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THE ECOLOGY OF THE MANGROVES OF SOUTH FLORIDA: A COMMUNITY PROFILE

by

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CHAPTER 12. MANAGEMENT IMPLICATIONS

12.1 INHERENT VULNERABILITY

Mangroves have evolved remarkable physiological and anatomical adaptations enabling them to flourish under conditions of high temperatures, widely fluctuating salinities, high concentrations of heavy metals (Walsh et al. 1979), and anaerobic soils. Unfortunately, one of these adaptations, the aerial root system, is also one of the plant's most vulnerable components. Odum and Johannes (1975) have referred to the aerial roots as the mangrove's Achilles' heel because of their susceptibility to clogging, prolonged flooding, and boring damage from isopods and other invertebrates (see section 6 for a discussion of the latter). This means that any process, natural or man-induced, which coats the aerial roots with fine sediments or covers them with water for extended periods has the potential for mangrove destruction. Bacon (1970) mentions a case in Trinidad where the Caroni River inundated the adjacent Caroni Mangrove Swamp during a flood and deposited a layer of fine red marl in a large stand of black mangroves which subsequently died. Many examples of damage to mangrove swamps from human activities have been documented (see section 12.2).

One of the few natural processes that causes periodic and extensive damage to mangrove ecosystems is large hurricanes (Figure 16). Craighead and Gilbert (1962) and Tabb and Jones (1962) have documented the impact of Hurricane Donna in 1960 on parts of the mangrove zone of south Florida. Craighead and Gilbert (1962) found extensive damage over an area of 100,000 acres (40,000 ha). Loss of trees ranged from 25% to 100%. Damage occurred in three ways: (1) wind shearing of the trunk 6 to 10 ft (2 to 3 m) above ground, (2) overwash mangrove islands being swept clean, and (3) trees dying months after the storm, apparently in response to damage to the prop roots from coatings by marl and fine organic matter. The latter type of damage was most widespread, but rarely occurred in intertidal forests, presumably because the aerial roots were flushed and cleaned by tidal action. Fish and invertebrates were adversely affected by oxygen depletion due to accumulations of decomposing organic matter (Tabb and Jones 1962).

Hurricane Betsy in 1965 did little damage to mangroves in south Florida; there was also little deposition of silt and marl within mangrove stands from this minimal storm (Alexander 1967). Lugo et al. (1976) have hypothesized that severe hurricanes occur in south Florida and Puerto Rico on a time interval of 25 to 30 years and that mangrove ecosystems are adapted to reach maximum biomass and productivity on the same time cycle.

12.2 MAN-INDUCED DESTRUCTION

Destruction of mangrove forests in Florida has occurred in various ways including outright destruction and land filling, diking and flooding (Figure 17), through introduction of fine particulate material, and pollution damage, particularly oil spills. To our knowledge there are no complete, published documented estimates of the amount of mangrove forests in Florida which have been destroyed by man in this century. Our conclusion is that total loss statewide is not too great, probably in the range of 3 to 5% of the original area covered by mangroves in the 19th century, but that losses in specific areas, particularly urban areas, are appreciable. This conclusion is based on four pieces of information. (1) Lindall and Saloman (1977) have estimated that the total loss of vegetated intertidal marshes and mangrove swamps in Florida due to dredge and fill is 23,521 acres (9,522 ha); remember that there are between 430,000 and 500,000 acres (174,000 to 202,000 ha) of mangroves in Florida (see section 1.3). (2) Birnhak and Crowder (1974) estimate a loss of approximately 11,000 acres (4,453 ha) of mangroves between 1943 and 1970 in three counties (Collier, Monroe, and Dade). (3) An obvious loss of mangrove forests has occurred in Tampa Bay, around Marco Island, in the Florida Keys, and along the lower east coast of Florida. For example, Lewis et al. (1979) estimated that 44% of the intertidal vegetation

Figure 16. Damaged stand of red and black mangroves near Flamingo, Florida, as it appeared 7 years after Hurricane Donna.

Figure 17. Mangrove forest near Key West as it appeared in 1981 after being destroyed by diking and impounding.

including mangroves in the Tampa Bay estuary has been destroyed during the past 100 years. (4) Heald (unpublished MS.) has estimated a loss of 2,000 acres (810 ha) of mangroves within the Florida Keys (not considered by Birnhak and Crowder 1974). So while loss of mangrove ecosystems throughout Florida is not overwhelming, losses at specific locations have been substantial.

Diking, impounding, and long-term flooding of mangroves with standing water can cause mass mortality, especially when prop roots and pneumatophores are covered (Breen and Hill 1969; Odum and Johannes 1975; Patterson-Zucca 1978; Lugo 1981). In south Florida, E. Heald (pers. comm.) has observed that permanent impoundment by diking which prevents any tidal exchange and raises water levels significantly during the wet season will kill all adult red and black mangrove trees. If conditions behind the dike remain relatively dry, the mangroves may survive for many years until replaced by terrestrial vegetation.

Mangroves are unusually susceptible to herbicides (Walsh et al. 1973). At least 250,000 acres (100,000 ha) of mangrove forests were defoliated and killed in South Viet Nam by the U.S. military. This widespread destruction has been documented by Tschirley (1969), Orians and Pfeiffer (1970), Westing (1971), and a committee of the U.S. Academy of Sciences (Odum et al. 1974). In many cases these forests were slow to regenerate; observations by de Sylva and Michel (1974) indicated higher rates of siltation, greater water turbidity, and possibly lower dissolved oxygen concentrations in swamps which sustained the most damage. Teas and Kelly (1975) reported that in Florida the black mangrove is somewhat resistant to most herbicides but the red mangrove is extremely sensitive to herbicide damage. He hypothesized that the vulnerability of the red mangrove is related to the small reserves of viable leaf buds in this tree. Following his reasoning, the stress of a single defoliation is sufficient to kill the entire tree.

Although mangroves commonly occur in areas of rapid sedimentation, they cannot survive heavy loads of fine, floculent materials which coat the prop roots. The instances of mangrove death from these substances have been briefly reviewed by Odum and Johannes (1975). Mangrove deaths from fine muds and marl, ground bauxite and other ore wastes, sugar cane wastes, pulp mill effluent, sodium hydroxide wastes from bauxite processing, and from intrusion of large quantities of beach sand have been documented from various areas of the world.

12.3 EFFECTS OF OIL SPILLS ON MANGROVES

There is little doubt that petroleum and petroleum byproducts can be extremely harmful to mangroves. Damage from oil spills has been reviewed by Odum and Johannes (1975), Carlberg (1980), Ray (in press), and de la Cruz (in press, b). Over 100 references detailing the effects of oil spills on mangroves and mangrove-associated biota are included in these reviews.

Petroleum and its byproducts injure and kill mangroves in a variety of ways. Crude oil coats roots, rhizomes, and pneumatophores and disrupts oxygen transport to underground roots (Baker 1971). Various reports suggest that the critical concentration for crude oil spills which may cause extensive damage is between 100 and 200 ml/m^2 of swamp surface (Odum and Johannes 1975). Petroleum is readily absorbed by lipophylic substances on surfaces of mangroves. This leads to severe metabolic alterations such as displacement of fatty molecules by oil hydrocarbons leading to destruction of cellular permeability and/or dissolution of hydrocarbons in lipid components of chloroplasts (Baker 1971).

As with other intertidal communities, many of the invertebrates, fishes, and plants associated with the mangrove community are highly susceptible to petroleum products. Widespread destruction of organisms such as attached algae, oysters, tunicates, crabs, and gobies have been reported in the literature (reviewed by de la Cruz in press, b; Ray in press).

Damage from oil spills follows a predictable pattern (Table 7) which may require years to complete. It is important to recognize that many of the most severe responses, including tree death, may not appear for months or even years after the spill.

In Florida, Chan (1977) reported that red mangrove seedlings and black mangrove pneumatophores were particularly sensitive to an oil spill which occurred in the Florida Keys. Lewis (1979a, 1980b) has followed the long-term effects of a spill of 150,000 liters (39,000 gal) of bunker C and diesel oil in Tampa Bay. He observed short-term (72-hour) mortality of invertebrates such as the gastropod Melongena corona and the polychaete Laeonereis culveri. Mortality of all three species of mangroves began after three weeks and continued for more than a year. Sublethal damage included partial defoliation of all species and necrosis of black mangrove pneumatophores; death depended upon the percentage of pneumatophores affected.

In addition to the damage from oil spills, there are many adverse impacts on mangrove forests from the process of oil exploration and drilling (Table 8). This type of damage can often be reduced through careful management and monitoring of drilling sites.

Although little is known concerning ways to prevent damage to mangroves once a spill has occurred, protection of aerial roots seems essential. Prop roots and pneumatophores must be cleaned with compounds which will not damage the plant tissues. Dispersants commonly used to combat oil spills are, in general, toxic to vascular plants (Baker 1971). If possible, oil laden spray should not be allowed to reach leaf surfaces. Damage during clean-up (e.g., trampling, compaction, bulldozing) may be more destructive than the untreated effects of the oil spill (de la Cruz in press, b).

12.4 MAN-INDUCED MODIFICATIONS

In south Florida, man has been responsible for modifications which, while not killing mangroves outright, have altered components of the mangrove ecosystem. One of the most widespread changes involves the alteration of freshwater runoff. Much of the freshwater runoff of the Florida Everglades has been diverted elsewhere with the result that salinities in the Everglades estuary are generally higher than at the turn of the century. Teas (1977) points out that drainage in the Miami area has lowered the water table as much as 2 m (6 ft).

Interference with freshwater inflow has extensive effects on estuaries (Odum 1970). Florida estuaries are no exception; the effects on fish and invertebrate species along the edge of Biscayne and Florida Bays have been striking. The mismanagement of freshwater and its effects on aquatic organisms have been discussed by Tabb (1963); Idyll (1965a,b); Tabb and Yokel (1968) and Idyll et al. (1968). In addition, Estevez and Simon (1975) have hypothesized that the impact of the boring isopod, Sphaeroma terebrans, may be more severe when freshwater flows from the Everglades are altered.

One generally unrecognized side effect of lowered freshwater flow and salt water intrusion has been the inland expansion of mangrove forests in many areas of south Florida. There is documented evidence that the mangrove borders of Biscayne Bay and much of the Everglades estuary have expanded inland during the past 30 to 40 years (Reark 1975; Teas 1979; Ball 1980).

Sections of many mangrove forests in south Florida have been replaced by filled residential lots and navigation canals. Although these canal systems have not been studied extensively, there is some evidence, mostly unpublished, that canals are not as productive in terms of fishes and invertebrates as the natural mangrove-lined waterways which they replaced.

Table 7. General response of mangrove ecosystems to severe oil spills (from Lewis 1980b)

Stage	Observed impact
<u>Acute</u>	
0 to 15 days	Deaths of birds, turtles, fishes, and invertebrates
15 to 30 days	Defoliation and death of small mangroves, loss of aerial root community
<u>Chronic</u>	
30 days to 1 year	Defoliation and death of medium-sized mangroves (1 - 3 m), tissue damage to aerial roots
1 year to 5 years	Death of large mangroves (greater than 3 m), loss of oiled aerial roots, and regrowth of new roots (often deformed)
	Recolonization of oil-damaged areas by new seedlings
1 year to 10 years (?)	Reduction in litter fall, reduced reproduction, and reduced survival of seedlings
	Death or reduced growth of young trees colonizing spill site (?)
	Increased insect damage (?)
10 to 50 years (?)	Complete recovery

Table 8. Estimated impact of various stages of oil mining on mangrove ecosystems (modified from Longley et al. 1978 and de la Cruz in press,b).

Stage	Activity	Impacts
Pre-exploration	Seismic surveys Clearing of survey lines Drilling "shot lines"	Crushing and clearing vegetation Vehicle track compaction Damage to natural levees
Site preparation	Canal excavation Dredge spoil deposition Road construction	Loss of habitat in disturbed areas Alteration of water flow pathways Increased turbidity, higher rates of sedimentation, and lowered dissolved oxygen in nearby waters
Drilling	Increased activity at site related to drilling	Continued high turbidity Release of toxic substances Displacement of wildlife
Production	Construction of platforms Construction of pipelines Maintenance dredging Placement of tanks and other equipment	Continued high turbidity Loss of additional habitat Further changes in wetland drainage patterns from pipeline construction Release of toxic substances Oil spills
Oil spills	Oil leaks and spills due to well blow-out, pipeline breakage, carelessness, and barge rupture Clean-up activities	Destruction of plant and animal populations Alteration of ecosystem processes such as primary production and decomposition Introduction of persistent toxic substances into soils

Weinstein et al. (1977) found that artificial canals had lower species diversity of benthic infauna and trawl-captured fishes and generally finer sediments than the natural communities. Courtney (1975) reported a number of mangrove-associated invertebrates which did not occur in the artificial channels.

Mosquito production is a serious problem in black mangrove-dominated swamps in Florida (Provost 1969). The salt marsh mosquitos, Aedes taeniorhynchus and A. sollicitans, do not reproduce below the mean high tide mark and for this reason are not a serious problem in the intertidal red mangrove swamps. Mosquitos lay their eggs on the damp soil of the irregularly flooded black mangrove zone; these eggs hatch and develop when flooded by spring tides, storm tides or heavy rains. As with the "high marsh" of temperate latitudes, there have been some attempts to ditch the black mangrove zone so that it drains rapidly after flooding. Although properly designed ditching does not appear to be particularly harmful to mangrove swamps (other than the area destroyed to dig the ditch and receive the spoil), it is an expensive practice and for this reason is not widely practiced. Properly managed diking can be an effective mosquito control approach with minimal side effects to black mangroves (Provost 1969). Generally, ditching or diking of the intertidal red mangrove zone is a waste of money.

Mangrove swamps have been proposed as possible tertiary treatment areas for sewage (see discussion by Odum and Johannes 1975). To our knowledge, this alternate use is not currently practiced in south Florida. Until more experimental results are available on the assimilative capacities and long-term changes to be expected in mangrove forests receiving heavy loads of secondary treated sewage, it would be an environmental risk to use mangrove forests for this purpose.

In many areas of the world mangrove swamps have been converted to other uses such as aquaculture and agriculture (see de la Cruz, in press, a). Although some of the most productive aquaculture ponds in Indonesia and the Philippines are located in former mangrove swamps, there is some question whether the original natural system was not equally productive in terms of fisheries products at no cost to man (Odum 1974). Conversion to aquaculture and agriculture is cursed with a variety of problems including subsequent land subsidence and the "cat clay" problem. The latter refers to the drastically lowered soil pH which often occurs after drainage and has been traced to oxidation of reduced sulfur compounds (Dent 1947; Tomlinson 1957; Hesse 1961; Hart 1962, 1963; Moorman and Pons 1975). Experience in Africa, Puerto Rico, and Southeast Asia confirms that mangrove forests in their natural state are more valuable than the "reclaimed" land.

12.5 PROTECTIVE MEASURES INCLUDING TRANSPLANTING

Protection of mangroves includes (1) prevention of outright destruction from dredging and filling; (2) prevention of drainage, diking and flooding (except for carefully managed mosquito control); (3) prevention of any alteration of hydrological circulation patterns, particularly involving tidal exchange; (4) prevention of introduction of fine-grained materials which might clog the aerial roots, such as clay, and sugar cane wastes; (5) prevention of oil spills and herbicide spray driftage; and (6) prevention of increased wave action or current velocities from boat wakes, and sea walls.

Where mangroves have been destroyed, they can be replanted or suitable alternate areas can be planted, acre for acre, through mitigation procedures (see Lewis et al. 1979). An extensive body of literature exists concerning mangrove planting techniques in Florida (Savage 1972; Carlton 1974; Pulver 1976; Teas 1977; Goforth and Thomas 1979; Lewis 1979b). Mangroves were initially planted in Florida at least as early as 1917 to protect the overseas railway in the Florida Keys (Teas 1977).

Both red and black mangroves have

been used in transplanting. As we mentioned in section 11, black mangroves seem to have certain advantages over red mangroves. Properly designed plantings are usually 75% to 90% successful, although the larger the transplanted tree, the lower its survival rate (Teas 1977). Pruning probably enhances survival of trees other than seedlings (Carlton 1974). Important considerations (Lewis 1979b; Teas 1977) in transplanting mangroves are: (1) to plant in the intertidal zone and avoid planting at too high or too low an elevation, (2) to avoid planting where the shoreline energy is too great, (3) to avoid human vandalism, and (4) to avoid accumulations of dead sea grass and other wrack.

Costs of transplanting have been variously estimated. Teas (1977) suggests $462 an acre ($1,140/ha) for unrooted propagules planted 3 ft (0.9 m) apart, $1,017 an acre ($2,500/ha) for established seedlings planted 3 ft (0.9 m) apart and $87,500 ($216,130/ha) for 3 year-old nursery trees planted 4 ft (1.2 m) apart. Lewis (1979b) criticized Teas' costs as unrealistically low and reported a project in Puerto Rico which used established seedlings at a cost of $5,060 an acre ($12,500/ha); he did suggest that this cost could be cut in half for larger projects.

12.6 ECOLOGICAL VALUE OF BLACK VS. RED MANGROVES

One unanswered question of current interest in Florida concerns the ecological value of black mangrove forests compared to intertidal red mangrove forests. In many respects, this is identical to the "high marsh" versus "low marsh" debate in temperate wetlands. One hypothetical argument which has been presented frequently in court cases during the past decade suggests that black mangrove forests have less ecological value than red mangrove forests to both man and coastal ecosystems. This argument is based on an apparent lack of substantial particulate detritus export from black mangrove forests above mean high tide and the generally perceived lack of organisms, particularly gamefishes, which use black mangrove forests as habitat.

The counter argument states that black mangrove forests are important for the support of wildlife and the export of substantial quantities of dissolved organic matter (DOM). Lugo et al. (1980) provide evidence that black mangrove forests do, in fact, export large quantities of DOM. They point out that (1) black mangrove leaves decompose more rapidly than red mangrove leaves and thus produce relatively more DOM and (2) absolute export of carbon from these forests, on a statewide scale, is equal or greater than from red mangrove forests.

12.7 THE IMPORTANCE OF INTER-COMMUNITY EXCHANGE

From previous discussions (sections 6 and 7.5 and Appendices B, C, D and E) it is clear that many species of fishes, invertebrates, birds, and mammals move between mangrove forest communities and other habitats including sea grass beds, coral reefs, terrestrial forests, and the freshwater Everglades. For example, the gray snapper, *Lutjanus griseus*, spends part of its juvenile life in sea grass beds, moves to mangrove-lined bays and rivers, and then migrates to deeper water and coral reefs as an adult (Croaker 1962; Starck and Schroeder 1971). The pink shrimp, *Penaeus duorarum*, spends its juvenile life in mangrove-lined bays and rivers before moving offshore to the Tortugas grounds as an adult. During its juvenile period it appears to move back and forth from mangrove-dominated areas to sea grass beds. The spiny lobster, *Panulirus argus*, as a juvenile frequently uses mangrove prop root communities as a refuge; when nearing maturity this species moves to deeper water in sea grass and coral reef communities (see discussion section 6.1). Many of the mammals (section 10) and birds (section 9) move back and forth between mangrove communities and a variety of other environments.

These are only a few of many

examples. Clearly, mangrove ecosystems are linked functionally to other south Florida ecosystems through physical processes such as water flow and organic carbon flux. As a result, the successful management and/or preservation of many fishes, mammals, birds, reptiles, and amphibians depends on proper understanding and management of a variety of ecosystems and the processes that link them. Saving mangrove stands may do the gray snapper little good if sea grass beds are destroyed. Pink shrimp populations will be enhanced by the preservation of sea grass beds and mangrove-lined waters, but shrimp catches on the Tortugas grounds will decline if freshwater flow from the Everglades is not managed carefully (Idyll et al. 1968). Successful management of south Florida mangrove ecosystems, including their valuable resources, will depend on knowledgeable management of a number of other ecosystems and the processes which link them.

12.8 MANAGEMENT PRACTICES: PRESERVATION

Based on years of research in south Florida and based on the information reviewed for this publication, we have concluded that the best management practice for all types of Florida mangrove ecosystems is preservation. Central to this concept is the preservation of adjacent ecosystems that are linked significantly by functional processes. The continued successful functioning of the mangrove belt of southwest Florida is highly dependent on the continual existence of the Everglades and Big Cypress Swamp in an ecologically healthy condition.

At no cost to man, mangrove forests provide habitat for valuable birds, mammals, amphibians, reptiles, fishes, and invertebrates and protect endangered species, at least partially support extensive coastal food webs, provide shoreline stability and storm protection, and generate aesthetically pleasing experiences (Figure 18). In situations where overwhelming economic pressures dictate mangrove destruction, every effort should be made to ameliorate any losses either through mitigation or through modified development as described by Voss (1969) and Tabb and Heald (1973) in which canals and seawalls are placed as far to the rear of the swamp as possible.

Figure 18. Mangrove islands in Florida Bay near Upper Matecumbe Key. Note the extensive stands of seedling red mangroves which have become established (1981) after a long period without major hurricanes. Mangrove islands in the Florida Keys tend to expand during storm-free intervals.