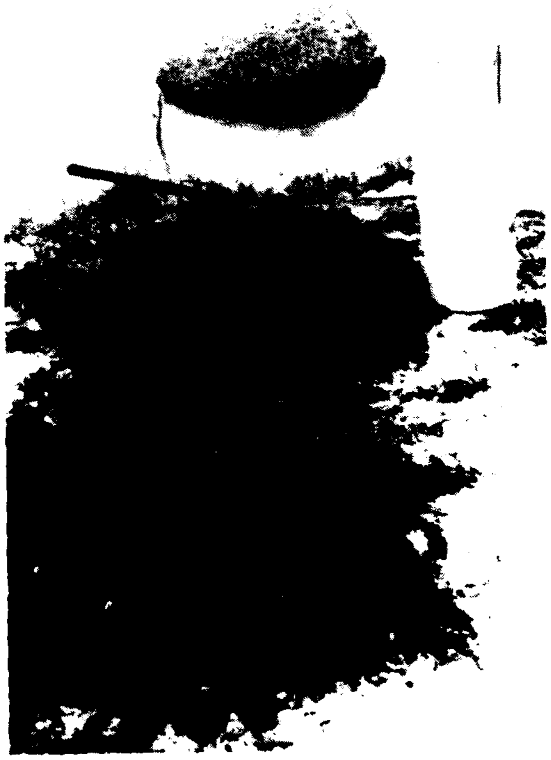

Figure 3. Peat and decaying seagrass wrack used as organic amendments to the marl substrate.

Prior to initiation of the planting operation, a two-day tidal monitoring survey was conducted to establish the time and height of the tidal stages at the transplant sites. Based upon the tidal reference points established during this survey, construction rods were installed 2 m apart in rows corresponding to the 0.0 m and +0.3 m (0.0 and +1.0 ft) MLW tidal heights. Rows were positioned in a staggered arrangement so that mangroves were planted at 1 m intervals along 42 m of shoreline at each site.

A hydraulic power auger and operator were rented (@ $25/hr) to bore transplant holes into the packed marl substrate at the three sites (Figure 4). Beyond the obvious economic and time saving advantages of a power auger, it was thought that the loosening of the packed marl in the area adjacent to the hole may improve the free exchange of seawater and prevent the formation of a subsurface hypersaline condition. Forty-two holes at each site (i.e., a total of 126), 0.41 m (16 in) in diameter and 0.45–0.61 m (18–24 in) deep, were bored at a cost of $1.00/hole. Boring and planting operations were accomplished during daytime low tides of –0.1 m (–0.3 ft) MLW which provided optimal working conditions (Figure 5). The loose marl removed from the augered holes was shoveled into a wheelbarrow and mixed 50:50 with one of two organic amendments (i.e., peat or seagrass wrack). Mangrove plants were then placed in the holes along with the marl:organic mixture and secured with bailing wire to a 1 m section of construction rod that was driven into the substrate immediately adjacent to the plant (Figure 6). A metal identification tag with coded treatment information was also attached to each plant. Transplants were made according to an experimental design which distributed the transplant treatments (i.e., developmental stages, tidal heights, and organic amendments) in a regular repeating triplet arrangement at each site. This arrangement was designed to minimize the effect of any within-site variation.

Figure 4. Power auger used to bore transplant holes (Site B).

Figure 5. Transplant crew working during low tide conditions (Site B).

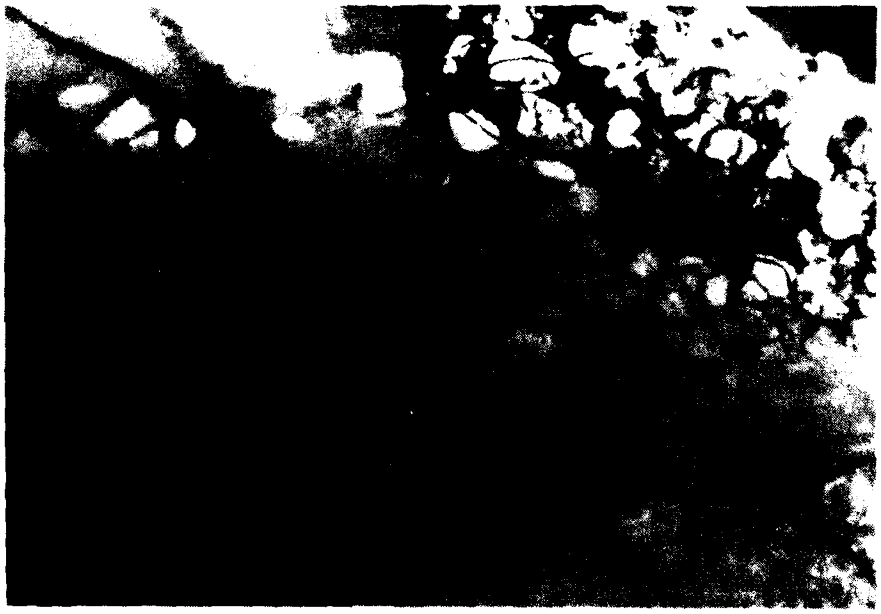

Figure 6. Mangrove propagule (Type A) with identification tag secured to construction rod.

MONITORING PROCEDURES

Transplant monitoring began in July 1977, and was continued until May 1979 with the assistance of students enrolled in the Environmental Marine Science Program at FKCC. The parameters of mangrove growth initially monitored included: (a) the height of each plant above substrate, (b) leaf count of propagules and seedlings only (not small trees), and (c) prop root counts of small trees only. As a result of subsidence of plants into the loosened substrate (also noted by Pulver, 1976) the growth parameters were modified. Beginning in October 1977, heights of plants were measured from a nylon band fastened around the trunk near the substrate. Leaf counts at this time were extended to include small trees to account for any lateral growth which might occur. Heights were measured from the nylon band to the tip of the central growth bud to the nearest millimeter using a meter stick. The presence or absence and comments on the general appearance of each plant were also recorded. The use of construction rods and identification tags greatly facilitated the location and monitoring of mangrove transplants during the two years of this study.

RESULTS

PROPAGULES (TYPE A)

Survival of propagules after 23 months of monitoring was 71% at the protected site and 57% at the partially protected site (Figure 7). At the exposed site (Site B), propagule survival decreased rapidly during the first three months to 30% and then more slowly to 7% at 19 months. Only one propagule survived at the exposed site after 23 months (Figure 7). The mean survival for propagules for all three sites was 45%.

Survival of propagules planted in the organic amendments at Site A was 75% in peat and 83% in seagrass wrack. At Site B, the only surviving propagule was planted in peat, while at Site C, 62% survived in peat and 50% in seagrass wrack. The mean survival for propagules at all sites was 48% in peat and 44% in seagrass wrack.

Survival of propagules planted at the two tidal heights was as follows: Site A: 57% at 0.0m and 100% at +0.1m; Site B: 0% at 0.0m and 7% at +0.1m; Site C: 43% at 0.0m and 71% at +0.1m. The mean survival rate of propagules at the two tidal heights was 33% at 0.0m and 59% at 0.1m.

Vertical growth of the propagules was similar at all three sites when average height measurements (i.e., Site A = 31.35 cm, Site B = 26.43 cm; Site C = 26.41 cm) were compared (Figure 8). The appearance of more rapid growth after March 1978, at the exposed site (Site B), was probably due to the lower number of plants surviving, thus skewing the statistical mean. The average number of leaves produced per plant generally parallels the trend in vertical growth (Figure 8). The slightly more erratic graph generated for leaf production at the exposed site is again probably due to the loss of plants at that site (only one survived).

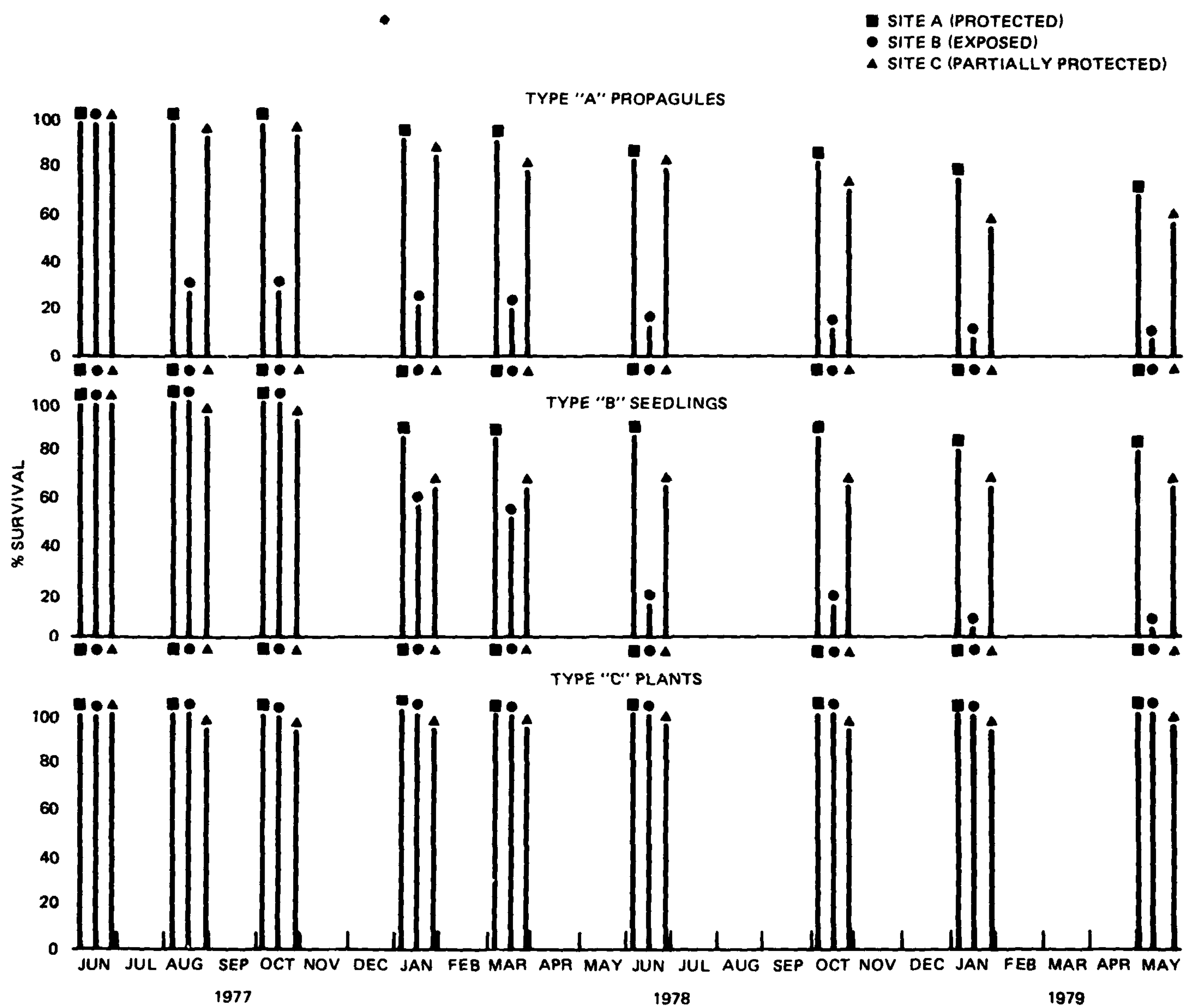

Figure 7. Survival of transplanted red mangroves.

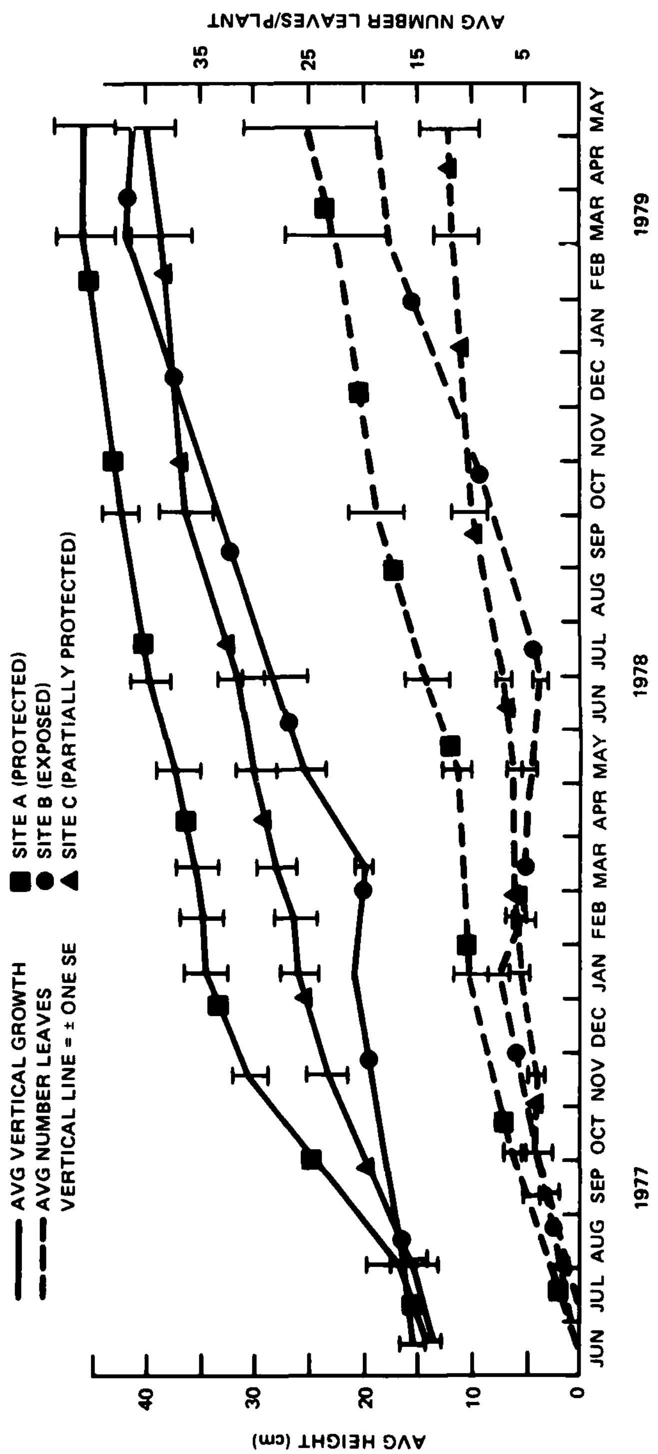

Figure 8. Growth of red mangrove propagules (Type A).

SEEDLINGS (TYPE B)

Survival of the transplanted seedlings was no more successful than that of propagules with a total of 48% remaining after 23 months. At the protected site 79% survived, while 64% survived at the partially protected site, and none remained at the exposed site (Figure 7).

Survival of seedlings planted in the two organic amendments was as follows: Site A: 50% in peat and 29% in seagrass wrack; Site B: no survivors; Site C: 36% in peat and 29% in seagrass wrack. The mean survival for seedlings for all sites was 29% in peat and 19% in seagrass wrack.

Survival of seedlings planted at the two tidal heights was as follows: Site A: 29% at 0.0m and 50% at +0.1m; Site B: 0% at 0.0m and 7% at +0.1m; Site C: 14% at 0.0m and 50% at +0.1m. The mean survival for seedlings at all sites was 14% at 0.0m and 36% at +0.1m.

The average vertical growth of seedlings (i.e., Site A = 8.47 cm; Site B = no survivors; Site C = 12.93 cm) was significantly ($P < 0.001$) less than propagules (Figure 9). Although this may be due to branching and lateral growth, the leaf count data (i.e., the average number of leaves per plant), does not support this explanation. The trend of slow growth is observed both in terms of increased vertical height and leaf production.

SMALL TREES (TYPE C)

Transplanted small trees provided the best survival with a total of 98% remaining after 23 months (Figure 7). Only one transplanted young tree was lost during that period. That loss occurred at the partially protected site during the first month following the transplant and may have resulted from mechanical injury incurred during the transplanting operation.

Vertical height measurements of the small trees failed to reveal any substantial growth. In fact, the data indicated negative growth in some cases due to subsidence. However, on-site observations revealed good growth of the plants although much of this was in the form of lateral branching. This growth is apparent upon examination of the leaf and prop root production data (Figure 10). Interestingly, the average number of leaves and prop roots did not increase significantly during the first year following transplanting. However, during the second year increases were observed in both leaves and/or prop roots at all sites. Using leaf and prop root counts as estimates of growth of small trees indicates the greatest growth occurred at the exposed site with a mean increase of 64 leaves and 5 prop roots. Growth of small trees at the protected site was observed principally in prop root development with a mean increase of 20 leaves and 6 prop roots. Yet growth at the partially protected site was slightly less, with a mean increase of 18 leaves and only 2 prop roots.

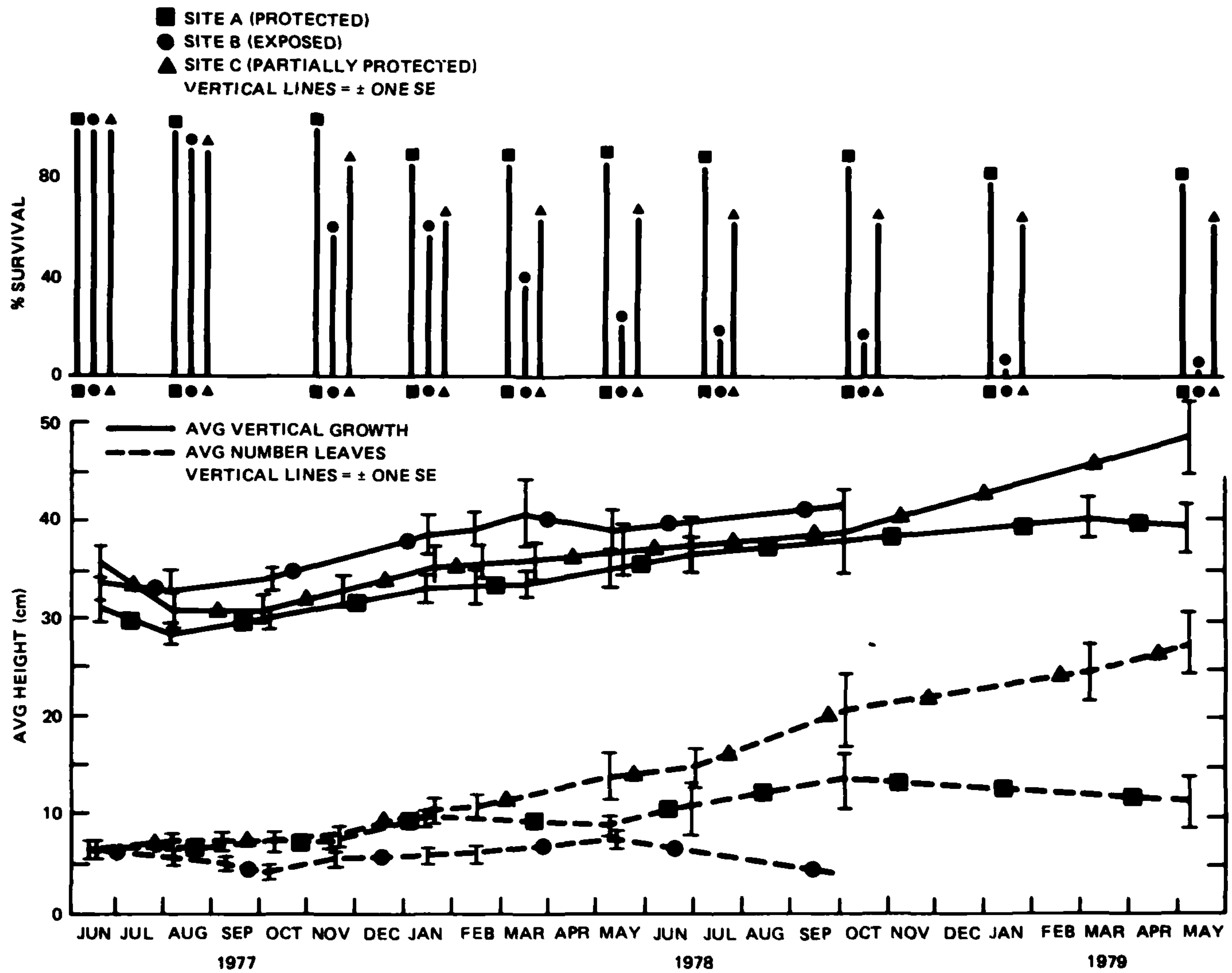

Figure 9. Survival and growth of red mangrove seedlings (Type B).

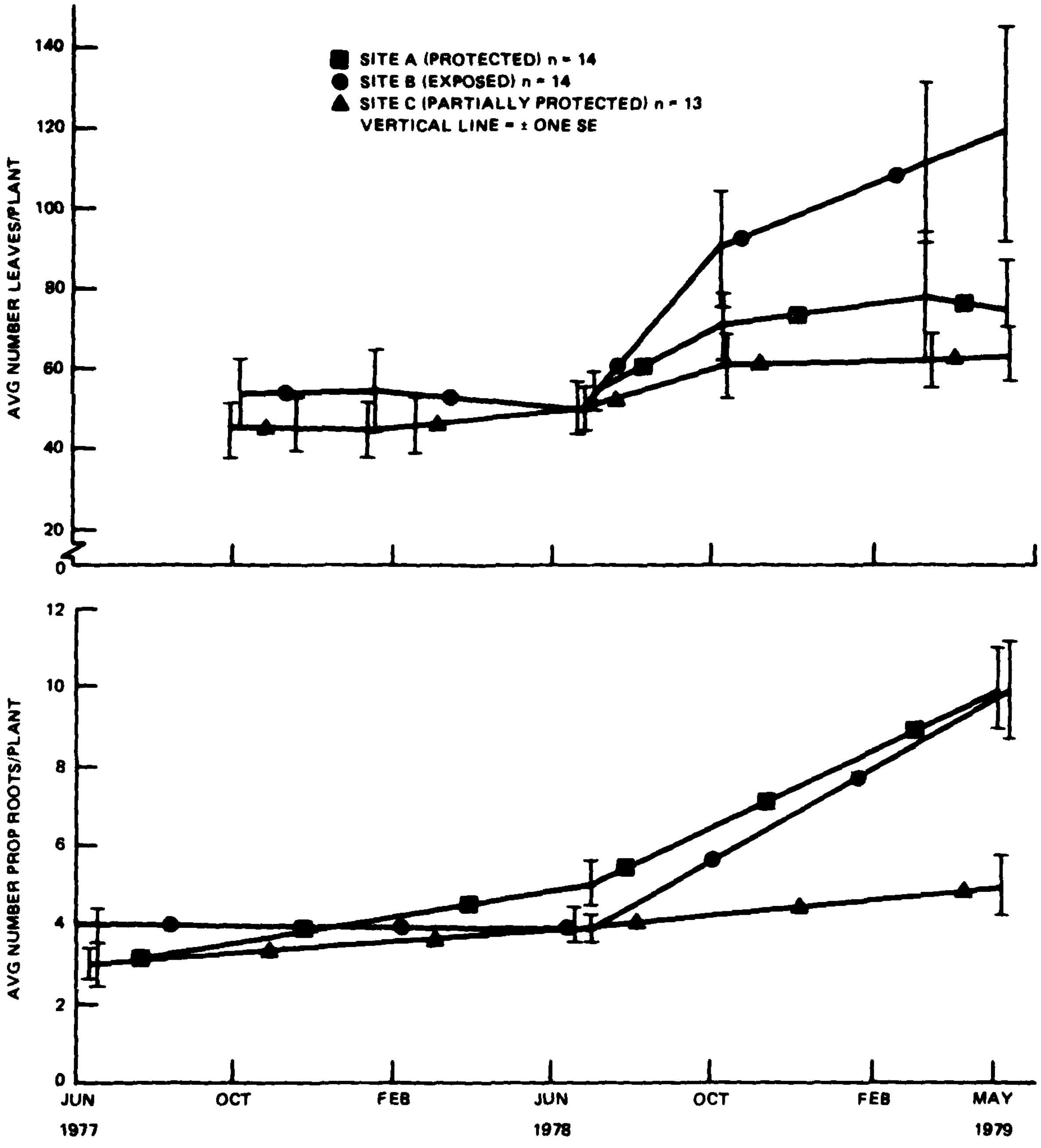

Figure 10. Growth of small red mangrove trees (Type C).

TRANSPLANT COSTS (1977 VALUES)

The costs of expendable items used for this transplant include the following:

4 bales of peat	$ 36.00
Power auger/operator (rental)	125.00
Nursery pots	24.00
Construction rods	11.50
Baling wire	3.50
	$200.00

The manpower requirements for the transplant project were divided as follows:

Supervisor (on site) $8.00 X 20 hr			=	$160.00
Technician:	Site preparation	6		
	Seagrass collection	2		
	Mangrove collection	6		
	Planting	30		
	@ $2.50 X	44	=	110.00
				$270.00

The total cost of transplanting 142 mangroves at 1m intervals along 126 m of marl shoreline was $470.00 or approximately $3.75/plant. This cost is quite attractive when one considers the expensive and nonbiological alternatives (i.e., seawalls, riprap, etc.) available for shoreline stabilization and erosion protection.

DISCUSSIONS AND CONCLUSIONS

The use of vertical height as an estimate of growth became a troublesome parameter to monitor and evaluate during this project. The subsidence mentioned previously, coupled with the effects of lateral branching obscured indications of real growth, particularly among the older plants. The nylon band used as a reference point for measuring heights provided only a temporary solution as many of these snapped off and were lost after one year. This occurred mostly with the small trees, apparently due to expansion of the trunk. Leaf counts and lateral branching would appear to provide a better overall indicator of growth than height alone, although the collection of these data can become tedious with the more mature plants.

The most rapid growth in terms of increased vertical height was observed among the propagules (i.e., mean increases of 31-26 cm). This is not surprising considering the need for the propagule to become established as rapidly as possible. The older plants, such as the seedlings and young trees, may divert some energy into adaptation to the new environment. Even without the effects of transplant shock the seedlings may direct energy toward the rapid production of secondary root systems for increased stability. This however, appears to be contraindicated in other studies (Savage, 1972a).

Substantial growth of small trees were not indicated until the second year. At the end of 23 months the average leaf count on young trees was noticeably higher at the exposed site than at the other two sites. This is probably due to the high quantity of seagrass debris that washed up on this shore. The accumulated beach wrack apparently contributed additional nutrients producing more luxuriant growth than often observed on marl shores (Teas, et al., 1976). Accumulation of organic debris on the other more protected shorelines was negligible in comparison. Paradoxically, the debris which was responsible for the burial and failure of propagules and seedlings at this exposed site appears to have been responsible for the more luxuriant growth of the surviving small trees.

In this study seedlings showed no advantage over propagules in terms of growth or transplant survival. At the end of 23 months, it is difficult to distinguish one age class from another. Several of the seedlings have begun to develop prop roots but propagules have not. Therefore one advantage of transplanting established seedlings as an erosion prevention measure is apparently an earlier onset of prop root development for stabilization.

The loss of propagules and seedlings appeared to be directly related to the wind and wave energy regime to which the shoreline is subjected. These younger plants were rapidly buried by seagrass debris carried in by strong prevailing wind driven waves. This burial process was augmented by high water levels during spring tides but this factor alone does not account for the loss of the propagules and seedlings. Tidal influences were observed to be similar at all sites. Survival of both propagules and seedlings was approximately twice as great at the +0.1m tidal level at all sites. This finding again demonstrates the sensitivity of developing mangroves to tidal elevation and the importance of carefully determining tidal heights to optimize transplant success as suggested by Lewis (1979).

The growth and survival of both propagules and seedlings planted in peat and seagrass wrack was quite similar. It appears that the use of commercial peat as an organic amendment offers no advantage over the more economical and readily available seagrass wrack.

The overwhelming success, in terms of survival, of the small trees used in this transplant indicates a preference for their use on exposed shorelines. This preference is suggested in summary by other studies (Savage, 1972b; Pulver, 1976) but with qualification. Caution is emphasized in that indiscriminate removal of young trees may adversely affect the donor site. However, considering future losses due to competition at the donor site, theoretically, a conservative percentage of trees may be removed without impact (Pulver, 1976; Teas, 1974). In light of the susceptibility of propagules and seedlings to loss by erosion and burying, the use of small trees appears to be singularly necessary for transplant projects intended to rapidly stabilize a shoreline against erosion.

Observations of these three transplant sites have suggested the need for continued monitoring through a third year. The focus of this further monitoring centers on:

1. The effectiveness of the transplanted mangroves in stabilizing these marl shorelines.

2. The effectiveness of the transplants in promoting natural recruitment on the shore.

Lost seedlings and propagules at the exposed site will be replaced by additional small trees. Wind and wave data will be collected and changes in the beach slope will be monitored. Recruitment from neighboring mangrove stocks will be monitored within the transplant plots and compared to similar shorelines without transplants. Growth rate and survival data will continue to be collected and compared with natural controls.

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