MANGROVE FORESTS: A TOUGH SYSTEM TO INVADE

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INTRODUCTION

Tropical forests are the most species-rich forests in the world. As many as 225 tree species per hectare have been reported in these ecosystems, values that are equivalent to almost finding a different tree species every other tree encountered in the forest. Under some conditions, tree species richness decreases in tropical forests. For example, Hart et al. (1989) reported that forests in Africa that were dominated by a single species had on average 18 tree species per 0.5 ha. Fewer species still are normally found in freshwater forested wetlands. Values in these systems range from 1 to 23 species per hectare, with averages at 8.3 and 6 species per hectare for riverine and basin freshwater wetlands, respectively (Lugo et al. 1988). Mangrove forests are even more species-poor, and, in fact, are among the most species-poor forest ecosystems in the tropics (Lugo et al. 1988). Mangrove stands can be found where the plant species list is only one tree species. In fact, Jansen (1985) asked: "where is the mangrove understory?" after he observed that mangrove forests contain no understory plants. Several articles were written trying to answer the questions raised by Jansen (Corlett 1986, Lugo 1986).

Environmental conditions within mangrove forests make it extremely difficult for plants to grow and reproduce. These include flooding, prolonged hydroperiods, anoxic conditions, and salinity. Salinity is the major obstacle to species invasion to mangrove forests because in order to survive in a saline environment, plants must possess highly specialized metabolism and mechanisms to either exclude salt or mitigate its effects on living cells. Worldwide, only 34 tree species have been identified as possessing these adaptations (true mangroves *sensu* Tomlinson 1986), 20 other species tolerate some salinity and are considered minor elements of mangroves, and an additional 60 species are considered mangrove associates (Tomlinson 1986).

Only a small fraction of the world's flora are halophytes (plants that tolerate salinity) and those taxa with halophytic species have a lower mean number of genera per family and a lower mean number of species per genera than non-halophytic taxa (Waisel 1972). This means that when considering the subject of mangrove invasions by exotic species, one has to realize that the species pool available to invade these ecosystems is limited on a global scale. If a tree was to be able to grow under the saline and hydrologic conditions of mangroves, it would by definition be a mangrove tree species, and should it be an exotic to Florida, it would not be an exotic to the mangrove environment. So, the first question one asks when finding an exotic tree species or any kind of exotic plant species growing inside a mangrove forest is: **is it a halophyte**?

I have witnessed non-halophytes (other than epiphytes) inside mangrove forests in Florida. For example, floating acquatic plants like the water hyacinth invade mangrove forests. However, their incursions into mangroves is short-lived and depend on one of two conditions: (1) how quickly the plant dies if it floated into saline water, or (2) how long the freshwater on which it floats lasts as freshwater inside the mangrove. Freshwater lenses occur in mangroves during periods of high rainfall or runoff, and it is possible for acquatic plants to occupy that space and survive as long as the freshwater lens maintains its integrity. Once the saline conditions is re-established, these invaders are doomed. So, the second question one must ask when finding a species invasion in the mangroves is: **what conditions of the environment is it occupying and how long will those conditions last?**

Mangrove forests usually have sharp ecotones with adjacent ecosystems because the saline condition of the mangroves is tidally and topographically determined. Wherever the tide transports saltwater, the mangroves will follow. But changes in elevation, even if on the order of centimeters, can create a sharp ecotone where the mangrove conditions end. Usually, these conditions either do not have salinity, do not flood, flood without salinity, or have salinity without floods. Depending on them, the adjacent ecosystem can be a freshwater wetland, a saline flat, a terrestrial ecosystem, or any combination of these. The transition from mangrove to nonmangrove conditions can be shaper as indicated or gradual, where mangroves become less and less important as the conditions change away from those that delimit the mangrove habitat.

In Florida, I have witnessed exotic plant pecies, including trees, invading the ecotones of mangroves. These trees can be observed growing quite successfully, but failing to penetrate the mangrove environment. Examples of these are the *Melaleuca quinquenervia, Casuarina equisetifolia,* and *Schinus terebinthifolius*. Loope et al. (1994) discusses these and other examples. These trees form dense and vigorous stands at mangrove ecotones, but fail to invade the saline soils of mangroves because they are not halophytes. Therefore, a third question one needs to ask when considering the invasion of exotic species into mangroves is: **What is the geographic location of the invasion, is it only at the ecotone or does it penetrate the forest?**

There is a quick action mechanism that promotes species invasions into forest ecosystems. That mechanism is disturbance. Disturbance events disrupt ecosystem structure and functioning, and can create conditions for the invasion of species. There are two ways in which disturbances can create conditions for species invasions. First, the disturbance alters microsite conditions on a temporal basis. For example, after a canopy opening, light energy and air temperatures increase in the resulting gap. Through succession, the gap is repaired and original stand conditions return. Invading species have a window of opportunity to enter the system during the time its repair and succession are taking place. The invasion after a frost of frost-intolerant mangroves by first tolerant *Spartina* marshes, is an example of how a disturbance can determine the dominance of species at a site (Lugo and Patterson Zucca 1977, Kangas and Lugo 1990).

A second way in which a disturbance can affect site conditions is through a radical modification of the environment such that succession is not likely to return to original conditions. Instead, succession may proceed through an alternative pathway into a different ecosystem state. An example would be if a disturbance changes the course of a river, or impounds a mangrove, or removes the mangrove substrate, i.e., the peat. Succession after these changes is likely to proceed to different

states because hydrological, edaphic, topographic, or even salinity conditions have been modified. Invading species have an opportunity toexploit the new environment and gain an advantage over the original species composition at the site. Species invasion of mangroves after a disturbance raise a fourth and fifth question. **Is the invasion a shortterm response to changes in microsite conditions?** or **Is the invasion the result of a longterm shift in the mangrove habitat?"**

My experience in Florida and elsewhere, suggests that exotic species fail to invade mangrove forests after disturbances, such as hurricanes, as long as the hurricane fails to change salinity and hydrological conditions. However, it is conceivable that native or exotic species could invade mangrove habitats in locations where the disturbance has changed the salinity and the hydroperiod of the stand. Smith et al. (1994) reported both native and exotic grasses and sedges growing on the tip-up mounds inside mangroves in the moths after passage of a hurricane. These elevated mounds lose their soil salt by leaching and become a different environment than the soil below.

Human activities such as the construction of canals, diversion of water flows, construction of roads, dredging, and filling, greatly modify mangrove wetland conditions, and could facilitate the introduction of native or exotics species into impacted mangrove habitats. In these instances, it is necessary to carefully access the environmental change, the nature of the species, and the spatial and temporal distribution of the species before one can conclude that a mangrove habitat is being invaded.

The observations of Pimm et al. (1994), Loope et al. (1994), and Smith et al.(1994) after Hurricane Andrew, impacted south Florida mangroves are consitent with the discussion above. The description by Loope et al. (1994) of the invasion of *Schinus* into "higher (less wet and less saline) areas within the mangrove zone" deserves further analysis and an ecophysiological determination on whether this species is a halophyte or not. Pimm et al. (1994) suggest that *Schinus* can outgrow mangroves in open areas, but this broad generalization is not supported by the description of the phenomena in Smith et al. (1994). Smith et al. (1994) qualify their observation to "along the upstream mangrove marsh interface" from the Shark River to the Chatham River where *Schinus* leafed out faster than the surviving mangroves. Clearly, the "invasion" of *Schinus* is at the ecotone and it is not clear if this species has the capacity to invade mangrove forests.

SUMMARY

Mangrove forests are a tough ecosystem to invade because there is a small species pool that can survive its salinity, hydroperiod, and anaerobic soil conditions. Even species that survive one of the conditions may not be able to survive all three. For example, *Conocarpus erectus*, listed erroneously as a mangrove, can tolerate salt but not flooding. The same is true of *Casuarina,* while *Melaleuca* tolerates flooding, but not salinity. Before one can conclude that a species has invaded a mangrove forest, one has to answer five questions that lead one to rule out the following: if the species has adaptation to salinity or not, if the species is just taking advantage of a temporary environmental condition, if the species is located at a particular geographic zone avoiding the stressors of the mangrove environment, if the species is temporarily taking advantage of a disruption of the forest by a disturbance, or if the disturbance has sochanged the habitat that it is no longer a mangrove environment. Reports of mangrove invasions by exotic species in south Florida may be premature.

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