Nutrient Controls on Biocomplexity of Mangrove Ecosystems

Mangrove Ecosystems

Mangrove forests are important coastal ecosystems that provide a variety of ecological and societal services. These intertidal, tree-dominated communities along tropical coastlines are often described as "simple systems," compared to other tropical forests with larger numbers of plant species and multiple understory strata; however, mangrove ecosystems have complex trophic structures, and organisms exhibit unique physiological, morphological, and behavioral adaptations to environmental conditions characteristic of the land-sea interface. Biogeochemical functioning of mangrove forests is also controlled by interactions among the microbial, plant, and animal communities and feedback linkages mediated by hydrology and other forcing functions. Scientists with the U.S. Geological Survey (USGS) at the National Wetlands Research Center are working to understand more fully the impact of nutrient variability on these delicate and important ecosystems.

Worldwide, there are about 50 mangrove species, but species richness in any particular forest stand may vary. In Florida and the Caribbean region, the most common species is *Rhizophora mangle* (red mangrove) (fig.1), which typically dominates the shorelines of islands and low-lying regions along continental margins. Red mangrove may occur with two other species; *Avicennia germinans* (black mangrove), and *Laguncularia racemosa* (white mangrove), in addition to a number of mangrove associates such as *Conocarpus erectus* (button mangrove) and *Batis maritima* (maritime saltwort). In the Indo-West Pacific realm, forests may have over 30 mangrove species plus additional numbers of associates. Some mangrove forests may exhibit low structural complexity, but others may contain a variety of forbs, ferns, vines, and epiphytes such as orchids and bromeliads.

What is Biocomplexity?

The study of biocomplexity is a rapidly developing area of research that seeks to better understand the emergent properties of ecosystems and how they may be affected as underlying mechanisms or external forcing functions change. Habitat stability is an emergent property of ecosystems that arises as a consequence of many processes interacting at different spatio-temporal scales and at different levels of biological organization. For mangroves, habitat stability is primarily

***Rhizophora mangle* (red mangrove)**

***Avicennia germinans* (black mangrove)**

***Laguncularia racemosa* (white mangrove)**

Figure 1. Dominant mangrove species occurring in Florida and the Caribbean region.

dependent upon maintenance of soil elevations within the intertidal zone despite changes in sea level, sedimentation or erosion rates, and other factors. Funding from the National Science Foundation's Biocomplexity Program has allowed scientists with the USGS to participate in a multidisciplinary project that focuses on microbial and nutrient controls on biocomplexity of mangrove forests. The 5-year Mangrove Biocomplexity Project was one of five projects funded by NSF during 2000 and involves 10 investigators from 7 research institutions. The project is coordinated by scientists at the Smithsonian Institution and is based on a long-term mangrove experiment in the MesoAmerican Barrier Reef System off the coast of Belize. The role of the USGS in the project is to determine the effects of nutrients on root growth, peat formation, and soil elevation change in mangrove forests at this primary field site in Belize, as well as other mangrove sites around the world.

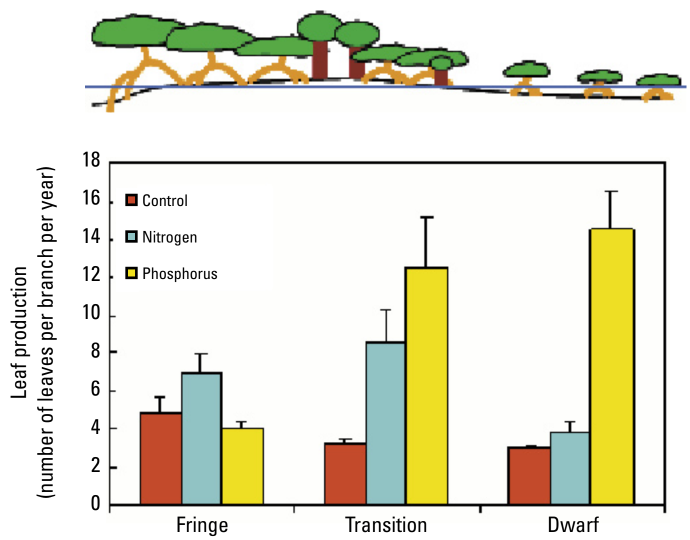
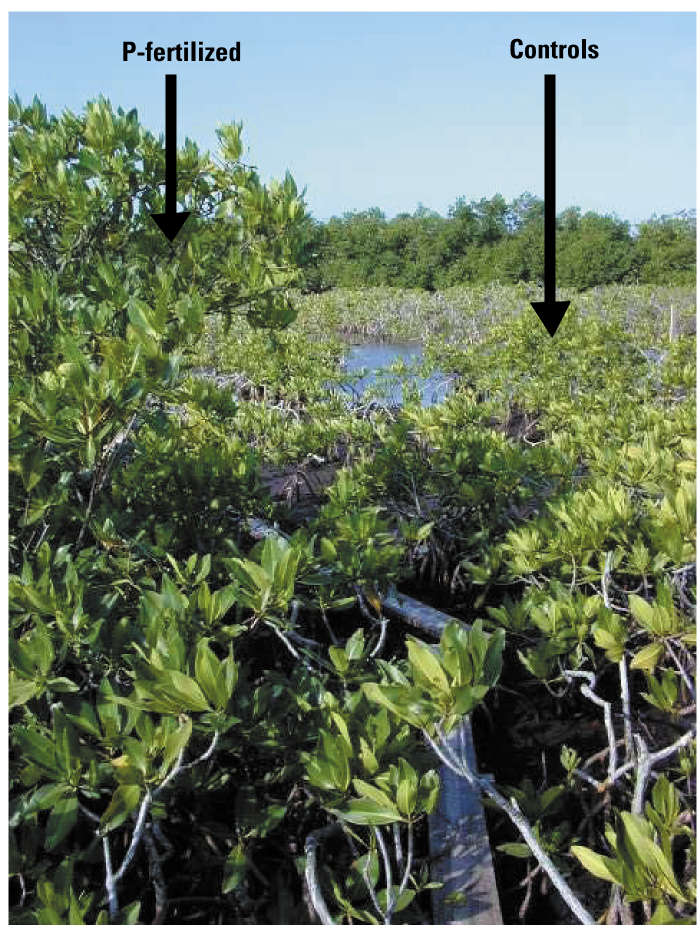


Figure 2. Response of red mangrove trees in Belize to additions of phosphorus (P) and nitrogen (N) fertilizer. The pattern of response indicates a unique switching pattern with fringe trees limited by N, dwarf trees in the forest interior limited by P, and transitional trees co-limited by N and P (McKee and others, 2002; Feller, McKee and others, 2003). Photograph (below) shows the larger stature of dwarf trees fertilized for 5 years in comparison to unfertilized controls.



Nutrient Limitations and Mangrove Growth

Mangroves exhibit a variety of growth forms, from trees that are over 25 m tall to bonsai-like specimens only 1 m tall. "Dwarf" mangroves can be found in Florida and throughout the Caribbean, and extensive stands occur in some areas of Central America. Although stunted growth may be caused by stress factors, such as excessive salinity or flooding, research in Florida and other locations has shown that nutrient limitation is often involved, either directly or indirectly (McKee and others, 2002; Feller, McKee, and others, 2003) (fig. 2). When dwarf trees are fertilized, their growth is stimulated, and they may ultimately attain heights equivalent to normal trees. Dwarf forms of all three species common to Florida and the Caribbean exist. The most common is dwarf red mangrove, which can be found in Florida, Belize, and other Caribbean mangrove ecosystems (McKee and others, 2002; Feller, McKee, and others, 2003). At Indian River Lagoon in Florida, stunted black and white mangroves grow in former mosquito impoundments (Feller,Whigham, and others, 2003).

Most research indicates that coastal wetlands are limited by a single nutrient, usually nitrogen (N); however, recent work in mangrove forests has shown not only that there may be more than one limiting nutrient but also that not all processes in mangrove wetlands are limited by the same nutrient. In Belize, dwarf trees were found to be limited by phosphorus (P), whereas taller trees growing along shorelines were nitrogen-limited, and transitional trees were co-limited by both nitrogen and phosphorus (McKee and others, 2002; Feller, McKee, and others. 2003) (fig. 2). Some forests may be limited by a single nutrient, as in Florida (Feller, Whigham, and others, 2003). In addition, processes other than mangrove production may be limited by different nutrients. Nutrient additions had different effects on decomposition, herbivory, and aboveground and belowground production by mangroves (Feller, McKee, and others, 2003). These findings suggest that a change in nutrient regime may have complex effects on mangrove ecosystem functioning that scientists are just beginning to understand. While nutrient addition may stimulate mangrove growth, it could have negative consequences for the ecosystem as a whole—even destabilizing the delicate balance between biotic and abiotic processes controlling soil elevations and habitat stability in peat-forming mangroves.

A global comparison of nutrient limitations to mangrove growth is essential to an understanding of how coastal eutrophication may impact these important ecosystems—in the United States, as well as in other countries. Collaboration between the USGS and the Smithsonian Environmental Research Center in Edgewater, Maryland has led to the establishment of multiple experimental sites in mangrove forests located in Florida, Louisiana, Belize, Honduras, Panama, Australia, and New Zealand (fig. 3). Research in different geographic areas will lead to more accurate models to predict global change impacts on mangrove ecosystems and better management plans for their conservation.

References Cited

Feller, I.C., McKee, K.L., Whigham, D.F., and O'Neill, J.P., 2003, Nitrogen vs phosphorus limitation across an ecotonal gradient in a mangrove forest: Biogeochemistry, v. 62, p. 145-175.

Feller, I.C., Whigham,D.F., McKee, K.L., and Lovelock, C.E., 2003, Nitrogen limitation of growth and nutrient dynamics in a disturbed mangrove forest, Indian River Lagoon, Florida: Oecologia, v. 134, no. 3, p. 405-414.

McKee, K.L., Feller, I.C., Popp, M., and Wanek,W., 2002, Mangrove isotopic fractionation ($\delta^{15}N$ and $\delta^{13}C$) across a nitrogen versus phosphorus limitation gradient; Ecology, v. 83, no. 4, p. 1065-1075.

For more information, contact
Karen L. McKee
U.S. Geological Survey
National Wetlands Research Center
700 Cajundome Blvd.
Lafayette, LA 70506
337-266-8500
http://www.nwrc.usgs.gov

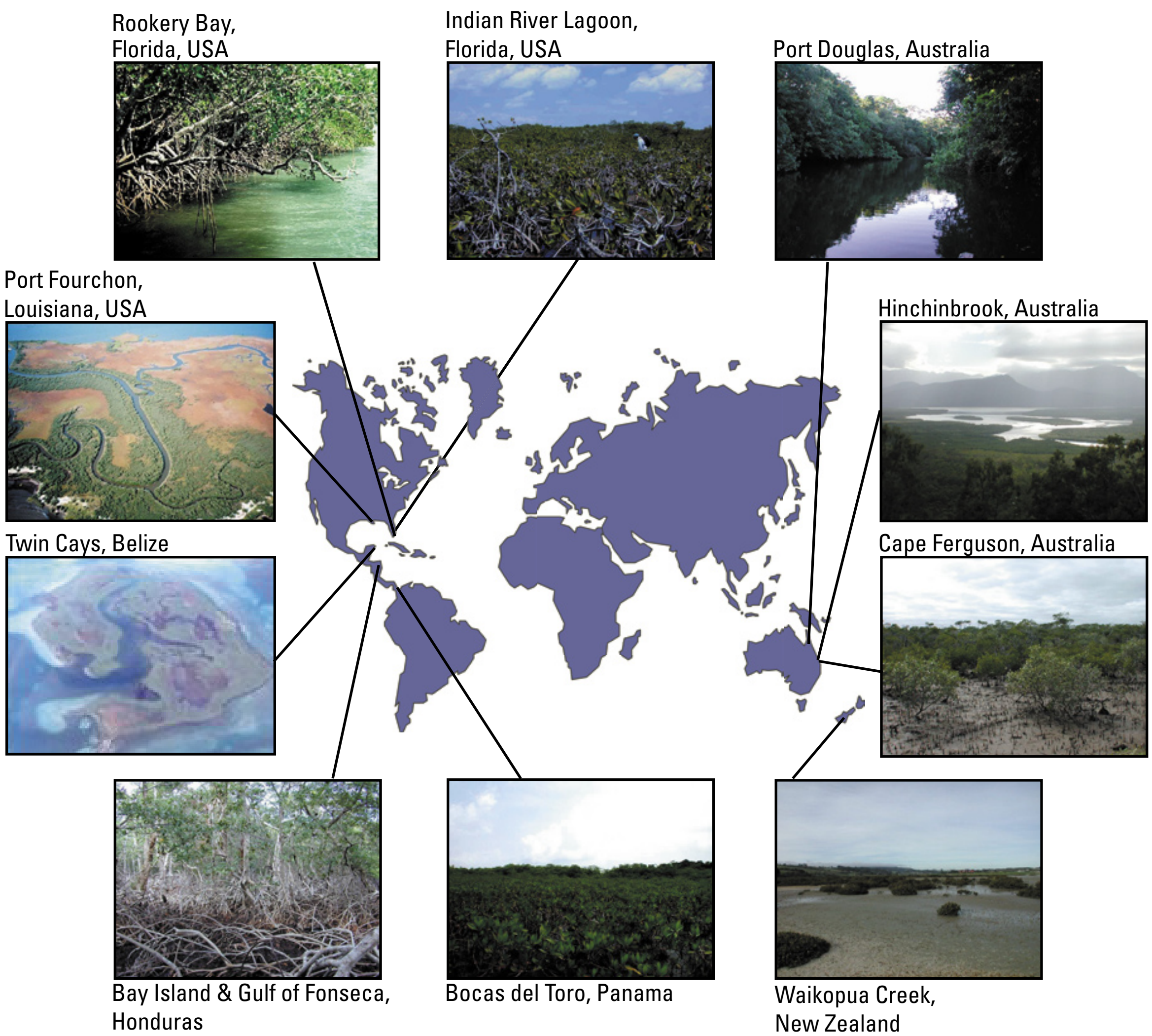


Figure 3. Location of multiple experimental sites where USGS scientists are studying nutrient controls on mangrove ecosystem structure and function.