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The effects of grapsid crabs on mangrove forest restoration

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Introduction

Mangrove forests once occupied 75% of the tropical coasts worldwide, but anthropogenic pressures have reduced the global range of these forests to less than 50% of their original total cover (Kairo, et al. 2001). Much of their disappearance is caused by the same threats that are facing wetland ecosystems around the world including soil pollution, water pollution, drainage, and land reclamation (Imbert, Rousteau, and Scherrer 2000). These threats result from the urbanization of the tropical coastlines where extensive mangrove forests exist and by the conversion of mangroves to areas of aquaculture. Intensive shrimp farming techniques developed in Taiwan in the 1970's gave way to a sudden rush in modern shrimp farming in Southeast Asia, the Caribbean, and Latin America, resulting in many mangroves being converted into aquaculture ponds. In the Indo-Western Pacific region alone, 1.2 million hectares of mangroves had been converted to aquaculture ponds by 1991 (Kairo, et al. 2001). Disturbances of the ocean adjacent to the mangroves, such as hurricanes and oil spills, also have a negative effect on mangroves.

Because mangrove forests are economically important to the people surrounding them, many mangroves have been actively managed within the last hundred years. Despite this management mangroves continue to disappear. As a result, current attention is focused on conservation of the world's remaining less-impacted mangroves and restoration of the far more extensive degraded mangroves (Ellison 2000). Most restoration work has focused only on techniques for growing mangrove trees with little attention paid to long term community structure or linkages with other systems (Kaly and Jones, 1998). Prior to 1982, the only explicit rationale or goal of mangrove restoration projects was afforestation for silviculture. Lewis (1982) recommended for the first time that restoration of mangrove forests should emphasize ecological values, animal habitats, and detrital food sources for inshore and pelagic food webs (Ellison 2000). Despite this change in thought, mangrove restorations are still not much different today than they were 20 years ago. In fact, many mangrove restoration projects, especially those in Southeast Asia, still explicitly seek to establish forest plantations in degraded mangrove areas (Ellison 2000). It is commonly thought that mangroves may be one of the easiest marine systems to reconstruct because of the apparent plasticity of mangrove assemblages, the presence of viviparous seedlings and the observation that these seedlings often have the best survival and growth rates where adult conspecifics are absent (Kaly and Jones, 1998). Although mangrove restoration may be considered easy, there are still some possible problems that could be encountered. Special attention should be paid to the loss of mangrove tree propagules due to propagule predation (Kairo et al. 2001). Some of the most frequently observed predators of mangrove tree propagules are small crabs belonging to the family Grapsidae and are referred to as grapsid crabs. Grapsid crabs are considered significant seed predators of mangroves and can be a threat to the successful regeneration or restoration of mangroves (Smith et al., 1989 and Dahdouh-Guebas et al., 1997). The purpose of this paper is to examine the effects of grapsid crabs on mangrove forest restoration.

The Mangrove Ecosystem

Mangrove forest, or mangal, are characterized by one or more species of salt-tolerant trees, or halophytes, that form distinct monospecific zones along tropical protected coastlines (Ellison and Farnsworth 1993). They are typically dominated by salt and flood tolerant trees and shrubs and are considered a type of wetland. Mangroves occur in a wide range of geomorphological settings ranging from the vast riverine and estuarine mangrove forests of Southeast Asia, the Sundarbans of Bangladesh and India, and along the Orinico River of Venezuela, to isolated mangrove cays that have developed atop carbonate sands and coral rubble along the coasts of the Caribbean, Micronesia, and the Andaman Islands (Ellison 2000).

Although there are 34 species belonging to 9 genera and 4 families that are major components of the mangroves worldwide and 20 species from 11 genera and 10 families that are minor components, individual mangrove ecosystems tend to have low species diversity and relatively simple structure (Rey 1999). Most mangrove forests are made up of only a few species and each species only grows in a certain area. The existence of more or less distinct zones, each dominated by different mangrove species is usually evident in well developed mangroves (Rey 1999). Although tides and successful seedling establishment play an important part in creating these zones, predation of certain propagules by herbivores, such as crabs, can also influence which species creates a certain zone.

Mangrove tree species are able to survive in salty environments because they can obtain fresh water from the salt water by either excreting excess salt from their leaves or by blocking absorption of salt at their roots. The three most well known mangrove species are the red mangrove (*Rhizophora mangle*), the black mangrove (*Avicennia germinans*), and the white mangrove (*Laguncularia racemosa*). The red mangrove typically grows along the waters edge. It can be identified by its prop roots which are above ground and make it appear as if it is standing or walking on the surface of the water. The black mangrove usually occupies slightly higher elevation upland from the red mangrove where it is only sometimes flooded by the tide. It can be identified by its numerous finger-like roots called, pneumatophores, which protrude through the soil. The white mangrove usually occupies the highest elevations, farther upland than either red mangroves or black mangroves. The white mangrove does not have any visible aerial roots, and therefore has to be identified by its leaves which are elliptical, light yellow green, and have two distinguishing glands (Department of Environmental Protection, Florida Marine Research Institute).

Mangroves are the only true viviparous plants, where the seed remains attached to the parent plant and germinates into a protruding embryo (propagule) before falling from the tree (Rey 1999). There are two strategies a propagule has for growing when it is dropped from a tree. It can either drop from the tree at low water and then plant itself in the mud which is called the planting strategy (vertical planting), or it can fall in the water at high tide and then float to another site where it settles and grows which is called the standing strategy (horizontal planting) (Dahdouh-Guebas 1998).

Due to their location between land and sea, mangrove forests contribute to shoreline protection, upland runoff regulation, and provide breeding, feeding, and nursery grounds for a wide range of fauna (Imbert, Rousteau, and Scherrer 2000). In addition, they are known for their high primary production and for the vast amount of products and income they provide to local communities. For centuries mangroves have provided timber and fuelwood, finfish and edible crustaceans, and bioactive compounds for tanning and medicinal purposes. Within the last hundred years mangroves have been actively managed for timber, fuelwood, and pulpwood production and more recently have been managed for ecotourism and the cultivation of fish and shrimp. Despite claims that mangrove forests can be managed sustainably, they continue to be degraded and are disappearing at a rate of about 1.5% per year (Ellison 2000).

Grapsid Crabs

Description of the Species

Of all benthic macrofauna inhabiting the mangrove forests, grapsid crabs are amongst the most important with regard to both the number of different crab species and the total number of crabs present (Dahdouh-Guebas, et al. 1997). Most grapsid crabs belong to the subfamily Sesarminae and many also belong to the largest genus in Sesarminae, called *Sesarma*. Some of the more commonly mentioned species in the literature are *Neosarmatium meinerti*, *Neosamartium smithi*, *Sesarma messa*, *Sesarma moluccensis*, *Metapograpsus latifrons*, and *Metapograpsus thukarhar* (Smith 1987, Lee 1998). There is considerable difference in the occurrence and diversity of mangrove grapsid crab species depending on the particular mangrove forest. The largest amount of diversity of grapsid crabs recorded is from peninsular Malaysia where 51 species of grapsids, of which 44 were sesarmines, were found (Lee 1998). This differs greatly from a recent review of the grapsid crabs of the Americas where 23 species of Sesarma were described but only 5 of these species are associated with mangroves.

Propagule Predation

Grapsid crabs can play a considerable role in the predation of mangrove propagules and may be a threat to either natural or artificial mangrove restorations (Dahdouh-Guebas, et al. 1998). A study by Dahdouh-Guebas, et al. (1997) looked at the predation rates of mangrove propagules by the grapsid crab, *Neosarmatium meinerti*, in order to determine how much of a threat this crab species is to mangrove regeneration and restoration. They planted propagules of six different mangrove tree species in the area where *N. meinerti* are present near Mida Creek and Gazi Bay in Kenya, Africa and observed how fast the propagules were predated by this species of crab. They found that predation occurred very fast with 50% of the propagules cleared after only 2 hours and 85% cleared after 24 hours. In order to overcome these high predation rates and possibly protect artificial regeneration plots, Dahdouh-Guebas, et al. (1998) suggests that the saturation method be used. The saturation method involves planting more mangrove propagules than necessary in order to ensure that some propagules escape predation and establish themselves. This method has been observed in nature where observations of over 500 mature propagules per tree at one time suggest that in natural conditions mangrove trees might saturate the crabs by dropping a large number of propagules in a short period. The saturation method has also been successful in reafforestation plots in Sulawesi, Indonesia where the people commonly plant propagules 25cm apart even though they are taught to plant them 50cm apart. They do this because they have found that planting more propagules allows at least some of the propagules to survive predation (Dahdouh-Guebas et al. 1997).

The type of planting strategy, horizontal or vertical, may also influence rates of predation by grapsid crabs. Dahdouh-Guebas, et al. (1997) found that *N. meinerti* had a clear preference for horizontally planted propagules during the first 3 hours following planting but by the end of 48 hours all propagules were predated regardless of how whether they were planted horizontally or vertically. They hypothesized that this is due to the weight and size of the propagules which make vertically planted ones difficult to handle for the crabs. The crabs first chose the easier propagules to move and once those were cleared they switched to the more difficult to move, vertically planted ones. The idea of preference depending on planting strategy ties in with the saturation method because when crabs are not saturated with food they will consume propagules irregardless of the planting strategy as shown in this study. However, vertical planting was still the best way to avoid immediate predation in this study and when combined with the saturation method it may have an even greater affect on propagule survival.

Although grapsid crabs tend to consume a large amount of propagules, some studies have shown that they can be selective in which propagules they consume depending on factors such as the nutritive values of the propagules and the density of the specific mangrove tree species in the canopy. Smith (1987) found a significant difference in predation among the propagules of five mangrove tree species which could almost entirely be accounted for by the difference in nutritive values of the mangrove propagules. In addition, he hypothesized that an inverse relationship between the amount of seed predation and the dominance of a tree species in mangrove forest canopies existed. In further studies, Smith et al. (1989) was able to prove that this relationship existed specifically among four species of *Avicennia* where the propagules of the four species were consumed in greatest quantity where they were rarest in the forest canopy and in least amounts where they dominated the canopy. The idea of a dominance-predation model among mangrove tree species and grapsid crab species suggests that propagule predation is dependent on the density of the mangrove species present. Considering that typical mangrove restorations involve planting monocultures or low-diversity polycultures, the idea of density dependent propagule predation suggests that restorations may have fewer problems with propagule predation if species mixtures are planted (Ellison 2000).

The selectivity of grapsid crabs can also alter recruitment of mangrove seedlings in species-specific ways that influence forest zonation (Lee 1998). Although tides and successful seedling establishment play an important part in creating these zones, predation of certain propagules by herbivores can also influence which tree species creates a certain zone. Ellison and Farnsworth (1993) found that the zonation patterns of Australian mangal is more influenced by predation pressure rather than the amount of light available for growth. Selectivity may also influence restorations if the propagules of one mangrove tree species are consumed more than another. A study by Smith et al. (1989) showed that grapsid crabs were able to exclude the mangrove species, *Avicennia marina*, from the mid-intertidal area of a mangrove forest by consuming 100% of its propagules, but when grapsid crabs were excluded from this area *A. marina* was able to become established and grow in this same mid-intertidal area. The method of crab exclusion is a possible way to increase propagule survival. Mangrove propagules need 25 days to establish in order to survive (Dahdouh-Guebas et al., 1998). Therefore if crabs were excluded from a restoration site, or portions of a site, for 25 days while propagules were establishing, propagule survival will increase. Crab exclusion can be accomplished by either preventing crabs from entering an entire restoration site with some sort of fence or by excluding crabs from individual propagules by placing the propagules inside bamboo during planting (Kairo et al. 2001).

The selectivity of crabs also extends to the age of the propagule. Dahdouh-Guebas et al. (1997) showed in a mangrove predation experiment that freshly collected mangrove propagules were more predated upon than mature propagules which had been stored for eight weeks prior to planting. These observations show that maturation may be a means of decreasing the palatability of propagules to crabs, and this may ultimately lead to less predation. Maturation can be accomplished quickly by storing propagules in moist, plastic bags for three days under natural shade to protect them from direct sunlight or slowly by storing them for up to 8 weeks in a humid, saline environment (Kairo et al. 2001 and Dahdouh-Guebas et al. 1997).

Nutrient Cycling

Although grapsid crabs can hurt a restoration through propagule predation, they also can have positive effects on a restoration once the threat of propagule predation is gone. Grapsid crabs not only feed on mangrove propagules but also on mangrove leaf litter. Through the feeding activities of grapsid crabs, large proportions of mangrove leaves are recycled within the forest (Lee 1998). The processing of leaf litter by grapsid crabs provides an important link in energy flow in mangrove ecosystems. The structure and function of mangrove ecosystems are likely to be seriously altered if the grapsid crab component of the biota is altered or destroyed (Lee 1998).

Conclusion

Consumption of mangrove propagules by grapsid crabs has profound ecological consequences on ecosystem structure and function (Lee 1998). Grapsid crabs consume mangrove propagules at high rates and can sometimes alter the distribution of mangrove tree species in an area because of their selectivity in propagule consumption. In order to protect mangrove restorations from being greatly affected by propagule predation certain methods need to be used. These methods include saturation of crabs with a large number of propagules, vertical planting of propagules, planting a mixture of species, and planting mature propagules. In addition, crab exclusion is another method that may be helpful.

The high species richness and abundance and the important ecological role of the grapsid crab demands special attention in mangrove conservation issues (Lee 1998). Planting recommendations for mangrove restorations are not currently integrated with the existing data on propagule predation (Ellison 2000). Considering that there are so many mangrove restorations occurring and many more that will likely be done in the future and looking at the large impacts propagule predation by grapsid crabs may have on a restoration, it is very important that research on this topic continue and results of this research be incorporated into suggested planting methods.

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