Natural and Mechanical Alterations of Mangrove Forests

A Review prepared by

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1.0 INTRODUCTION

Mangroves are plants that live in the intertidal zone, and are thus exposed to daily inundation for at least brief periods with salt water. There are currently 69 species of plants called mangroves in various parts of the world (). Sixty-five of these are trees, three are ferns and one is a palm. Numerous experiments have shown that mangroves can tolerate exposure to saltwater, but do not require it to live. Thus they are correctly call facultative halophytes (i.e., can tolerate salt) not obligatory halophytes (i.e., can only live in a saltwater environment).

Among the other adaptations of plants called mangroves, are a tolerance for anaerobic conditions in the soil surrounding their roots and thus the presence of the toxic gas hydrogen sulfide in either dissolved or gaseous form in the soil. This is a characteristic shared with plants found in flooded soils, both freshwater and saltwater, called wetland plants. Because saltwater typically has larger amounts of dissolved sulfur in the form of the sulfate radical, hydrogen sulfide production is an order of magnitude greater in flooded marine soils.

2.0 ECOLOGICAL VALUE

Up until the late 1960's, mangrove forests were not considered a valuable, functional, ecosystem, in Florida, or anywhere else (Lugo and Snedaker 1974). It was only after a joint research project done to complete the doctoral theses of two graduate students at the University of Miami produced Odum (1971) and Heald (1971), that the true role of mangroves in a unique detritus based food web was documented. Lugo and Snedaker (1974) summarized the ecological role of mangroves and noted that Odum (1971) had found that decayed leaf material from mangroves (i.e., mangrove detritus) was a principal component in the food web of south Florida estuaries where most of the sport and commercial finfish of the Gulf of Mexico spend some portion of their lives.

Odum et al. (1982) and Lewis et al. (1985) provide expanded summaries of the knowledge gained in the 10 years following the original recognition of the real ecological role of mangroves. In particular the role of mangrove detritus as a source of energy to support both food items of fish, and small fish themselves that became food items for larger predators, including larger fish, wading and diving seabirds, and ultimately man as he harvested fish as food items was clearly demonstrated.

Beyond that role, mangrove forests were found to provide a directly utilized habitat to shelter juvenile life history stages of many of the commercial shellfish and finfish species important in both the multi-billion dollar commercial and recreational sport fishing industries in Florida. Odum et al. (1982) lists 217 species of fish found in mangrove habitats and Lewis et al. (1985) illustrated the life histories of several commercially and recreationally important shell fish and finfish species, documenting the unique role of mangrove forests and associated habitats (i.e., oligohaline marshes, tidal flats, seagrass meadows, salt barrens) as critical nursery habitat for species like pink shrimp and spiny lobster that are often harvested as adults in habitats far removed from their mangrove nursery habitat.

Mangrove forest habitat, and production of fish and shellfish, are also critical to the life history requirements of many species of wading and diving seabirds and shorebirds. These include nesting habitat for species such as the Brown pelican, Great Blue heron, Reddish egret and Roseate spoonbill, among others.

This importance as habitat is highlighted by declines in the overall numbers of shellfish, finfish and seabirds as the amount of mangrove habitat has declined. Localized analyses are summarized by Lewis et al. (1985) and show an overall decline of 150,000 acres or 23% of the historical mangrove forest acreage in Florida, with a 44% decline in total mangrove and tidal marsh habitat (from 24,830 acres to 13,906 acres) for Tampa Bay. These losses are largely due to dredging and filling of shallow coastal mangrove habitat to create waterfront property with deep channels for both commercial use by ports, and private waterfront homes with boat slips.

The remaining acreage of mangroves thus becomes more valuable as a refuge for all forms of marine life, and those species dependent on mangroves for food, refuge, nesting, spawning and resting habitat.

3.0 GROWTH AND REGROWTH

Mangroves only occur in a portion of the earth where warm temperatures are normal, and freeze events rare. Thus they are limited to tropical and subtropical regions of the world. This is normally described as between 31° north latitude and 37° south latitude (Tomlinson 1986). Close to these latitudinal range limits mangroves may be frequently subjected to natural partial or complete defoliation as a result of below freezing temperatures that can kill the terminal shoots and highest branches, but may leave the lower branches, portions of the trunk and root system still alive depending on the severity of the freeze event (Macnae 1966, Lugo and Patterson-Zucca 1977). This pattern is attributed to the latent heat capacity of water-saturated sediments under the mangrove canopy which buffers those portions of the trees closest to the soil surface from freezing temperatures.

These same areas are also subject to hurricanes or cyclones that also can cause defoliation, and breakage and loss of limbs of mangrove trees (Wadsworth and Englerth 1959, Craighead and Gilbert 1962). Additional physical impacts to mangroves may include the harvest of all or portions of the trees for timber or charcoal production, or trimming or cutting of the trees where they block a view, such as a water front view in a community located on the water.

All of the above described impacts cause a certain amount of stress to mangrove trees, and some species survive and some die as a result. The response depends on the species of mangrove involve. Since the 69 species of mangroves are not all related to one another, but in fact come from 16 families of plants, it represents an example of convergent evolution, where different plant species, often unrelated, evolve and adapt through time to tolerate similar stressors, in this case saltwater and anaerobic soils. However, they can still retain certain physiological characteristics of their far removed genetic past. One of these characteristics is the ability to recovery and regrow after one or more of the above stressors is applied.

Published reports on silvaculture of mangroves report active cultivation and replanting for human use as far back as the middle of the 19th century (Lewis 1982). One of the earliest detailed reports on mangrove forest management for wood and charcoal production notes that cultivation and harvest plans were prepared as early as 1904 for mangrove forests in portions of Malaysia (Watson 1928).

Although direct commercial utilization of mangrove wood is non-existent in the United States, it is a widespread practice in much of the tropical portions of the world. Where forests are disturbed or clear cut, regeneration may come from volunteer seeding, manual replanting, or vegetative growth from some remaining portion of the plant (Field 1996).

Tomlinson (1986) is considered the definitive source of information on growth and reproduction in mangroves. He devotes considerable attention to the describing six "architectural tree models" in mangroves (Figures 1 and 2). Tomlinson states:

> These models are abstract, but dynamic; they constitute for each species the deterministic component of form; the visible expression of the architectural model of a tree at any time is referred to as its "architecture"... Trees may conform more or less precisely to their architectural model (i.e., they may or may not be "model conforming"). They can deviate considerably from the idealized model because the architecture is modified by environmental influences (mechanical damage, predator attack, shading) that divert the normal course of development...The most usual response in the form of the branched tree to other environmental perturbations is "reiteration," a partial or more usually complete repetition of the architecture of the tree...Reiteration may involve for example, either regeneration of new trunk units from previously dormant meristems ("reserve meristems") or reorientation of existing axes [see Fig 1, C]...These processes are the opportunistic component of form. Regeneration of new units is the usual response to mechanical damage and depends on the availability of reserve meristems, which are developed very unequally in different mangroves.

Tomlinson (1986) further describes the availability of reserve meristems in *Avicennia* as allowing coppicing, while in *Rhizophora*, it does not. Coppicing is vegetative regrowth after disturbance, usually from a cut stump, also called "stump sprouting." He notes that "complete regeneration of the crown in possible, at least theoretically, after trunk damage

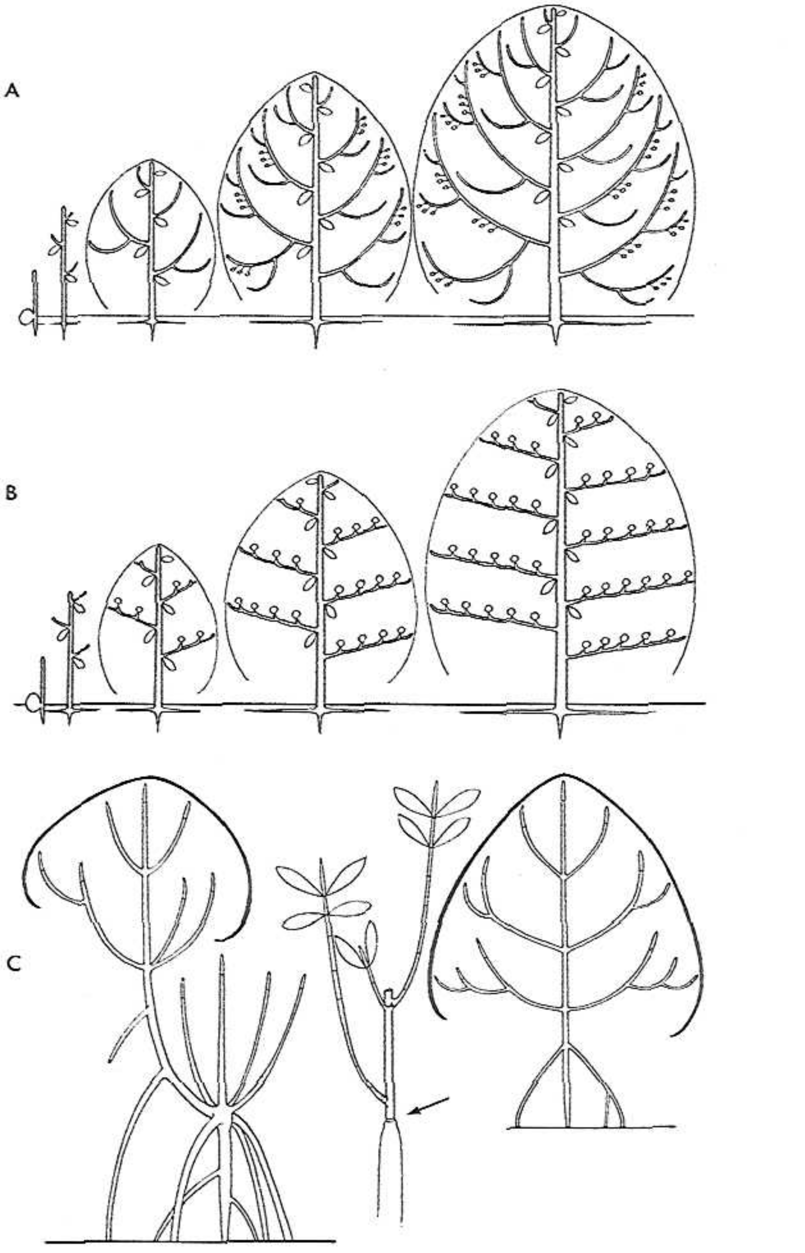

Figure 4.1. Common architectural tree models in mangroves. (A) Attims's model, with continuous growth of the trunk repeated in the branches, which have lateral inflorescences (e.g., *Rhizophora* spp.). (B) Pettit's model, with rhythmic growth of the trunk; the branches have terminal inflorescences and develop by substitution growth (e.g., *Lumnitzera littorea*). (C) Reiteration in *Rhizophora mangle*. Right: the tree conforming to its architectural model (Attims's model, here with pronounced branch tiers); left: reiteration by reorientation of an existing branch to form a reiterated crown; center: reiteration by prolepsis, significant only in seedlings. Reiteration in this species may occur from adventitious buds on the hypocotyl (i.e., below the cotyledonary node – arrow). (After Hallé et al. 1978)

Figure 1. Common architectural models in mangroves (from Tomlinson 1986, Figure 4.1, page 63)

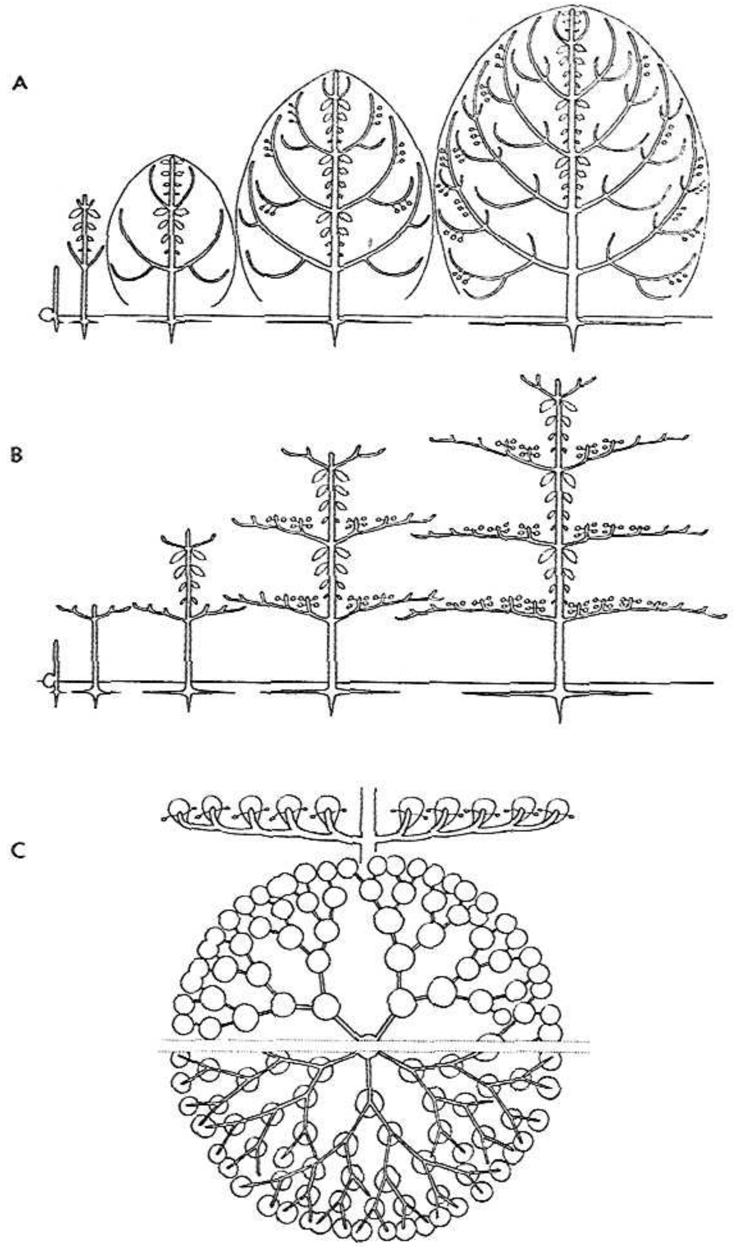

Figure 4.2. Other common architectural models in mangroves. (A) Rauh's model, with rhythmic growth, undifferentiated branches, and lateral inflorescences (e.g., *Xylocarpus* spp). (B) Aubréville's model, with rhythmic growth of the trunk, branches plagiotropic by apposition, and inflorescences lateral (e.g., *Terminalia catappa*). (C) A single branch tier in part B from the side (top), from above (middle), and from below (bottom) to show the distribution of leaf rosettes (circles) that can fill space in an economical and photosynthetically efficient manner. (After Hallé et al. 1978)

Figure 2. Other common architectural models in mangroves (from Tomlinson 1986, Figure 4.2, page 64)

or decapitation, from "resting" or "reserve" buds on the persistent trunk portion…" and refers to these as epicormic branches.

Table 1 compares the tolerance for vegetative plant loss and natural recovery for the three mangrove species in Florida.

Table 1. Regenerative capabilities and limitations of Florida's mangrove species (modified form Hamilton and Snedaker (1964) and Araujo (2002).

SPECIES	ROOTS	STUMP	TRUNK	BRANCHES	LOSS OF FOLIAGE	REMARKS
Avicennia germinans (black mangrove)	Yes	Yes	Yes	Yes	Yes	
Laguncularia racemosa (white mangrove)	Yes	Yes	Yes	Yes	Yes	
Rhizophora mangle (red mangrove)	Yes	No	No	Yes	Yes	2.5 cm (1 inch diameter maximum limit for branch regeneration

4.0 MECHANICAL ALTERATION

There are several studies on the effects and subsequent response of the application of standard silvacultural and horticultural practices to mangroves, although some include species not found in Florida, and the literature base is relatively small. Pulver (1976) reports reports an increase in height, branch development and production of new foliage after trimming of small mangroves (about 2 m or 6 feet tall) prior to experiments with transplanting. In general terms, red mangroves were the slowest to recover from pruning., but both black and white mangroves grew from 1-4 times faster than unpruned controls.

Gill and Tomlinson (1971) found lateral buds on red mangroves would not grow on pruned branches originally greater than 2.5 cm (1 inch) in diameter. At that size the branches would be 2-3 years old. They recommended pruning be restricted to branches of a diameter smaller than that. However, the removal of leaves without damage to branch structure does not affect the formation of new foliage (Lugo and Snedaker 1974). In contrast, black and white mangroves recover well from extensive pruning, including that of major branches (Savage 1972).

In spite of limited branch regrowth, horticulturally pruned red mangroves can maintain a high incidence of fruiting when approximately 70% of the foliage is left intact on the tree (Estevez and Evans 1978). Their data suggests also that the maximum pruning threshold limit for red mangroves is approximately 50% of the branches and foliage.

With all the above information in mind, limited pruning of canopy foliage, or careful removal of understory branches, as required to provide waterfront views has been an accepted and permitted practice in Florida [Carlton 1974, Stevely and Rabinowitz 1982, Florida Department of Environmental Regulation undated (a), undated (b)].

Some forms of mechanical alteration of mangroves have been identified as beneficial to mangrove growth. Tree thinning, where smaller diameter trees are removed to reduce competition between trees and therefore allow greater growth per tree is a common practice (Watson 1928, Teas 1979, Putz and Chan 1986). Selective pruning has also been cited as stimulating primary productivity by inducing the development of new sprouts in most mangroves (Araujo 2002). However, improper alteration could either reduce the complexity of the forest or disrupt some ecological processes such as organic matter input (Jordan 1971).

Snedaker et al. (1992) reports on the recovery of a mixed-species mangrove forest in south Florida after the removal of a major part of the above-ground foliage. They found two distinct patterns of recovery and canopy reclosure consistent with previous discussions here. Species such as the black and white mangrove with reserve or secondary meristems quickly produced new leaves and shoots in response to elevated light levels. Red mangroves, on the other hand, were limited by the slow production of new branch structure and was unable to regenerate limbs larger than one inch at the time of trimming, and therefore had limited in its regrowth following canopy removal. There was an increase in seedling establishment, but the effect was minor in its ultimate contribution to eventual canopy recovery at a lower elevation than the original.

The maximum heights of the reds in the Snedaker et al. (1992) study were 9.0m (29.25) feet tall. Most of them died from their reduction to 4.8 m (16 ft) in height. The die off of these severely trimmed tall reds did not run its full course until several years later, those documenting the need for great caution in trimming larger red mangroves.

Estevez and Evans (1978) have focused on loss of ecosystem function after pruning. There study looked at various types of pruning including uniform removal of the lower canopy from lower edge upward (grazing or undercutting), removal of the canopy from top down (hedging) and selective limb removal leaving the canopy intact (windows) on propagule production of red mangroves. Best remaining propagule production occurred with windows, least with hedging, and in between values were found with undercutting.

Beever (1991) study in the Southwest Florida Aquatic Preserve found no net positive value of trimming to production of mangroves and hypothesized that primary production was reduced based upon the measured parameters.

In contrast, Parkinson et al. (1999) working in the Indian River Lagoon evaluated litter fall response of red mangroves to selective pruning over a 33 month period. They concluded that mean litter fall was not significantly different before and after pruning. However, they did not the invasion of the mangrove forest edge by Brazilian pepper, *Schinus terebinthifolius*, as a result of trimming, and cautioned that cumulative impacts of stress from repeated trimming could be detrimental.

A recent proposal to the Lee County Board of County Commissioners to remove some canopy height from 4 ha (10 acres) of mixed mangroves averaging 11-13 m (35-40 feet) in height, down to 10 m (32 ft)(Morris-Depew Associates, Inc. 2002) resulted in a negotiated settlement to limit the impact on tall red mangroves to avoid the types of impacts seen in the Snedaker et al. (1992) study (Araujo 2002).

Thus the published science of mangrove trimming, though limited, does provide, and is being used to develop, logical guidelines for mangrove trimming to avoid major biological impacts in site specific cases.

The key question at hand in the current case of Pinellas County considering modifications of its current mangrove trimming rules is the question of whether trimming in stages (i.e., no more than 25% of the total height of a tree at one time, and waiting one year to trim another 25%) down to a final height of 2 m (6 ft) or 4 m (12 ft), appears to be answered regarding any red mangroves taller than 4 m (12 ft). That answer is that the science would indicate that no limbs or trunks greater than 2.5 cm (1 inch) in diameter should be cut for any trimming, since the danger of death to the tree is great. So in the case of red mangroves it is not a question of what height can they be trimmed to, but what diameter of limbs can be cut, since the current Pinellas County rule prohibit any trimming that will likely cause the death of the trimmed tree.

This is similar to the final recommendations of the Science Subcommittee of the Mangrove Technical Advisory Committee (MTAC) established by the Florida Department of Natural Resources in 1994 (MTAC 1994) to provide technical guidance on mangrove trimming. Their final recommendation was:

> For red mangrove trees of greater than 1 inch dbh [diameter breast high], black mangrove trees of greater than 8 inches dbh and white mangroves of greater than 12 inches dbh no top trimming is recommended.
>
> Selective removal of lateral branches in this and larger size classes can provide a view window. The combination of top trimming trees less than the specified dbh and uplifting trees of greater dbh and height creates a view window in a zone between the topped mangroves and the uplifted mangroves. Widow sizes can be up to 15 feet in vertical dimension and can be adjusted to site specifics by design

> and permit. This view window would be located site specific and can constitute 100% of lateral limbs and branches in red mangrove forests, provided that no trunks greater than the specified dbh by species are topped trimmed.
>
> Mangrove forests permitted for top trimming and thinning will not exceed 25 l.f. in width as measured from trunk to trunk. Mangrove forests of less than ½ acre continuous extent, irrespective of site boundaries, may be considered for all forms of alteration regardless of width as specified below.
>
> All species of mangrove trees greater than six feet in height and less than 20 feet in height may be reduced in extent to the point at which the trunk or branch diameter is one inch, provided no trunk is cut below six feet in height, and no branch is cut in the areas below six feet in height or above 20 feet in height.

It is often misunderstood that the final regulations on mangrove trimming instituted by the State of Florida in 1996 did not follow the recommendations of the above referenced committee. It is therefore not correct to state that there was, or is today, scientific support to allow all mangroves to be cut down to 2 m (6 feet) in height no matter the species, dbh or height.

For the other two regulated species (black and white mangroves), the question of trimming to 2 m (6 feet) or 4 m (12 feet) as a preferred alternative has not been adequately tested to provide clear guidance, particularly for larger trees, as noted above from the MTAC (1994), although white mangroves appear to be very amenable to management, and can resprout or coppice even after being cut off at ground level (Wadsworth 1959).

Black mangroves can coppice, but in west central Florida, the largest and oldest trees left in the forest are usually black mangroves because they can resist freeze impacts better than the other two species (Estevez and Mosura 1985). Because of this, they are likely to be the major producers of litter and therefore the organic production important to nearshore fisheries. In addition, after major freeze events, they are likely to be the only remaining trees capable of maintaining litter production until the other species recover, and supporting nesting and roosting by migratory and resident bird species, and arboreal invertebrates. For these reasons, great caution should be exercised with removing the tops (total canopy removal) of larger (i.e. greater than 6 m (20 ft) tall) black mangroves.

These science based professional observations are in large part more anecdotal than based on hard scientific data for mangrove forests of west central Florida. For that reason, it is recommended that management decisions should be made as needed to continue mangrove forests management with public support, and addition scientific data gathered to amend any final trimming guidelines after more data are available.

Literature Cited

Araujo, R. 1992. Mangrove protection and regulation in Florida: an overview with conflicts. Unpublished report, Division of Marine Affairs and Policy, Rosenstiel School of Marine and Atmospheric Science. University of Miami, Miami, Florida. 11 p.

Araujo, R. 2002. A literature review of the effects of natural and mechanical alteration on mangrove. Unpublished report, Division of Marine Affairs and Policy, Rosenstiel School of Marine and Atmospheric Science. University of Miami, Miami, Florida. 9 p.

Beever, J.W. 1991. The effects of fringe mangrove trimming for view on the Southwest Florida Aquatic Preserves. Unpublished report. Florida Freshwater Fish and Game Commission, Punta Gorda, Florida. 72 pp.

Carlton, J.M. 1974. Land-building and stabilization by mangroves. Env. Cons. 1(4):285-294.

Cintron, G., and Y. Shaeffer-Novelli. 1982. Mangrove forests: ecology and response to natural and man-induced stresses. In: Coral Reefs, seagrass Beds, Mangroves and Their Interaction in the Coastal Zones of the Caribbean. Workshop, West Indies Laboratory, Farleigh Dickinson University, St. Croix, U.S. Virgin Islands.

Craighead, F.C., and V. Gilbert. 1962. The effects of hurricane Donna on the vegetation of southern Florida. Quart. Jour. Fla. Acad. Sci. 25:1-28.

Davis, J.H., Jr. 1940. The ecology and geologic role of mangroves in Florida. Carnegie Institute, Washington, DC. Pub. 517. Tortugas Lab. Pap. 32:303-412.

Estevez, E.D., and R.K. Evans. 1978. The effects of pruning on reproduction by the red mangrove, *Rhizophora mangle*. Pages 26-42 in Lewis, R.R. (ed.), Proceedings of the Fifth Annual Conference on Restoration of Coastal Vegetation in Florida. Tampa, Florida, Hillsborough Community College.

Estevez, E.D., and L. Mosura. 1985. Mangrove forests of Tampa Bay. Basis 1.

Florida Department of Environmental Protection. Undated (a). Homeowners guide to mangroves. 6 p.

Florida Department of Environmental Protection. Undated (b). Mangrove trimming guidelines for homeowners. 16 p.

Heald, E. 1971. The production of organic detritus in a south Florida esturary. Univ. Miami Sea Grant Tech. Bull. 6. 110 pp.

Halle, F., R.A.A. Oldemann, and P.B. Tomlinson. 1978. Tropical trees and forests – an architectural analysis. Springer-Verlag. Berlin.

Hamilton, L.S., and S.C. Snedaker (eds.). 1984. Handbook for mangrove area management. U.N. Environment Programme and East-West Center. 123 p.

Jordan, C.F. A world pattern in plant energetics. Am. Scient. 59:425-233.

Lewis, R.R., R.G. Gilmore, D.W. Crewz and W.E. Odum. 1985. Mangrove habitat and fishery resources of Florida. Pages 281-336 in W. Seaman, Jr., (ed.). Florida aquatic habitats and fishery resources. Florida Chapter, American Fisheries Society, Kissimmee, Florida. 543 p.

Lugo, A.E., and C. Patterson-Zucca. 1977. The impact of low temperature stress on mangrove structure and growth. Trop. Ecol. 18:149-161.

Lugo, A.E., and S.C. Snedaker. 1974. The ecology of mangroves. Ann. Rev. Ecol. Syst. 5:39-64.

Noakes, D.S.P. 1955. Methods of increasing growth and obtaining natural regeneration of the mangrove type in Malay. Malay Forester 18:23-30.

Odum, W.E. 1971. Pathways of energy flow in a south Florida estuary. Univ. Miami Sea Grant Tech. Bull. 7. 162 pp.

Odum, W.E., C.C. McIvor, and T. J. Smith, III. 1982. The ecology of the mangroves of south Florida: A community profile. FWS/OBS-81/24. U.S. Fish and Wildlife Service, Washington, DC. 144 p.

Mayo, K. 1993. A study of regrowth from pruned Rhizophora mangle branches. Thesis. Nova University, Ft. Lauderdale, Florida. 35 pp + append.

Mangrove Technical Advisory Committee. 1994. Science committee final recommendations, transmitted via letter dated November 29, 1994, from James W. Beever III to Bill Caton, Bureau of Aquatic Plant Management. 9 p.

Morris-Depew Associates, Inc. 2002. Applicants public hearing analysis: Palmas Del Sol/Gulf Harbour notice of proposed change. Lee County, Florida. 14 pages.

Parkinson, R.W., M. Perez-Bedmar and J.A. Santangelo. 1999. Red mangrove (*Rhizophora mangle*) litter fall response to selective pruning. (Indian River Lagoon, Florida, U.S.A.). Hydrobiologia 413: 63-76.

Pulver, T.R. 1976. Transplant techniques for sampling mangrove trees, *Rhizophora mangle*, *Laguncularia racemosa*, and *Avicennia germinans*, in Florida. Florida Department of Natural Resources, St. Petersburg, Florida. Publication No. 22.

Putz, F.E., and H.T. Chan. 1986. Tree growth, dynamics, and productivity in a mature mangrove forest in Malaysia. Forest Ecol. Management 17:211-230.

Savage, T. 1972. Florida mangroves as shoreline stabilizers. Florida Department of Natural Resources, St. Petersburg, Florida. Professional Papers Series No. 19. 46 p.

Snedaker, S.C., M.S. Brown, E.J. Lahmann and R.J. Araujo. 1992. Recovery of a mixed-species mangrove forest in South Florida following canopy removal. J. Coast. Res. 8(4):919-925.

Stevely, J., and L. Rabinowitz. 1982. Mangroves - a guide to planting and maintenance. MAP-25. Sea Grant Marine Advisory Program, University of Florida, Gainesville, Florida.

Teas, H.J. 1979. Silvaculture with saline water. Pages 117-161 in A. Hollander et al. (eds.). The Biosaline Concept. Plenum Publishing, New York, N.Y.

Tomlinson, P.B. 1986. The botany of mangroves. Cambridge University Press, New York, N.Y. 419 p.

Wadsworth, F.H. 1959. Growth and regeneration of white mangrove in Puerto Rico. Carib. Forester 29(3-4):29-51.

Wadsworth, F.H. and G. Englerth. 1959. Effects of the 1956 hurricane on forests of Puerto Rico. Carib. Forester 20:38-50.

Watson, J.G. 1928. Mangrove forests of the Malay Peninsula. Malay Forest Record No. 6.