

Revised 4/7/92

Estuarine Ecology

Productivity and the Detrital System of Mangrove Wetlands

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One of the most notable aspects of mangrove wetland communities is their high level of net primary productivity and how this relates to the overall diversity, faunal abundances, and health of subtropical and tropical estuarine systems. Additionally, mangroves exhibit high rates of tree growth and decomposition, export large quantities of organic carbon, and have high biomass turnover rates (Lugo, 1997). Mangrove trees produce as much as 80% of the total organic materials in estuarine waters and contribute to the detrital flow of the open estuary. (Burns, 1976).

This detritus, rather than phytoplankton, forms the basis of the estuarine food chain (Cantillo *et al*, 2000). The principle flow of energy in this chain is: mangrove debris → bacteria and fungi → primary consumers (detritus consumers) → secondary consumers (lower, middle and top carnivores)(Fig. 1)(Heald *et al*, 1984). This food chain is largely dependent upon freshwater flow or in some cases, tidal action. The largest and most robust mangrove stands are directly associated with riverine conditions and these mangroves are dependent upon primary nutrients that are transported from upriver (Craighead, 1971; Lugo *et al*, 1973).

The mangrove detrital system is very important in converting mangrove productivity into an exportable estuarine resource. Mangrove leaves, propagules, and other plant parts are converted to smaller pieces by "shredders", such as crabs, and then decomposed. Mangrove associated fungi is extremely important in this process and has been the subject of extensive study (Kohlmeyer and Kohlmeyer, 1979). The decomposition of this litter forms high protein material that is the basis of the food web leading to the commercial fisheries of estuaries (Fell and Master, 1980).

Georgia salt marshes, the temperate counterpart to mangrove wetlands, support large commercial fisheries that are supported by the high productivity of this ecosystem (Schelske and Odum, 1962). The productivity is based primarily on cordgrass (*Spartina alterniflora*), which forms the basis of the food chain much as mangrove detritus does. Only a small amount of the actual vegetation is consumed,

while the bulk of this net photosynthetic production is transferred to animal consumers via detritus (the only actual marine grazer on south Florida mangroves is the boring isopod, *Sphaeroma terebrans*) (Heald *et al*, 1984).

Primary productivity in mangroves is studied either by measuring gross primary productivity (GPP) and respiration (R) through the enclosure of plant portions in plastic gas exchange bags or by estimating net primary productivity ($GPP - R = NPP$) through the collection of plant litter in pans or baskets. Extensive research in south Florida, including Biscayne Bay, has been done through these methodologies (Teas, 1976; Miller, 1972; Pool *et al*, 1977; Lugo and Snedaker, 1975). Pool *et al* (1977) estimated that south Florida sites in general have an average leaf turnover rate (annual leaf fall + canopy leaf biomass) of 0.97.

Mangrove community ecology in general is described in the Biscayne National Park Research Guide Report entitled "**Mangrove Wetland Communities**" and additional detailed descriptions of South Florida mangrove ecology is available in Cantillo *et al* (2000), Lugo and Snedaker (1974), and Davis (1940).

BISCAYNE NATIONAL PARK RESEARCH

Productivity in southern Biscayne Bay and Card Sound depends upon the inputs of effluent from benthic grasses and macroalgae, plankton, and mangrove and swamp grass communities. Mangroves especially make a substantial contribution to the food chain with leaf fall exceeding three tons (dry weight) per acre per year (Fell *et al*, 1972). These fallen leaves, in addition to millions of mangrove propagules, are converted by microbial activity to detritus and constitute the basis of the entire estuarine food chain.

In comparison to the overall average leaf turnover rate for south Florida (0.97), Turkey Point in Biscayne National Park has a rate of only 0.8 (Teas, 1976; Pool *et al*, 1977). Teas (1976) measured a total of 7,876 hectares of mangrove forest, including examples of all community types, in the greater Biscayne area. From this study, Teas reported a total NPP of 56,505 mtC/yr. Figures for individual communities can be found within his publication, but vary from 1.28 mt/ha/yr for Sparse Scrub to 10.7 mt/ha/yr for Coastal Band. Propagule production is suggested to be approximately twice the annual rate of the leaf debris and contributes greatly to the detrital system as many do not germinate and thus decompose within the leaf litter (Heald *et al*, 1984).

Despite the mangrove reputation for high productivity, these are actually low rates compared to other tropical forests, which average 25.3 mt/ha/yr (Teas, 1976). This can possibly be attributed in part to the environmental stresses that many Biscayne mangroves undergo in areas of former freshwater marsh. However, south Florida mangrove wetlands in general were found to have a lower above-ground biomass compared to mangrove forests in other parts of tropical America. Florida

above-ground biomass ranges from 7,868-129,643 kg dry weight per hectare compared to 279,212 kg/ha for mangrove wetlands in Panama (Lugo and Snedaker, 1974). This reduced biomass is attributed to the prevalence of hurricanes in south Florida, which regularly limit mangrove tree growth.

After mangrove litter falls to the ground, it is rapidly infested by large quantities of fungi as opposed to bacteria and other detrital organisms (Fells *et al*, 1972). Upon decomposition, there is a significant increase in the relative amount of protein, providing a substantial resource to the ecosystem as it is utilized directly by detrital feeders or indirectly via bacteria (*ibid*). At least one species of fungi, *Cercospora rhizophorae*, attacks red mangrove leaves while they are still on the tree, inducing them to drop prematurely (Creager, 1962).

The fungal species present in Biscayne National Park, as well as their succession, were studied by Fell *et al* (1972) and Fell and Master (1975) at Turkey Point, Mangrove Point, and Card Sound. Fell and Master utilized the standard mesh bag technique to submerge leaf litter and observe decomposition. Fungi were isolated by incubation of leaf discs on corn meal agar dishes containing seawater with streptomycin sulfate and penicillin G (Fell and Master, 1980). Fell *et al*. (1972) additionally sampled for fungi on submerged mangrove seedlings within Biscayne Bay and Card Sound. These fungi were sampled through membrane filtration, discing, discing and baiting, and damp chamber incubation.

Sixty-six genera of fungi were isolated from the south Florida mangrove leaves used by Fell *et al* (1972). Of these, fifty-three were of the family Deuteromycetes, six from Ascomycetes, five from Phycomycetes, one from Myxomycetes and one from Actinomycetes. Fell and Master (1980) found the most common genera worldwide to be *Nigrospora*, *Phyllosticta*, *Alternaria*, *Cladosporium*, *Cylindrocarpum*, *Pestalotia*, *Fusarium*, *Aspergillus*, *Drechslera*, *Penicillium*, *Trichoderma*, *Phytophthora*, *Gliocladium*, and *Lulworthia*. The genus *Phytophthora* occurred on nearly all samples after 2 to 3 weeks, with *P. vesicula* and *P. spinosa* var. *spinosa* being the most prevalent species on south Florida samples (*ibid*). On mangrove propagules, fifty-seven species of fungi have been isolated with twenty-seven from the family Ascomycetes, seventeen from Sphaeropsidales, six from Ascomycetes, two from Oomycetes, one from Zygomycetes, and one from Myxomycetes. A full list of fungi identified from fungal succession studies in Biscayne Bay can be found on table VII-3 for mangrove leaves and table VII-5 for mangrove propagules of Fell *et al*, 1972.

Fell and Master (1975) collected mangrove leaves from the north to the south end of Biscayne Bay, including Turkey Point and Mangrove Point within Biscayne National Park. Studies of fungi on these leaves led to findings that the genus *Phytophthora* (especially *P. vesicula* and *P. spinosa* var. *spinosa*), previously not recorded from mangrove communities, is actually an important member of the degradation flora. Two species of fungi, new to science, *Phytophthora epistomium* and *Pythium grandiporangium*, were discovered in Biscayne Bay during this study (*ibid*).

The fungi genera isolated from mangrove leaves are generally ubiquitous saprophytes, commonly associated with the breakdown of plant material. Fell *et al* (1972) reports that many of these genera have been reported from terrestrial soil, terrestrial leaf litter, freshwater, seawater, sea grasses, mangrove muds, and salt marshes. The composition of fungal communities of the leaves, propagules and woody portions are significantly different, with few genera being associated with more than one of these communities (*ibid*).

One of the basic changes of decomposing mangrove litter is a reduction in carbon content and an increase in nitrogen. The changes in these elements were monitored for a summer in a field station located in Card Sound. The results showed a 50% change in carbon and a 20% change in nitrogen over fifteen weeks (Fell and Master, 1980). A model generated by Fell and Masters demonstrated that fungi were required for the nitrogen immobilization as well as the increase in the amount of organic carbon leached from the leaves (*ibid*).

A variety of fungi species were described from Biscayne Bay by Kohlmeyer and Kohlmeyer (1965) prior to the work of Fell and Master. Their discoveries include *Buella haliotrepha* (Ascomycetes) from black mangrove roots, and *Hyrdonectria tethys* (Ascomycetes) and *Halocyphina villosa* (Fungi Imperfecti) from driftwood between mangrove roots.

Detritivores feeding on mangrove debris actually consume primarily the bacteria and fungi, which are the most easily digestible components of protein rich detritus particles. These primary consumers represent many taxa, however Heald *et al* (1984) suggest that the most important components of this trophic level in south Florida red mangrove communities may include twelve species of crustaceans (four amphipods, four mysids, two carideans, one penaeid shrimp and a xanthid crab), six fishes, two polychaetes, several copepod and isopod species, and larval chironomid midges. Of these Heald *et al* (1984) list some of the most important as being the amphipods, *Melita nitida* and *Corophium lacustre*; the xanthid crab (*Rhithropanopeus harrisi*), the snapping shrimp (*Alpheus heterochaelis*) and fish such as the sheepshead killifish (*Cyprinodon variegatus*), gold-spotted killifish (*Floridichthys carpio*), diamond killifish (*Adinia xenica*), sailfin molly (*Poecilia latipinna*), crested goby (*Lophiogobius cyprinoides*), and striped mullet (*Mugil cephalus*). Additionally, Fell *et al* (1972) isolated a number of species from mangrove leaves of Biscayne National Park, including seven nematodes, *Rhabditis marina*, *Diplolaimelloides delyi*, *Diplolaimella ocellata*, *Oncholaimus domesticus*, *Haliplectus dorsalis*, *Monhystera* sp. and *Enoplus* sp.; a harpacticoid copepod, *Leptocaris tristetosa*; and two foraminifera, *Trichohyalis* sp. and *Quinqueloculina* sp.

Most of the information discussed in the scientific literature concerns principally red mangrove forests. Forests composed primarily of black or white mangrove trees have distinct differences in detrital flora and fauna as well as productivity and their role in the energy flow of the estuary. Black mangrove forests, for example, are flushed less frequently than red mangroves, yet are still important contributors in the export of

detritus. Primary consumers are different in this forest type, with important south Florida species being the pulmonate molluscs (*Melampus coffeus* and *Cerithidea scalariformis*)(Heald *et al*, 1984).

RECOMENDATIONS

1. Mangrove shorelines represent the most productive portion of Biscayne National Park. However, in many parts of Biscayne Bay, mangroves have been altered through urbanization and industrialization activities. Although mangroves are now protected by law, any future activities along the shoreline should take into account the potential impact on estuarine productivity.
2. Wherever possible, destroyed or altered mangrove communities should be restored. These communities are reservoirs of productivity, fueling local fisheries.

ADDITIONAL INFORMATION

Biscayne National Park Research Guide Sections:

- Estuarine Ecology: Mangrove Wetland Communities
- Estuarine Ecology: Mangroves and Fishes
- Climate: Hurricanes and Vegetation
- Geology: Mangroves and Geology
- Organismal Biology: Mangrove Botany

VOCABULARY

Detritus: Organic debris

Estuary: A semi-isolated coastal area that is diluted by freshwater discharge.

Halophyte: A salt tolerant vascular plant

Isopods: An order of crustaceans generally having a flattened body and with both benthic and planktonic species.

Mangal: Mangrove Swamp

Mangrove: From the Portuguese "mangue" for an individual mangrove tree and the English "grove" for a group of trees. A group of botanically diverse, salt-tolerant trees and the ecosystem that they encompass. This system dominates many intertidal regions in tropical and subtropical latitudes.

Pneumatophores: Fleshy pencil-sized root structures found on black and white mangroves. Pneumatophores commonly extend 6 inches or more above saturated soil, are covered with abundant lenticils, and permit the submerged roots to obtain atmospheric oxygen.

Productivity: The rate at which a given quantity of organic material is produced by organisms.

REFERENCES CITED AND CONSULTED

Burns, L.A. 1976. Ecosystem models of mangrove communities in Biscayne Bay. In: Thorhaug, A., and \A. Volker (eds.). *Biscayne Bay: Past/Present/Future*. A Symposium presented by the University of Miami, April 2-3, 1976. University of Miami Sea Grant. Pp. 113-132. (**Science Files BISC: Top shelf of bookcase**)

Develops models for mangrove community dynamics within Biscayne Bay. The models emphasize the following ecological aspects of mangroves in the coastal region: 1. productivity of mangroves is controlled by a synergistic interaction between tidal flow and fresh water availability. 2. interception and filtration of surface runoff by mangroves captures nutrients otherwise lost to the open sea, improving water quality in the process. 3. detrital production by mangroves helps fuel food chains supporting fisheries and bird populations. 4. shallow brackish waters around mangroves are nursery and breeding grounds for many estuarine dependent animals.

Cantillo, A.Y., K. Hale, E. Collins, L. Pikula, and R. Caballero. 2000. Biscayne Bay: Environmental History and

Annotated Bibliography. NOAA Technical Memorandum NOS NCCOS CCMA 145, Silver Spring, MD.
(Science files BISC: top shelf of bookcase and on CD-ROM)

Descriptions of all ecological, geological, and physical topics of Biscayne Bay as well as an extensive annotated bibliography covering these topics. This report includes many topics in the central and northern Bay, outside of the park boundaries.

Craighead, F.C. 1971. *The Trees of South Florida*. University of Miami Press, Coral Gables, Florida. 212p.

Creager, D.B. 1962. A new *Cercospora* on *Rhizophora mangle*. *Mycologia*, 54: 536-539. (Science Files BISC: Biscayne Section: Fungi – Mangrove Associated)

A leafspot on red mangrove, Rhizophora mangle L., was collected by District plant inspectors R.W. Swanson and R.T. McMillan, Jr. at Fairchild Tropical Gardens, Miami, Florida, January 16, 1962. Since this appears to be the only species of Cercospora known to occur on the genus, Rhizophora, the name Cercospora rhizophorae and the following technical description is proposed.

Davis, J.H. Jr. 1940. The ecology and geology role of mangroves in Florida. *Carnegie Inst. Wash. Publ.* 32: 305-412.

Fell, J.W., B. Hopper, R. Cefalu, and I.M. Master. 1972. Mangrove Detrital System. In: Bader, R.G. and A. Roessler. *An Ecological Study of South Biscayne Bay and Card Sound*. University of Miami, RSMAS, pp. VII, 1-27. (Science Files BISC: Biscayne Section: Fungi – Mangrove Associated)

Results of a program to investigate the microbiological activities associated within benthic mangrove (Rhizophora mangle) detrital communities. The program seeks to identify the species of organisms that are associated with mangrove leaf degradation; to determine the functional role of these organisms in the conversion and transfer of leaf organic material to organisms of higher trophic levels; and to assess the effects of normal and abnormal environmental factors on the individual organisms and on their interrelated roles within the detrital community.

Fell, J.W. and I.M. Master. 1975. Phycomycetes (Phytophthora spp. nov. and Pythium sp. nov.) associated with degrading mangrove (Rhizophora mangle) leaves. *Can. J. Bot.* 53(24): 2908-2922. (Science Files BISC: Biscayne Section: Fungi – Mangrove Associated)

Fungi of the genus Phytophthora were found to be associated with the initial stages of leaf litter decay of Rhizophora mangle L. and other Rhizophora species in estuarine and coastal marine waters. Phytophthora appears to be an important component of red-mangrove litter degradation systems throughout the tropics, which includes the Atlantic, Pacific, and Indian Oceans. The distributions of Phytophthora vesicula Anastasiou et Churchland and four new species of Phytophthora are discussed, as well as their occurrence in other tropical marine allochthonous spermatophytic leaf litter. The descriptions of the new species and varieties, Phytophthora bahamensis, P. epistomium, P. mycoparasitica, P. spinosa var. spinosa, and P. spinosa var. lobata are presented. Pythium was rarely observed in the mangrove litter system, although one species, Pythium grandisporangium sp. nov., is described.

Fell, J.W. and I.M. Master. 1980. The association and potential role of fungi in mangrove detrital systems. *Botanica Marina*, 23: 257-263. (Science Files BISC: Biscayne Section: Fungi – Mangrove Associated)

Field examination of decomposing mangrove (Rhizophora mangle) leaves demonstrated a sequence of fungal populations during different stages of decay. During this period there was an increase in nitrogen (~20-28% and a decrease in carbon (~50%). A laboratory model was designed to examine the potential role of fungi mediating these biochemical changes. The ratio of carbon to nitrogen (<12) of the flocculated material suggests a high food value available for the animals associated with litter decomposition.

Kohlmeyer, J. and E. Kohlmeyer. 1965. New marine fungi from mangroves and trees along eroding shorelines. *Nova*

Hedwigia, 9(1-4): 89-104. (Science Files BISC: Biscayne Section: Fungi – Mangrove Associated)

Taxonomic descriptions of new marine fungi found on mangroves of Biscayne Bay.

Kohlmeyer, J. and E. Kohlmeyer. 1979. *Marine Mycology, The Higher Fungi*. Academic Press, Inc., New York.

Lugo, A.E. 1997. Old-growth mangrove forests in the United States. *Conservation Biology*, 11(1): 11-20. (Science Files BISC: FL & Caribbean Section: Mangroves)

This paper demonstrates that criteria used to identify old growth forests in the Pacific Northwest have not proven applicable in other ecological life zones, namely mangroves. Mangroves require specialized criteria in order to classify them as old-growth. These conditions include substrate, stand structure and function, and regional distribution regimes. Mangroves offer a challenge to the concept of old-growth and this analysis shows that it is necessary to avoid geographic biases based on particular conditions such as the Pacific Northwest. Although there is useful information regarding mangroves in general, the article is not very useful in terms of Biscayne National Park management, as most of Biscayne National Park's mangroves are young forests.

Miller, P.C. 1972. Bioclimate, leaf temperature, and primary production in red mangrove canopies in south Florida. *Ecology*. 53:1. pp.22-45. (Science Files BISC: Biscayne Section: Mangroves)

A model of primary production and transpiration of red mangrove forest canopies was developed from the energy-budget equation of individual leaves to clarify some of the physical processes affecting primary production. The canopy distribution of red mangrove appears to be nearly optimum to maximize the efficiency of water utilization rather than production. This indicates that the canopy is adapted to maximize production under conditions of saturated water supply. Data was collected north and south of Turkey Point, Biscayne National Park.

Pool, D.J., S.C. Snedaker, and A.E. Lugo. 1977. Structure of mangrove forests in Florida, Puerto Rico, Mexico, and Costa Rica. *Biotropica* 9(3): 195-212.

Teas, H..J. 1976. Productivity of Biscayne Bay mangroves. In: Thorhaug, A., and A. Volker (eds.). *Biscayne Bay: Past/Present/Future*. A Symposium presented by the University of Miami, April 2-3, 1976. University of Miami Sea Grant. Pp. 103-113. (Science files BISC: top shelf of bookcase)

Discusses five types of mangrove communities in Biscayne Bay and their estimated productivity. Net primary productivity (10.7 metric tons of dry matter per hectare per year) is somewhat low compared to other tropical forests. The paper suggests that further research is needed on mangroves growing under stressed conditions, on marl soils that were formerly freshwater marshlands. Despite losses to landfill activities there is possibly a greater area of mangrove coverage today than there was in 1900. This is due to the landward encroachment of mangroves following salinization caused by the draining of the Everglades, the cutting of agricultural ditches, and the blocking of overland freshwater flow by roads and levees.

Sources regarding relevant research outside of Biscayne National Park:

Heald, E.J., W.E. Odum, and D.C. Tabb. 1984. Mangroves in the Estuarine Food Chain. In: Gleason, P.J. *Environments of South Florida – Present and Past II*. Miami Geological Society, Coral Gables, FL., pp. 149-156. (Science Files BISC: FL & Caribbean Section: Mangroves)

Discussion centers around the seemingly different roles of red and black mangroves in estuarine food chains. Red mangroves, the majority of which are intertidal and riverine, produce large quantities of detrital material upon which is based a food chain from microorganisms to top carnivores of sport and commercial value. Many black mangrove communities, by virtue of their location, are probably not significant exporters of detritus to adjacent estuaries. Their

importance lies apparently in the mosquito-killifish food chain culminating in the same top level carnivores as the red-mangrove-based system.

Lugo, A.E. and S.C. Snedaker. 1974. The ecology of mangroves. *Annual Review of Ecology and Systematics*, 5: 39-64. (**Science Files BISC: FL and Caribbean Section: Mangroves**)

Using an ecosystem approach, the authors attempt to describe and highlight the importance of mangrove wetlands. Although this paper is not specific to Biscayne Bay, the mangroves described are those of south Florida. Although broad in scope, the information in this article is highly useful.

Lugo, A.E., M. Sell, and S. Snedaker. 1973. Mangrove ecosystem analysis. In: *The role of mangrove ecosystems in the maintenance of environmental quality and a high productivity of desirable fisheries*. Center for Aquatic Sciences, Univ. of Florida, Gainesville, Rept. To the Bur. Sport Fish. and Wildl., pp: E1-E60.

Lugo, A.E. and S.C. Snedaker. 1975. Properties of a mangrove forest in southern Florida. In: Walsh, G.E., S.C. Snedaker, and H.J. Teas. (eds.) *Proceedings of the International Symposium on Biology and Management of Mangroves, Honolulu, Hawaii, 1974*. Gainesville. Institute of Food and Agricultural Sciences, University of Florida. pp.170-2122 (**Science Files BISC: FL and Caribbean Section: Mangroves**)

Characterizes the ecological properties of fringing and basin mangroves of Rookery Bay, Florida.

Schelske, C.L. and E.P. Odum. 1962. Mechanisms maintaining high productivity in Georgia estuaries. *Proc. Gulf. Carib. Fish. Inst.*, 14th Ann. Sess.: 75-80.