

Puerto Rico:
DNR

Department of Natural Resources

Technical Report

ESTABLISHMENT AND RESTORATION OF MANGROVES

A manual for environmental managers

Document prepared by Gilberto Cintrón, Marine Resources Section, Department of Natural Resources, Government of Puerto Rico, P.O. Box 5887, Puerta de Tierra, Puerto Rico, 00906.

From: Ariel

Department of Natural Resources

Technical Report

ESTABLISHMENT AND RESTORATION OF MANGROVES

A manual for environmental managers

Document prepared by Gilberto Cintrón, Marine Resources Section, Department of Natural Resources, Government of Puerto Rico, P.O. Box 5887, Puerta de Tierra, Puerto Rico, 00906.

CONTENTS

	<u>Page</u>
Introduction	1
Planting seedlings	3
Transplanting trees	4
Spacing	7
Selection of habitat	7
Air layering	8
Costs	9
Success of restoration efforts	11
Aesthetic enhancement of mangrove trees and forests	15
Bibliography	17

PREFACE

The preparation of this manual was supported by the U.S. Coastal Zone Management Program (NOAA) and the Department of Natural Resources of Puerto Rico. The author also received travel and subsistence funds from the International Union for Conservation of Nature and Natural Resources (IUCN) to participate in a Mangrove Handbook Writers Workshop jointly sponsored by IUCN and UNESCO, held at the East-West Center Environment and Policy Institute (Hawaii) in October 1983. At that meeting the draft of this report was read and reviewed by the workshop participants, and many suggestions were received and incorporated. The resultant text was contributed to the meeting and will appear as a chapter in the forthcoming Mangrove Handbook.

Although all participants to the workshop provided suggestions for the contents and format of the text, especially substantive contributions were received from Dr. Peter Saenger (Australia), and S.C. Snedaker (Univ. of Miami, Rosentiel School of Marine and Atmospheric Sciences). Dr. Saenger edited the original text and added data pertaining to old world mangrove species. To all, the author expresses his thanks.

INTRODUCTION

The establishment or restoration of mangroves is an important management option which can be applied for the stabilization of unvegetated areas (such as river banks, shorelines, canals, spoil heaps) or to enhance or regulate natural regeneration.

In general planting of large tracts for non-silvicultural objectives is best left to nature because of the expense involved. However it is possible to prepare the terrain and accelerate the recovery of a stand by planting in naturally "bald" spots or thinning of dense clumps of arrivals to avoid "stagnation".

If an area has been subjected to a stressor then it is necessary, for success, that the source of stress has been largely removed and only tolerable amounts left, before attempting restoration. It will also be desirable to remove dead standing and fallen wood to avoid damage to the new growth at the site.

Before attempting the restoration of a particular area, consideration should be given to the following:

- * Select target sites carefully. If the area has contained mangroves before, determine the cause of loss and make sure the stressor has been removed. Naturally "blank" areas may be hypersaline or too elevated for successful establishment.

- * The selection of the species to plant should always be made on the basis of the dominant species at nearby locations having similar

elevations, frequency of inundation, and exposure. Because of their ease of handling and planting, species of the Rhizophoraceae (Rhizophora, Bruguiera, Ceriops and Kandelia) are the most suitable species for restoration projects, but they may not always be appropriate.

- * Soil elevation should be low enough that the area is frequently flooded by tidal water, and there is adequate circulation. Stagnant areas tend to overheat.

- * Measure interstitial (soil) salinities. Interstitial salinities will determine the most suitable species. For example, areas above 55‰ are not suitable for Rhizophora mangle.

- * Areas must be sheltered from wave action and current scour.

- * Remove dead standing wood and clean-up the area. Floating or falling debris will uproot and damage planted seedlings.

- * Control the spacing of seedlings. Dense plantings result in slower growth due to competition. For Rhizophora spp. the recommended spacing for seedlings is 0.6 - 1.2 m.

- * Recently fallen propagules may be collected from nearby mangrove areas or they may be collected from trees. Use only ripe propagules. For red mangrove, use those propagules in which the abscission layer has developed. (These are easily detached from the parent tree). Select healthy propagules and discard malformed or damaged ones. Maintain the collected material wet and avoid exposing it to overheating during transportation and before planting. Propagules can be carried in a foam icebox or

a wet burlap (hessian) sack.

* Propagules should not be inserted too deeply into the substrate.

For example, Rhizophora should be planted only deep enough that it will not fall over. For a 20-30 cm seedling the planting depth should be 4-7 cm.

Planting Seedlings

Rhizophora is one of the easiest and most economical species to use for planting. These propagules may be collected and stored for more than 20 days in a moist container before use, and they can be allowed to develop primary roots without impairment of their vigor. Mortality of these seedlings is site-specific and may range from 10-70%. Although usually the recently collected mature hypocotyl is used for planting, it may in some circumstances be appropriate to grow these in a nursery before planting. A better survival rate and more rapid growth in the early stages may result. The advantage cited for this planting method is that the seedling is allowed to develop a healthy root system before implantation. However, the higher nursery costs and increased difficulty of planting will often offset this advantage.

Seedlings of other species (eg. Avicennia, Heritiera, Laguncularia, Cynometra) may be sown by hand. They should be left on the surface and not buried, although some gentle pressure can be used to push them into the soft sediments. They must be seeded at a time when the area is not

expected to be flooded by tides for at least a week so that the seeds do not become dispersed and have time to become established. It is to be expected that a much lower percentage of the seedlings will become established (probably less than 50%) so it is important to ensure that distribution of propagules to the site is repeated as necessary.

Transplanting Trees

Small trees of: Rhizophora mangle, Avicennia germinans and Laguncularia racemosa (five or more years old, 0.5-1.5 m high) have been successfully replanted. Planting of trees of this size may be desirable where seedlings are at a risk of being uprooted and washed away. The larger size of the trees and their more extensive root system offers a promise of greater and faster shore protection than can be achieved using seedlings. This technique may also be used to salvage individual trees in areas which are to be used for other purposes. These can serve as a pool of trees for restoration purposes in other areas.

The survival of larger trees following transplantation appears to be poor. For instance, the transplantation of 13 black and 1 white mangrove trees 5-13 cm in diameter and up to 6 m high resulted in the death of all trees within 6 months. These trees had been root pruned 5-6 months before transplantation and were top pruned to 1/4 - 1/3 their height at the time of transplanting. Moving the trees rather than pruning caused the mortality.

Other species eg. Avicennia marina, Aegiceras corniculatum and Rhizophora stylosa can also be transplanted. For plants less than 1 metre high, success rates of approximately 80% have been achieved.

When the root ball and soil free transplanting techniques for planting small trees are compared, the root ball method yields higher survival rates (85% VS 65% after 3 months) when the trees are planted at natural depths and leaves intact. Leaf stripping resulted in an initial high rate of leaf production but after 4 months the normal (unpruned) trees had a greater leaf complement. Leaf pruning did not seem to affect survival.

Pruning before replanting apparently enhances recovery; pruned trees grow better and suffer less defoliation than unpruned ones. Pruning increases the ratio of root to above ground structure so that more roots support less foliage. Reduced foliage also decreases water loss during the adaptation period following transplantation. Trees or bushes to be replanted should be pruned to two thirds or their original height.

Unpruned and some pruned individuals of Rhizophora and Laguncularia exhibited defoliation following transplantation. First, the older proximal leaves turned yellow and were dropped. The distal leaves were only dropped in cases of complete or nearly complete defoliation. In Laguncularia and Rhizophora defoliation occurred within 36 days after replanting but in Avicennia this occurred later, some 84 days after. Rhizophora suffered little defoliation even if unpruned and pruning resulted in a 23% decrease in growth after transplant. Pruned and unpruned Laguncularia had difficulty

in becoming established but pruning did increase growth rates of this species following transplanting.

Pruned and unpruned Avicennia respond well to transplantation although some trees will show partial defoliation. Pruning increases growth slightly subsequent to transplanting.

Care must be taken in pruning Rhizophora. If pruned back to branches greater than 2.5 cm, there will be no sprouting and the branch will continue to die-back. It is recommended that pruning be restricted to smaller diameter branches only. In contrast Avicennia and Laguncularia are extremely tolerant of pruning, and this can include major branches as well.

Where individuals are being pruned for transplantation the root ball diameter should be as large as possible and no less than one half the original (unpruned) tree height. The root ball must be dug from a depth of at least 20-25 cm to reduce damage to the root system. The root ball should remain intact. In the case of Rhizophora, proproots should be included in the root ball but if severed they should be left on the tree for possible regrowth.

Replanting should be made at approximately the same tidal level as the original habitat. The root ball should be placed in the prepared hole, watered and stamped down while replacing soil to seal the space between the root ball and the sides of the hole. During this stage care must be taken not to bury or damage proproots or pneumatophores. It is possible that slow release fertilizers placed in the hole before planting could aid in the recovery process.

Spacing

The determination of proper spacing intervals should be based on the distance which will minimize early competition. Thinning and an increase in spacing will occur naturally without human intervention; however, a stand can be managed to avoid periods of slow growth due to competition. By selecting an appropriate spacing, artificial thinning is postponed to later stages of development of the stand.

A planting distance of .4 m - .6 m has been used in plantations of Rhizophora mucronata in the Philippines. For mixed stands of R. apiculata and R. mucronata a spacing of 1.8 x 1.8 m has been recommended. In general at a mean tree spacing of more than one meter, self pruning does not start until the 7th year.

Selection of Habitat

Each species should be planted within its tidal and flooding tolerance range and in suitably sheltered locations. In most cases it will be possible to ascertain these site characteristics by observing the growth of mangroves in the immediate vicinity. Where this is not possible more time consuming steps must be taken to ascertain the elevation of the site above the tidal datum and to predict flooding depths. Species tolerant of submersion should be planted at the seaward edge (eg. Rhizophora mangle, R. stylosa, Avicennia marina, Sonneratia spp.).

Ideally planting should be made behind a protective mangrove fringe. When such a fringe is not available it may be advisable to develop a

protective barrier by transplanting small mangrove trees.

At the landward margins, species tolerant of drier conditions should be used (eg. Lummitzera racemosa, Ceriops spp., Excoecaria agallocha, Laguncularia racemosa).

Air Layering

Air layering has been suggested as a promising technique to provide stock plants for transplantation without removing mangroves from a source area. It is a commonly used horticultural technique in which short segments of bark and phloem are stripped to the cambium and the exposed area is wrapped with Sphagnum moss and aluminum foil to retain moisture. This promotes the development of roots at the girdled area and allows the branch (the layer) to be removed from the parent plant and planted.

Experiments with this propagation technique have been limited to branches < 2.5 cm since in Rhizophora mangle there appears to be no regrowth on branches greater than that size. In summary, these investigations found that the girdling was more easily done in Laguncularia racemosa, followed by Rhizophora mangle and Avicennia germinans. However, the technique was most successful with R. mangle (rooting success 39%) followed by L. racemosa (35%) and A. germinans (6%).

R. mangle produced the longest roots and these often protruded from the aluminum foil. These roots were firm, had good color and often had short secondary roots. L. racemosa and A. germinans produced smaller roots. A. germinans often produced roots off the stem above the layer site.

Callus formation occurred in 45% of the R. mangle airlayers, 20% of the A. germinans and 15% of the L. racemosa which had not produced roots.

Layering was done internodally, although when the internodal length was short, adjacent nodes may have been included. The girdled area was covered with Sphagnum moss saturated with distilled water. The Sphagnum was placed around the cut covered within aluminum foil and secured with tape. It has been suggested that this technique should be attempted at the beginning of the wet season to assure exposure to moisture (and in Florida to warm weather). Moisture appears to be a crucial factor determining the success of the technique. Too little water (drying) impairs root formation whereas too much water may promote fungal and bacterial infections and cause death of the branch above the wound.

Additional work is needed to ascertain the practicability of this technique. Among the variables which still need further experimentation are: type of wrapping material (aluminum foil, plastic or other), and effect of application of rooting hormones, and whether the plants can be planted directly or need to be stored under mist conditions for some time.

Costs

The cost of restoration of mangrove areas may be highly variable depending on such factors as the local labor costs, characteristic of a site (its accessibility), its proximity to propagule sources, the need for nursery stock and whether propagules or more mature stock (transplanting)

is used.

In Malaysia, for example, the following costs were found: At Port Klang, Selangor, contractors were paid M \$40.00 per acre, while at Matang, Perak, Forestry Department staff undertook planting at M \$30 - \$80 per acre over a four-year period (1977-1981).

For red mangrove (R. mangle) planting, in the U.S.A., restoration cost of \$10,175/ha for a spacing of 30 cm, \$2,470/ha for 61 cm and \$1,140/ha for 91 cm have been reported. The costs of similar projects using black (A. germinans) or white (Laguncularia racemosa) mangrove were about twice the above estimates: \$22,400/ha for 30 cm distances, \$5,400/ha for 61 cm and \$2,510/ha for 91 cm spacing. The cost of planting 3 year old trees at 123 cm spacing was estimated at \$216,130/ha based on nursery grown stock at a price of \$35.00 per unit. These costs were extrapolated from small scale experimental plantings and exclude profits and overhead. Other expenses which can increase these costs considerably are the need for pre-planting surveys (biological & topographic), site preparation and administrative (permit transmittal, etc.).

Actual costs for a red mangrove (R. mangle) planting project at a 91 cm spacing was \$12,500/ha, more than 10 times the cost of the small scale experimental planting. This was based on the actual costs incurred until 1979 for a large scale mangrove restoration project on St. Croix (U.S. Virgin Islands).

Success of Restoration Efforts

The success of many planting efforts is difficult to assess. The degree of exposure to wind and wave action is a crucial factor. Efforts to plant on rapidly eroding shorelines, exposed locations or in areas of heavy boat washes end with very little success. When nature does the planting, the propagules disseminate over broad areas and only those which reach the proper locations develop into mature trees. This is achieved through massive plantings in space and through time so that "opportunistic" plantings can take place during unusual periods when conditions may briefly become conducive to establishment. Once established, these plants may fare better and have a greater chance of becoming mature trees.

Often man attempts to plant trees in areas where none are found. This invariably results in a waste of effort since the same forces that eliminated nature's plantings take care of man's.

In 1938 John Henry Davis planted 4100 Rhizophora mangle seedlings at Long Key, Tortugas, Florida. These were planted on calcareous sands and muds and on coral ballast where mangroves were forming a pioneer community. The plantings were made to see if a thick stand of R. mangle could be developed to hasten the natural process of establishment of the swamp. By July 1939 about 3300 (80%) had survived. Thirty two years later none of these planted trees could be found.

At a high energy site in the St. Lucie River (Florida) all of 178 seedlings planted were lost within 7 months. At a moderate energy site where seedlings had been planted in jute mesh, survival was less than 10% after one year. At a low energy site on the east coast (isolated from public access) 90% of the plants survived after 4 years. At Charlotte Harbor (Florida) in a low energy site 85-90% of 60,000 propagules survived after one year the majority were alive after the end of the second year.

In a location in the south coast of St. Croix, U.S. Virgin Islands 75% of the red mangrove seedlings planted survived after one year and 40% survived for 2 years. A total of 86,000 red mangrove seedlings were planted. Success with black mangrove (sown by hand) was low (1-2%) and only successful where wave and current energy levels were minimal. In some areas growth of the black mangroves was very rapid, with some trees attaining 1 m in height in 20 months. Flower and seed production was seen at the end of this period in this species.

Planting in a dredge spoil island in Florida resulted in a survival of 15.7% of the 2477 trees which had been planted. These had been planted 0.9 m apart and had root balls 20-38 cm in diameter. Some of the transplanted trees had been treated upon planting with 100 g of 6-6-6 fertilizer. Three years after the initial planting there were some 389 survivors only. The main factor impairing survival was attributed to the settling of the island, which resulted in some submergence of the planted trees (possibly stressing the plants) and the enhancement of erosion.

Embedded tires have been used to protect the transplants from uprooting by erosion. Embedding in tires does not appear to affect growth; for instance no difference in new leaf production has been found between plants grown in tires and those planted outside of tires. Tire embedded trees are vulnerable to storms which erode the sand around the tires and can toss them on the beach. Trees protected by tires and planted below high tide level may be vulnerable to attacks by wood boring isopods such as Sphaeroma.

Planting in high energy environments yields poor results, for instance 920 seedlings of the three major mangrove species were planted at the Tampa Electric Company's Big Bend Power Plant, in Tampa Bay and although some of the seedlings were provided with artificial protection (such as stakes and rubber tires), the success rates were low. Only 1% of the red mangrove, 16% of the blacks and 10% of the white mangroves survived. The survival of planted red mangrove propagules was the poorest, only 2%. These low success rates were due to erosion caused by storm-induced waves and tides during winter.

Experimental plantings in an exposed area of North Biscayne Bay resulted in a survival of only 7 of the 370 plants (red, white and black mangroves) after 10 months and none survived after 24 months. In a low energy canal site, survival after six months of 57 red mangrove trees (0.6-2.7 m tall), 13 black mangrove (1.2-2.5 m) and 18 white mangroves (.3-3.6 m) was 100%.

This review shows that uprooting by waves and erosion is a crucial factor impairing the success of many artificial restoration projects. This stems from the attempt to plant trees along fringes where the rate of attrition is high and where restoration would necessitate a continued planting effort with no guarantee of success. Planting efforts are most successful in riverine environments which are characterized by lower energy levels, low salinities, high nutrient levels and very suitable environments. Even in these environments, a mature fringe of trees is left along the river banks when clearcutting to protect the inner areas from scouring and erosion. It seems that quite often mangroves are planted in exposed locations and marginal to poor substrates. Since the trees grow poorly (and slowly) in these environments they are vulnerable to uprooting for a longer time period while subjected to greater exposure.

Planting on spoil islands has the risk that settling will increase exposure and erosion and lead to loss of the planted trees. If designed to be planted with mangroves the island must be provided with an overburden so that when stabilized it will achieve the proper elevation in reference to the tidal datum. Since in most instances there are propagule sources, spoil islands, once created and naturally stabilized, tend to become colonized by mangroves. Such naturally colonized by mangroves. Such naturally colonized islands are common in dredged channels in Florida, Puerto Rico and Venezuela (Lago Maracaibo). Vegetation becomes adapted to the characteristics of the islands. For example, in

Venezuela the outer fringe is dominated by Laguncularia racemosa while the inner part of the island was colonized by Avicennia germinans. In Puerto Rico and Florida many sandy dredge spoil islands have outer fringes of Rhizophora mangle whereas the inner higher portion of the island is populated by the Australian pine (Casuarina).

Aesthetic Enhancement of Mangrove Trees and Forests

There are a variety of situations in which horticultural practices can be employed to enhance the aesthetic appearance of mangroves and/or create a panoramic view from inland sites. The practices can be divided into two types based on the ultimate objective. First, individual trees or groups of trees, can be pruned, trimmed or shaped for aesthetic purposes in residential and waterfront settings in urban areas. In general, standard horticultural techniques can be employed without any modification or concern about the foliar response of the tree or trees. The only qualification is that some species of mangroves have regenerative limitations which must be taken into account during the pruning or trimming.

In the second type of horticultural management, the objective is to reduce the height of a forested area to achieve a panoramic exposure of adjacent areas. In general, this objective is met through the topping and/or removal of selected trees to stimulate coppice regrowth and/or the rapid growth and development of seedlings and small saplings. When the coppice and new sprout growth forms a full, but lower-level complement of foliage, the remaining trees can be topped or removed. Annual

pruning and trimming of the new growth is all that is required to maintain the vegetation at a desired height. Based on the regeneration characteristics of the species, different strategies are employed to achieve the final result. For example the Rhizophora cannot survive a complete removal of branches and foliage. When an abundant propagule source is available, however, total removal of selected trees (approx. 50 percent of population on site) is recommended to stimulate seedling/sapling growth). In the event there is an inadequate propagule source (unlikely in most areas) or there is a high probability of competitive domination by other mangrove species, the Rhizophora should be pruned or cut back in stages over a period of several years.

An advantage afforded by the ability of mangroves to be managed using standard horticultural practices is that certain objectives, albeit limited, can be attained without the destruction or total removal of the mangrove forest. The practice is non-controversial and may also be considered an alternative to the complete removal of mangrove forests for competing aesthetic reasons.

BIBLIOGRAPHY

- Autry, A.S., V.N. Stewart, M. Fox, and W. Hamilton. 1973. Progress report: Mangrove planting for stabilization of developing shorelines. Q.J. Fla. Acad. Sci. 36:17 (Abstr.).
- Carlton, J.M. 1974. Land-building and stabilization by mangroves. Environ. conservation, 1: 285-294.
- Carlton, J.M., and M.D. Moffler. 1978. Propagation of mangroves by Air-Layering. Environmental Conservation, Vol. 5, No. 2, p. 147-150.
- Cintron, G., and Y.S. Novelli. 1982. Mangrove Forests: Ecology and response to natural and man induced stressors. In: Coral Reef, Seagrass Beds and Mangroves: Their interactions in coastal zones of the Caribbean. Workshop, West Indies Laboratory, Fairleigh Dickinson Univ. St. Croix U.S.V.I.
- Davis, J.H. 1940. The ecology and geologic role of mangroves in Florida. Carnegie Inst. Wash. Publication. 517: 303-412 (Papers from the Tortugas Lab. Vol. 32).
- Gill, A.M., and Tomlinson, P.B. 1971. Studies on the growth of Red Mangrove (Rhizophora mangle L.). 3: Phenology of the shoot. Biotropica 3 (2), pp. 109-124.
- Hannan, J. 1975. Aspects of red mangrove reforestation in Florida. Pp. 112-121. In: R.R. Lewis (Ed.), Proceedings Second Annual Conference on Restoration of Coastal Vegetation in Florida. Hillsborough Community College, Tampa, Florida. 203 pp. p. 46, 47.
- Kinch, J.C. 1975. Efforts in marine revegetation in artificial substrates. Pp. 102-111. In: R.R. Lewis (Ed.), Proceedings Second Annual Conference on Restoration of Coastal Vegetation in Florida. Hillsborough Community College, Tampa, Florida. p. 46.
- Lewis, R.R., 1979. Large scale mangrove restoration on St. Croix, V.I. Pp. 231-242. In: D.P. Cole (Ed.), Proceedings of the Sixth Annual Conference on Restoration and Creation of Wetlands. Hillsborough Community College, Tampa Florida. p. 45.
- Lewis, R.R. 1981. Economics and feasibility of mangrove restoration. Pp. 88-103. In: R.C. Carey, P.S. Markovits and J.B. Kirkwood (Eds.), Proceedings U.S. Fish and Wildlife Service Workshop on Coastal Ecosystems of the Southeastern United States. U.S. Fish and Wildlife Service, Office of Biological Services, Washington D.C. FWS/OBS-80159. 257 pp.