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Transplant Techniques for Sapling Mangrove Trees, *Rhizophora mangle*, *Laguncularia racemosa*, and *Avicennia germinans*, in Florida

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Florida Department of Natural Resources
Marine Research Laboratory

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ABSTRACT

Pulver, T. R. 1976. Transplant Techniques for Sapling Mangrove Trees, *Rhizophora mangle*, *Laguncularia racemosa*, and *Avicennia germinans*, in Florida. Fla. Mar. Res. Publ. No. 22. 14 pp. Handling and transplanting techniques were investigated for three species of mangroves, *Rhizophora mangle, Laguncularia racemosa, and Avicennia germinans.*

Survival and growth were used as indicators of success. Excellent results were obtained by replanting 0.5-1.5 meter mangroves having rootball diameter equal to one-half the tree height. Pruning before or just after replanting enhanced recovery and improved growth rates for experimentals in each species tested. *Rhizophora* reestablished most successfully in both pruned and unpruned treatment groups, while *Laguncularia* was least successful. Pruning of non-replanted control trees accelerated growth in *Avicennia* and *Laguncularia,* but slowed growth in *Rhizophora* when compared with unpruned controls.

This study demonstrated the feasibility of routine transplanting of maturing mangroves; procedures are recommended.

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CONTENTS

INTRODUCTION

ECOLOGICAL BACKGROUND

In many parts of the world, silvaculture techniques have been developed for mangrove management (Watson, 1928; Noakes, 1955; Wadsworth, 1959). Direct commercial utilization of mangroves (e.g., lumber, tannin, charcoal), has been largely overlooked in Florida, possibly because of abundant material substitutes as well as socioeconomic differences. However, with increased knowledge of ecological relationships, the environmental functions of Florida mangroves, *Rhizophora mangle* (red mangrove), *Avicennia germinans* (black mangrove), and *Laguncularia racemosa* (white mangrove) are becoming economically important. Mangroves are significant to Florida's coastline because of their roots which aid in stabilizing shores, their leaf fall which subsidizes marine food webs, and their mere presence which provides nursery areas for marine animals and nesting areas for birds. The removal or destruction of these trees and the associated mangrove habitat by waterfront development endangers the overall ecology of Florida's coastal zone.

Through their leaf and wood fall, mangrove swamps, particularly those of *Rhizophora*, contribute considerable amounts of detritus to adjacent estuaries (Heald, 1971). During subsequent breakdown, these materials become food and substrate for numerous microorganisms and thus begin a food web containing economically important shrimps, crabs, and fishes (Sastrakusmah, 1971; Odum, 1971). Additionally, fresh water runoff is partially impeded and filtered such that some nutrients are stored as mangrove biomass for slow release into the estuary via the detrital food chain (Snedaker, 1973). Utilization of this nutrient uptake may, if properly managed, serve as a "natural" means of tertiary sewage treatment (Lugo et al., 1971), particularly if heavy metals and other such potential intoxicants are previously removed.

Mangroves are distributed world wide in intertidal areas. Their intolerance to cold apparently restricts the species to tropical and subtropical latitudes. In Florida, *Avicennia* seems to be the most cold hardy (Savage, 1972), *Laguncularia* the least, and *Rhizophora* somewhat intermediate. Savage feels this is reflected in the northerly extent of each species. On the east coast, St. Johns County is the northern limit for *Avicennia* (Moldenke, 1960) and Volusia County is the limit for *Rhizophora* and *Laguncularia* (Graham, 1964; Carlton, 1975). Along the Gulf, *Avicennia* and *Rhizophora* extend to Levy County (Leopold, 1950; Graham, 1964) and *Laguncularia* to Hernando County (Graham, 1964). North of Levy County, *Avicennia* occurs occasionally as shrubs which appear bushy as though perhaps pruned by frost. *Laguncularia* also occurs north of its mainland limit as Savage (1972) reports finding two specimens on Seahorse Key (Levy County). Although no lethal minimum temperatures could be found in the literature for each mangrove species. Savage (1972) reported that –9.4°C (15°F) recorded on December 13, 1962, killed black mangrove in the Cedar Key area. No reports of heat death in mangroves were found. The high temperatures reported by Kolohmainen et al. (1973) for a thermally loaded bay in Puerto Rico, indicate *Rhizophora* successfully withstands water temperatures of 40°C (104°F). Miller (1974) proposed that natural mangrove stands can be successfully used to shade and cool power plant effluent without severe damage to the trees.

Additional factors enter into local distribution of each species. All have anatomical structures for air conduction to subterranean roots (Scholander et al., 1955). All three species require low energy habitats and are unable to withstand continually shifting substrates.

Elevation ranges for all three species overlap and mixed stands are common. *Rhizophora* has the lowest elevation range; from 0.3-0.7 m "of continuous water coverage to a few inches coverage a few times per month" (Davis, 1940). Thus *Rhizophora* generally inhabits frequently inundated areas, as attested by the substantial waterborn export of leaf debris from these communities (Odum, 1971; Heald, 1971; Snedaker, 1973). *Avicennia* generally grows in slightly higher, less frequently inundated areas (Davis, 1940) and most export is in the form of decomposed organic matter instead of leaf debris (Snedaker, 1973). The tidal range for *Avicennia* is from "a few inches of continuously standing water" to areas "inundated only a few times per month" (Davis, 1940). Davis gives no specific elevation range for *Laguncularia*, but mentioned that it frequently occurs mixed into *Rhizophora* and *Avicennia* communities, apparently tolerating nearly all levels and frequencies of submersion.

Surface water salinity in mangrove stands is related to elevation, frequency of inundation, evaporation, and rainfall as well as salinity of surrounding waters. In frequently inundated areas, surface salinities within the stands remain nearly the same as surrounding waters. As elevation increases and inundation becomes increasingly infrequent, salinity of water trapped in depressions becomes more influenced by the relative amounts of evaporation and rainfall between tidal coverages; salinity in these pools is therefore highly variable (Davis, 1940).

Of the three species, *Avicennia* tolerates the broadest and highest salinity range; from "nearly fresh" to as much as 50.0‰ for surface water and 80.0‰ for interstitial water (Davis, 1940). "Typical" salinities for *Avicennia* are 36.8‰ for surface water and 51.1‰ for interstitial water (Davis, 1940; Morrow and Nickerson, 1973). *Rhizophora,* often more frequently inundated, usually experiences a narrower range of 31.9-34.9‰ for surface water and 29.1-35.6‰ for interstitial water (Davis, 1940). However, *Rhizophora* does form communities in "fresh or nearly fresh water" as exemplified by the inland dwarf communities of south Florida (Davis, 1940). Although the literature states no specific salinity range for *Laguncularia,* its occurrence suggests a broad tolerance.

PREVIOUS TRANSPLANT ATTEMPTS

Early researchers mention occasional transplant attempts but do not adequately describe techniques. Bowman (1917) reported that mangroves were successfully transplanted by the Florida East Coast Railway for ballast retention along the overseas extension to Key West. Davis (1940) studied environmental effects on seedling establishment and survival in numerous plantings as well as in sample plots of naturally established seedlings. His largest planting on Long Key, Tortugas, contained 4,100 seedlings, of which 19.5% died during the first year.

Recent transplant reports, however, have discussed techniques. Six 4.5 to 6.5 m *Rhizophora* were transplanted with a tree crane and backhoe by Gill (1971) and the Dade County Parks Department. Five of these were thriving in 1973 when I visited the site. Savage (1972) investigated the potential value of Florida mangroves for shoreline stabilization through laboratory and field tests with seedling transplants by pruning adult trees. Autry et al. (1973) attempted to establish 920 seedlings on a breakwater at the Tampa Electric Company's Big Bend Power Plant in Tampa Bay, but obtained minimal survival due to winter storms. As of June 30, 1973, a total of 2,477 *Rhizophora* and "some" *Avicennia* (0.7-2.4 m height) have been transplanted near Marco Island, Florida. Survival was 33.2% (Marco Applied Marine Ecology Station, 1973).

My preliminary experiments were designed to compare certain basic handling techniques using survival and growth as indicators of success. Lower survival rates of previous transplant attempts prompted comparison of techniques without added stress of site relocation. To evaluate techniques alone, experimental plants were removed and replaced in the same hole.

METHODS AND MATERIALS

Forty trees of each of the three species (120 trees total) were selected on the basis of height (0.5 to 1.5 m) and structure (i.e. presence of proproots or pneumataphores) that would correspond to age of five or more years according to calculations made by Savage (1972). Trees of each species were tagged using camouflaged aluminum foil stamped with consecutive numbers and randomly assigned to one of four groups of ten trees each. In the first, a control group, trees were left undisturbed throughout the experiment. The second, also a control, had the tops pruned but the trees were not removed. In the third and fourth groups, both experimental, trees were dug out and replanted in situ. Those in Group 4 received top pruning while those in Group 3 did not.

Washout of the root system by a shifting substrate has been the most prevalent cause of transplant mortality (Bowman, 1917; Davis, 1940; Savage, 1972; Autry et al., 1973; Marco Applied Marine Ecology Station, 1973). Therefore, sites used in this study were chosen for the wind and wave protection afforded by surrounding shorelines (Figure 1). Exposure ranged from south to east on site #1, and from

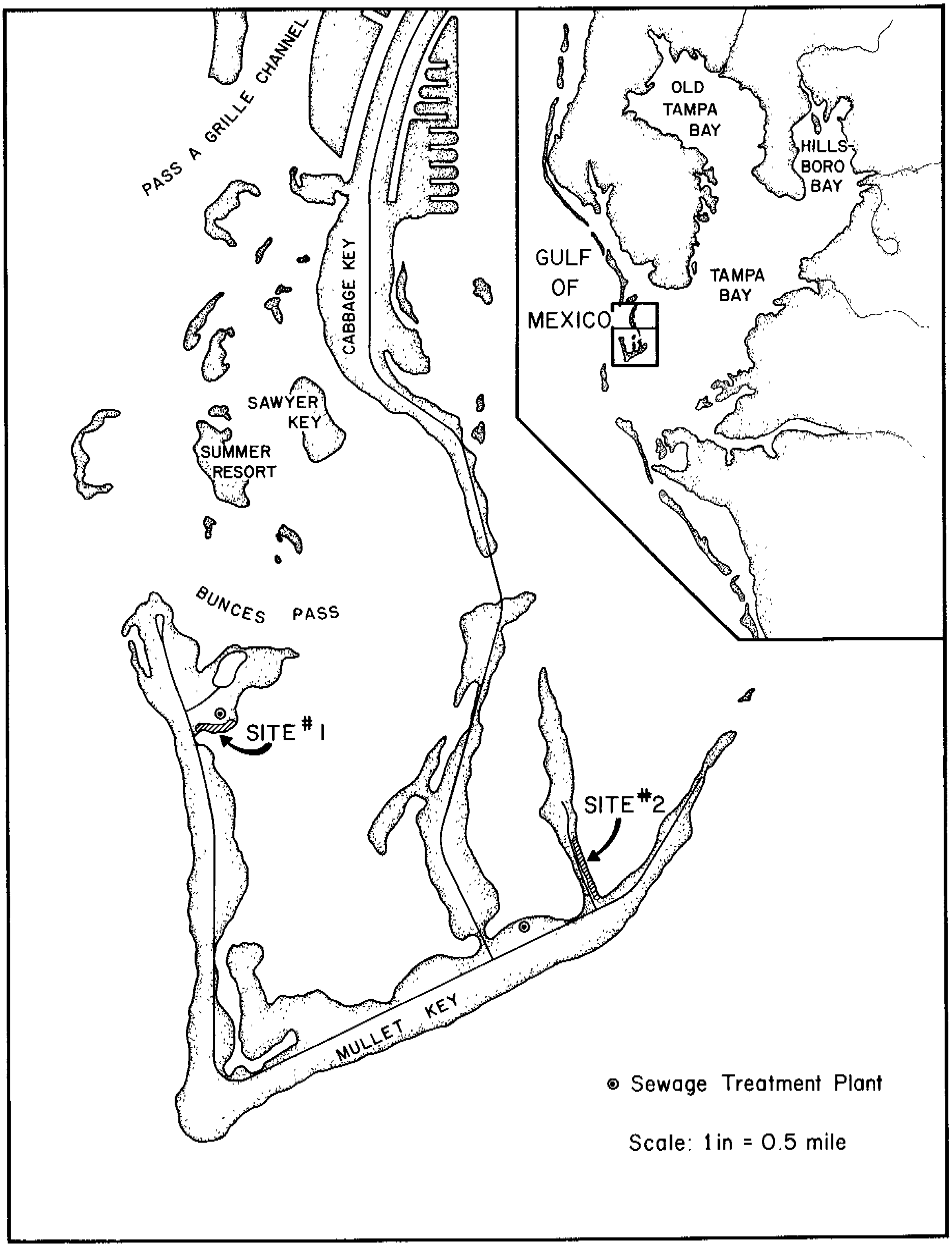

Figure 1. Map of study area.

north to northeast on site #2. This precaution eliminated wash-out mortalities and allowed better evaluation of techniques being tested. Further disturbance from foot traffic and possible development was eliminated by using restricted access areas on Mullet Key, a part of the Pinellas County Parks System. There was the possibility of nutrient enrichment from a small sewage treatment plant near each site (Figure 1). However, due to random selection of trees, experimentals and controls should have received equal effects.

SITE DESCRIPTION

Site #1 was a mixed mangrove stand with 4- to 6-m trees landward and younger ones along the shoreline. Site #2 was predominantly *Avicennia* with only one tree larger than 2 m. Macroscopically, substrate appeared to be mixed shell and sand on both sites to a depth of 25 cm. Thirty *Avicennia* used in this experiment were located at site #2, all other trees were located at site #1. Most trees used were on the seaward side of the stand. Elevation of individual trees also varied and was not determined in this study.

Figure 2. Tree before replanting showing measuring technique.

Vertical growth (ΔH) was used as a simple measurement of reestablishment success. Heights were taken as the vertical distance from the highest bud to the ground (Figure 2). All measurements were taken with a meter stick and were rounded to the nearest 1 cm. Relationships between growth of experimentals and their corresponding controls is conveniently expressed as the growth ratio (ΔH exp: ΔH control). Trees to be pruned and/or replanted in situ were premeasured on March 13-22, 1973, to determine height before pruning and allow calculation of any settling after replanting. Pruning of Groups 2 and 4 was accomplished with anvil-type clippers on March 13 and 14, by removing all growth above 66% of the original height. Trees in Groups 3 and 4 were dug out and replanted on March 19, 21, and 22, 1973. All trees were left undisturbed thereafter. Initial heights of all trees were taken on 26 March, with additional growth measurements taken on 25-30 May, 12-17 July, 29-30 November 1973, and 21 and 27 February 1974 (Table 1).

Roots of in situ replants were severed with a shovel and trees were lifted out of the ground with soil intact around the roots (Figure 3).

Figure 3. Tree removed from hole with rootball intact.

TABLE I. AVERAGE GROWTH AND OTHER DATA FOR EACH GROUP OF MANGROVES AFTER PRUNING (MARCH 13-14, 1973) AND REPLANTING (MARCH 19-22, 1973).

	RHIZOPHORA				*LAGUNCULARIA*				*AVICENNIA*			
	UC	PC	UR	PR	UC	PC	UR	PR	UC	PC	UR	PR
Height 1 (cm) (March 26)	103.1	64.3	99.8	78.4	104.1	68.3	97.2	67.9	103.9	73.3	106.9	77.7
Height 1 (cm) (May 25-30)	102.0	64.6	98.7	79.2	103.6	72.9	96.5	71.3	105.5	79.8	108.7	79.8
ΔH_1 (cm) (65 days)	–1.14	0.4	–1.2	0.9	–0.5	4.4	–0.2	3.4	1.6	6.5	1.8	2.2
Height 2 (cm) (July 12-14	104.3	68.4	100.7	82.2	104.9	78.6	94.5	72.4	106.9	85.8	106.8	82.9
ΔH_2 (cm) (48 days)	5.34	4.0	2.0	3.0	1.3	5.9	–2.0	1.2	1.4	6.1	–1.0	3.0
Height 3 (cm) (Nov. 29-30)	123.5	82.9	107.3	88.9	128.9	104.9	98.9	84.1	117.7	110.2	107.4	89.8
ΔH_3 (cm) (136 days)	16.15	14.2	6.6	6.7	24.0	26.3	4.4	11.6	10.8	24.4	1.9	7.9
Height 4 (cm) (Feb. 21-27)	126.5	82.5	108.2	91.3	52.2	104.9	87.7	87.6	113.9	111.6	109.0	90.9
ΔH_4 (cm) (89 days)	3.03	–0.4	0.9	2.4	3.6	–0.3	–1.3	3.6	1.0	1.4	1.76	1.1
ΔH_5 (cm) March-Feb (338 days)	23.5	18.2	8.4	12.9	29.3	36.6	0.5	19.8	9.9	38.3	2.1	13.2
Rootball diam			19.8	21.3			18.0	17.9			19.4	19.5
Rootball diam/ Height 1			.512	.647			.486	.642			.485	.641

Growth Ratio (H_5 Experimental / H_5 Control)	PC/UC=0.778 UR/UC=0.359 PR/PC=0.709	PC/UC=1.293 UR/UC=0.018 PR/PC=0.541	PC/UC=3.869 UR/UC=0.212 PR/PC=0.345
UC=Unpruned Control	PC=Pruned Control	UR=Unpruned Replanted	PR=Pruned Replanted

The resulting root ball was kept at a size practical for two men to handle. The largest diameter of the root ball was measured to the nearest 1 cm with a meter stick. Water salinity in the resulting hole was measured with a handheld temperature compensated refractometer (American Optical Co.). Most replants were made at low tide to prevent surface water from running into the holes and altering the interstitial water salinity readings. After measurements were taken, the tree was replaced in its original position in the ground, and the soil stamped in around the root ball. Approximately 6 l of seawater were added to the base of each tree to facilitate sealing (Figure 4).

Figure 4. Replanted tree after being washed in.

RESULTS AND DISCUSSION

REPLANTING AND GROWTH

Recovery from pruning or in situ replanting, or both, was excellent. There were only three mortalities (5%) in replanted groups (all *Avicennia*). Two of these were in the unpruned replanted group and one was in the pruned replanted group. One additional tree in the unpruned replanted group lost over half its height to an air boat and was eliminated from growth calculations along with the mortalities.

Loss of older proximal leaves was the usual response to replanting and occurred in both pruned and unpruned replanted groups of all species. First indication of this was yellowing of proximal leaves, immediately followed by defoliation. Older leaves were always dropped first, distal leaves being dropped only in the case of complete or nearly complete defoliation. Wilted branch tips and new growth were not observed; however, measurements indicate some tip dieback. Most defoliation in *Laguncularia* and *Rhizophora* occurred shortly less than 36 days after replanting. However, defoliation seemed to be postponed in *Avicennia* and most was noted 84 days after replanting.

Adverse effects of replanting *Rhizophora* without pruning were minimal. Only one tree was partially defoliated after 36 days. This group had the highest mean growth ratio for the year, 0.36. In contrast, trees in the *Laguncularia* group had significant difficulty reestablishing. Eight trees were partially defoliated 36 days after replanting. This replanted group had a growth ratio of only 0.02. Aside from the two mortalities, unpruned *Avicennia* responded fairly well to replanting. Although eight trees were partially defoliated the yearly mean growth ratio was 0.21, nearly that of *Rhizophora* (Table 1).

Pruning before replanting consistently enhanced recovery, yielding more growth and slightly less defoliation than the unpruned replanted technique. Best results were obtained with *Rhizophora*, which had a growth ratio of 0.70 and only one defoliated tree (Figures 5 and 6).

Pruned *Laguncularia* had a growth ratio of 0.54, 30 times the growth obtained without pruning (growth ratio 0.02); only three were defoliated. Pruned *Avicennia* fared only slightly better than unpruned trees, producing a growth ratio of 0.34 (as compared to 0.21) (Table 1, Figures 5 and 6); five *Avicennia* had partially defoliated.

Despite varied root ball sizes, mean root ball diameter to unpruned height ratios were nearly the same for unpruned replanted groups: 0.51 for *Rhizophora,* and 0.49 for *Laguncularia* and 0.49 for *Avicennia*. Ratios were equally consistent for groups pruned before replanting:

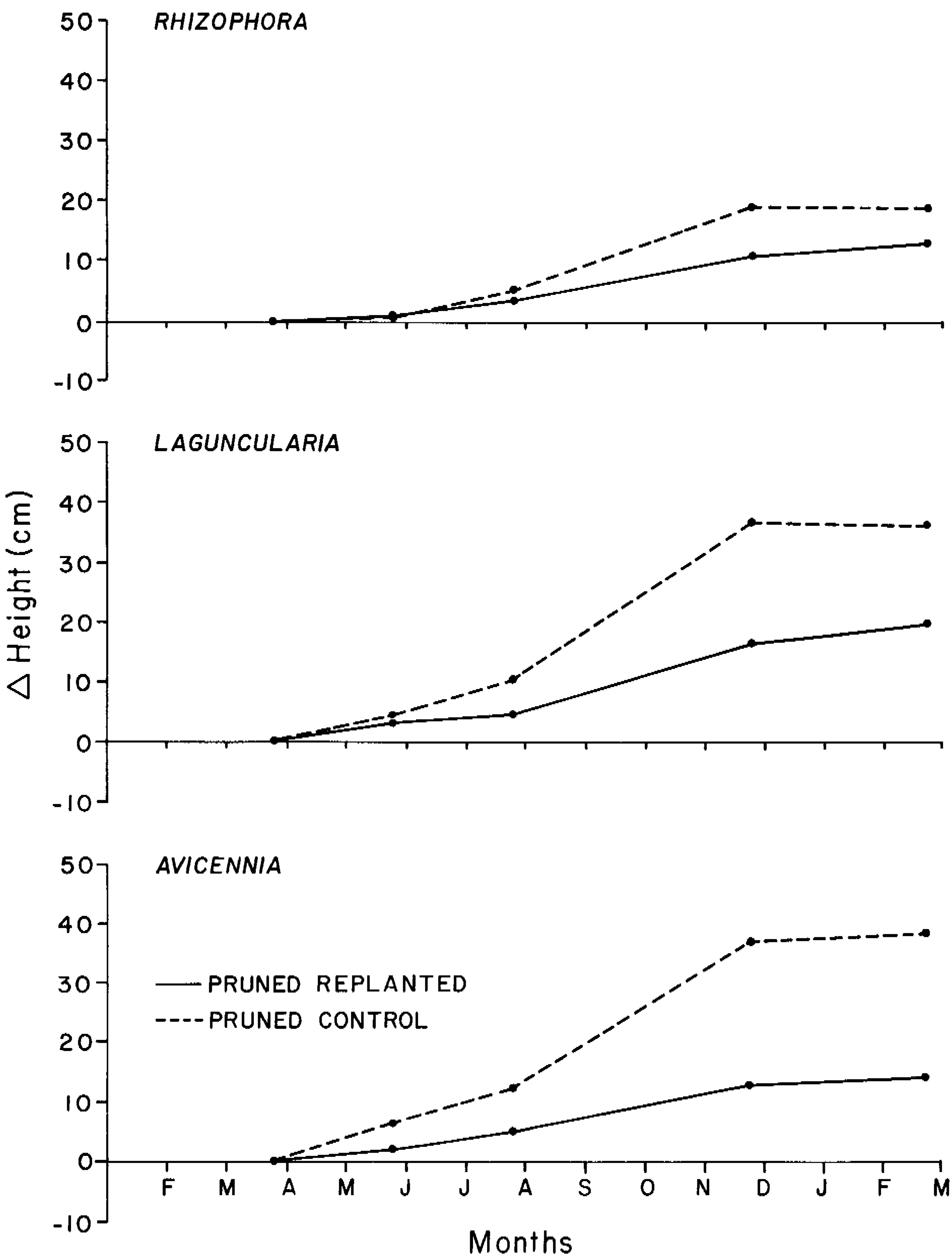

Figure 5. Difference in tree height between initial measurements on March 26th and subsequent measurement dates to illustrate growth with time.

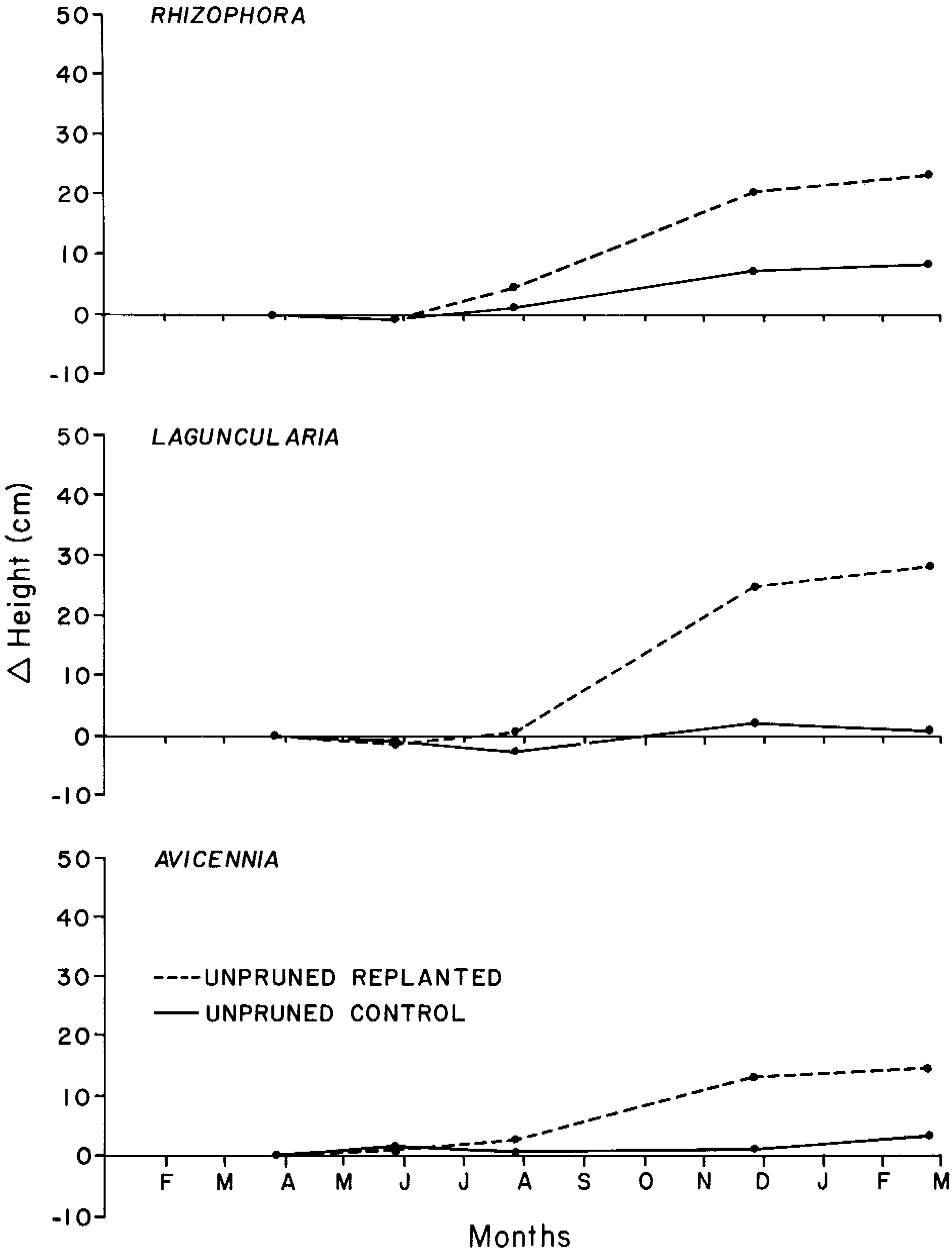

Figure 6. Change in tree height with time for unpruned replanted trees and unpruned control trees (non replanted).

0.46 for *Rhizophora*, 0.46 for *Laguncularia* and 0.48 for *Avicennia*. The amount of roots supporting pruned trees was essentially the same as the amount of roots supporting unpruned trees with more foliage. The advantage of pruning becomes apparent when one considers reduced foliage also means a reduction in transpiration.

In comparisions of unpruned controls, *Avicennia* appeared to be the slowest growing of the species tested. Unpruned *Rhizophora* controls grew 2.4 times as much as the unpruned *Avicennia* controls. *Laguncularia* appeared to grow fastest, producing 28.3 cm growth per year or 2.9 times as much as *Avicennia* (Table 1).

Salinities for interstitial water under replanted trees were 35-46 ‰ ($\bar{x}$=39.6‰) for *Rhizophora*, 27-54‰ ($\bar{x}$=40.00‰) for *Avicennia*, and 35-47‰ ($\bar{x}$=41.1‰) for *Laguncularia*. Mean salinity varied little between the two replanted groups within a species, the greatest difference was 3.2‰ in *Avicennia*. These salinities indicate a minimum tolerance range.

PRUNING

Comparisons between pruned and unpruned control groups within a species were used to quantify, as much as possible, the overall effect of pruning. *Rhizophora* was the slowest species to recover from pruning. Pruned controls grew only 18.2 cm per year, or 23% less than growth attained by unpruned controls. Growth was, however, apparently enhanced by pruning in *Avicennia* and *Laguncularia*. Pruned *Avicennia* controls grew 38.3 cm or a statistically significant 3.87 times as much as unpruned controls. Pruned *Laguncularia* grew 36.6 cm per year or 1.29 times as fast as controls (Figure 7).

Although the pruning technique was standardized for this experiment, work done by others suggests optimal pruning methods differ slightly between species. Gill and Tomlinson (1971) found lateral buds on *Rhizophora* would not grow on branches pruned back to a diameter greater than 2.5 cm and recommended pruning be restricted to smaller diameters. In contrast, *Avicennia* and *Laguncularia* recover well from extensive pruning, including that of major branches (Savage, 1972). E. Neubecker (personal communication) reports *Laguncularia* sprouts on 5-8 cm wood after pruning.

CONCLUSIONS AND RECOMMENDATIONS

The need for transplanting mangroves in Florida is occurring with increasing frequency, particularly with recognition of the value of these trees in providing shoreline storm protection, replacing damaged or destroyed shoreline communities, and as prunable ornamentals in public and private shoreline areas. The following preliminary recommendations are based primarily on the results of this limited study and review of the literature. Personal observations and discussions with other workers are also included. These recommendations are subject to revision and do not constitute State policy; they do, however, represent preliminary guidelines to be used as needs arise.

Tops and side branches should be pruned to ⅔ their original length shortly before or directly after transplanting to reduce mortality and aid recovery. According to Gill and Tomlinson (1971), it is necessary to selectively prune *Rhizophora* so that the distal end of the pruned branch is not greater than 1 cm in diameter. *Avicennia* and *Laguncularia* were found to recover well from extensive pruning, confirming Savage's (1972) study. Maximum pruned branch diameter need only be limited to 5 or 8 cm (E. Neubecker, personal communication).

Trees should be removed with a root ball diameter about half the original tree height. This is quite simple since a major portion of the root system lies near the surface allowing easy removal of trees with a shallow (20-25 cm deep), lightweight root ball. A rootball diameter approximately ½ the original tree height is generally sufficient to sustain a 0.5 to 1.5 m pruned mangrove through the recovery period. Keeping the rootball intact seems advantageous; however, it is possible to successfully transplant bareroot (E. Neubecker, personal communication). *Rhizophora* proproots should be included in the rootball when possible. If severed, they should be left on the tree without further pruning for possible regrowth.

The rootball should be watered and stamped down while replacing soil to aid sealing between the rootball and sides of the hole. This procedure and any subsequent watering are likely to be more important in higher, less frequently inundated situations. Trees should be replanted approximately the same level in the ground as they were in the original habitats. Care should be taken not to cover pneumata-

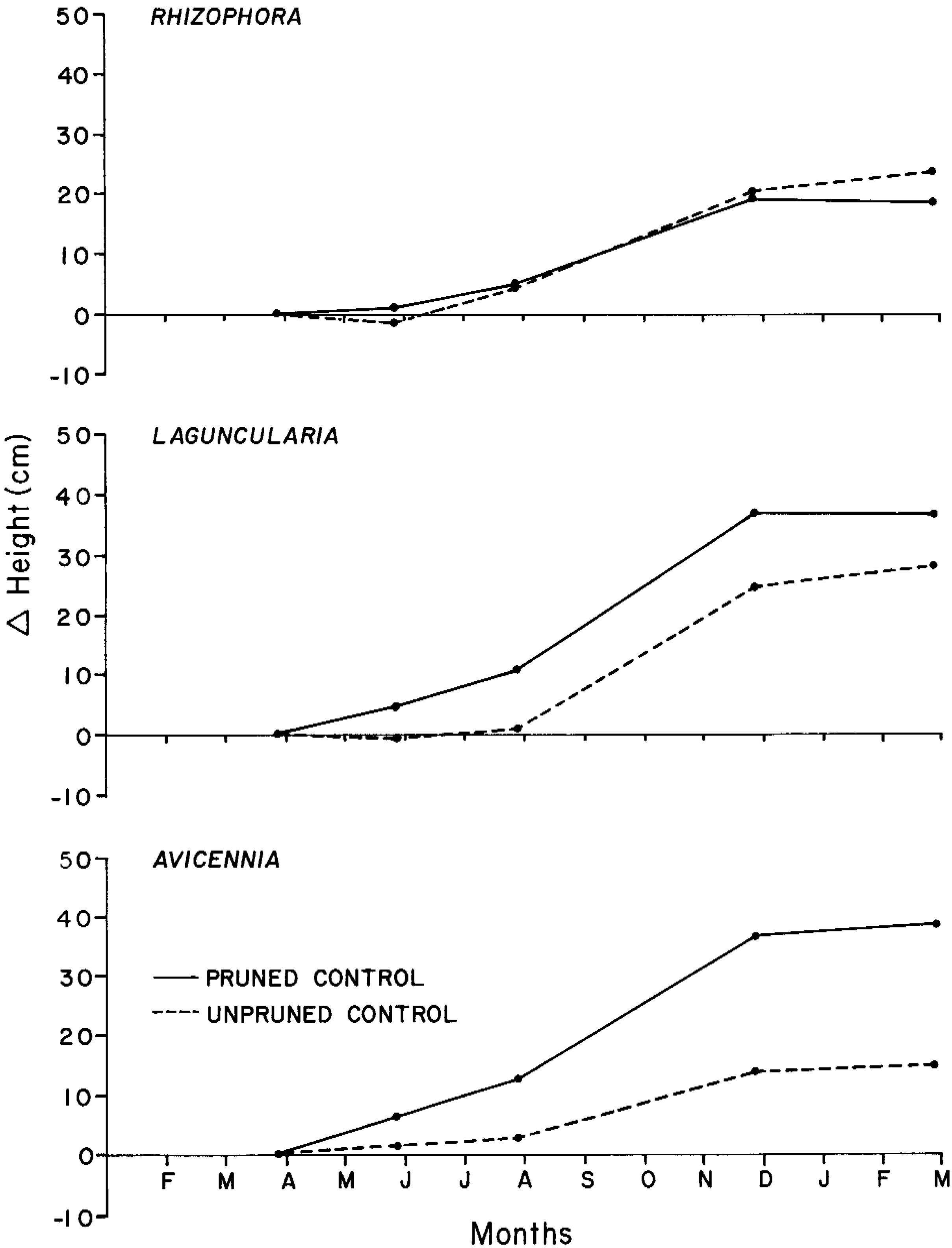

Figure 7. Change in tree height with time for pruned and unpruned controls (non-replanted trees).

phores or proproots because this will reduce aeration of subterranean roots and, possibly inhibit quick recovery of trees. Slow release organic fertilizers such as composted manure, worked into the hole before planting may aid the recovery process.

When trees are translocated great distances to an area where it is not known which species will be most successful, mixed stands can be planted to gain all the advantages offered by each species. The following comparisons illustrate that each species has adaptations which may make its use more desirable in a given planting situation. *Laguncularia* seems to be the fastest growing but is the least hardy to cold (Savage, 1972), a concern when transplanting is in the northern part of its range. Conversely, *Avicennia* seems the slowest growing but most cold hardy. According to Davis (1940), who worked with mature undisturbed stands, *Rhizophora* frequently tolerates the deepest submersion, *Laguncularia* the driest soil, and *Avicennia* the highest salinity. *Avicennia* and *Rhizophora* have well developed aerial root systems to trap seaweed and debris, *Laguncularia* does not. If on the other hand, nearby mangrove stands exist, one can decide which species to transplant by determining the dominant species at the same elevation and exposure of the established site.

Trees should never be planted in unstable substrates. All three species have a common limitation often overlooked before transplanting; substrate stability. Presence of scattered mangroves, established seedlings, other salt marsh vegetation, fine muddy substrate, or dark odorous anaerobic soil near the surface may be used as natural indicators of favorable substrate stability. Absence of these may not necessarily indicate unfavorable conditions, but a few test transplants may be advisable to make any final determination of transplant feasibility.

Each tree regardless of species, should be planted at an elevation similar to that at which it originally grew. Windrows of seaweed or debris, wet sand, high barnacles on seawalls or mangroves, and the waterline are generally the easiest references for transferring elevation from one place to another along the waterfront without need of instruments.

From this preliminary work, transplanting 0.5 to 1.5 m mangroves seems quite practical if done in areas where proper conditions exist. Their larger size and more extensive root systems offer promise of greater and faster shoreline protection than can be achieved using seedlings. Presently, however, older trees must be supplied at the expense of existing natural stands. Trees approved for removal during shoreline construction also seem likely candidates; however, both alternatives offer a very limited supply of trees, not to mention further deprivation of a natural and necessary environment. This situation dictates the pursuit of nursery stock. However, seedlings raised in nurseries would take four to six years to reach this size. Conversely, air layers or rooted cuttings, if large enough (0.5-1.5 m) may provide a faster, more efficient method of obtaining stock for restorative work.

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ADDENDUM

SUGGESTED MANGROVE TRANSPLANTING TECHNIQUES*

From this preliminary work, transplanting 1.0 to 1.5 m mangroves seems quite practical if done in areas where proper conditions exist. Their larger size and more extensive root systems offer promise of greater and faster shoreline protection than can be achieved using seedlings. Presently, however, older trees must be supplied at the expense of existing natural stands. Trees approved for removal during shoreline construction also seem likely candidates; however, both alternatives offer a very limited supply of trees, not to mention further deprivation of a natural and necessary environment. This situation dictates the pursuit of nursery stock; however, seedlings raised in nurseries would take four to six years to reach this size. Conversely, air layers or rooted cuttings, if large enough (0.5 to 1.0 m), may provide a faster, more efficient method of obtaining stock for restorative work. Experiments have shown 1.0 m air layers of *Laguncularia* root quite readily. Smaller *Avicennia* air layers have produced callousing and some swelling where roots should appear. No attempt was made to air layer *Rhizophora*. *Laguncularia* cuttings also show great promise for rooting under freshwater mist. *Avicennia* and *Rhizophora* cuttings rotted under freshwater mist. Seawater misting of *Avicennia* should be attempted due to the salt-excreting nature of the plant. Inclusion of a small proproot on *Rhizophora* cuttings or air layers should prove beneficial to successful propagation.

In addition to transplanting experiments, a small survey was conducted to determine progressive natural (e.g., shade out) mortality of a given stand as its mean height increases from about one to two-and-a-half meters, the largest practical size for transplanting. To do this, we first assumed all mortalities (decreases in density) resulted from competition with other trees in the immediate area. Due to the short time allotted for the survey, we allowed density changes between stands (four of red, eight of white and five of black) having different mean heights to represent changes which occur in three stands (one of each species) over several years. Stands composed of one predominant species, and with density visually appearing to approach maximum, were selected. Thus, plotted density data would yield a fairly smooth curve for each species which random sampling would not have given us with the small sample size.

Rectangular quadrats were laid out with posts and string, two adjacent sides measured with a meter stick, and the enclosed area computed. Quadrat size ranged from 3.8 to 4.3 m^2 for stands of mean height to 1.4 m and from 6. 0 to 9.2 m^2 for stands taller than 1.4 m. Heights were measured with a 3 m length of PVC pipe marked in 2 cm increments. Height measurements were taken of all trees in each quadrat. Seedlings in all samples and understory trees less than 1.8 m in the 2.5 m samples were not measured or included in density calculations as those were later additions and did not reflect mortality occurring among the original trees.

Densities for *Laguncularia* decreased from 57.5 trees/m^2 for 0.9 m height to 4.3 trees/m^2 for trees 2.5 m tall (Figure 8 [Figure 1 in original publication]). Overall, *Avicennia* and *Rhizophora* densities were always lower than *Laguncularia*. *Rhizophora* decreased from 26.8 trees/m^2 for 1.2 trees to 8.3 trees/m^2 for 1.9 m trees (Figure 8). *Avicennia* density decreased from 21.4 trees/m^2 at a height of 1.1 m to 6.2 trees/m^2 at 2.3 m.

These data suggest that within the time required for 1.0 m trees to grow to 1.8 m height at least 50% of them will be naturally thinned out, presumably by competition. Therefore, if transplant stock of 0.5 to 1.5 m trees has to be temporarily removed from natural stands, every other tree could theoretically be taken, providing that in such removal care was taken not to damage those remaining. This estimate is conservative because our density estimates ignored both seedlings and understory trees which were numerous, particularly in the taller (2.3-2.5 m) stands. However, with demand for mangroves steadily increasing, commercial sources should soon become available, and hopefully tree removal from natural stands will then be unnecessary.

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*Excerpt from Pulver, T. R. 1975. Suggested mangrove transplanting techniques. Pages 122-131 in R. R. Lewis, ed. Proceedings of the Second Annual Conference on Restoration of Coastal Vegetation in Florida. Hillsborough Community College, Tampa, Florida.

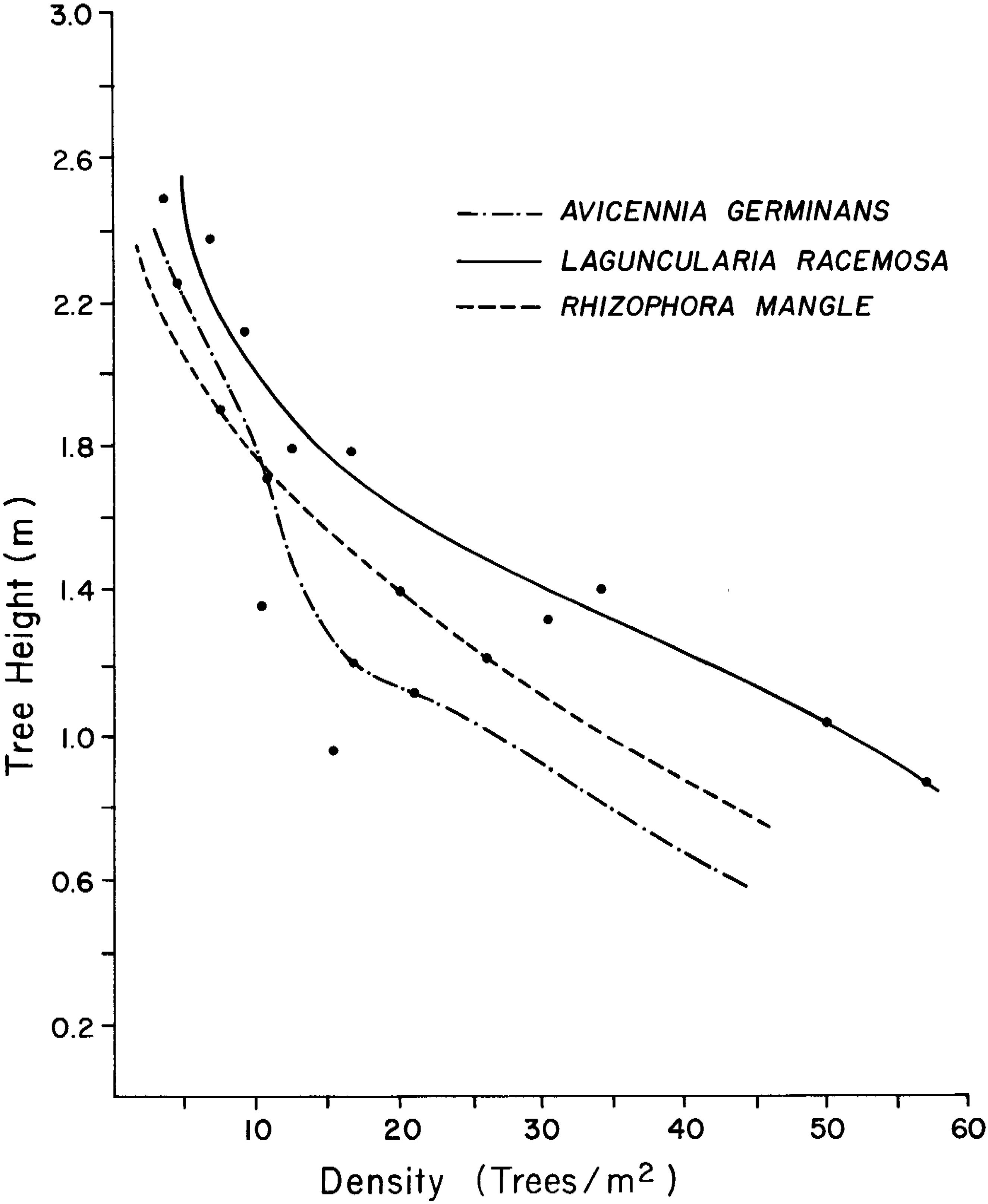

Figure 8. Mangrove tree density for different height classes.