Global Change Impacts on Mangrove Ecosystems

Global Threats to Mangrove Ecosystems

Mangroves are tropical/subtropical communities of primarily tree species that grow in the intertidal zone. These tidal forests are important coastal ecosystems that are valued for a variety of ecological and societal goods and services. Major local threats to mangrove ecosystems worldwide include clearcutting and trimming of forests for urban, agricultural, or industrial expansion; hydrological alterations; toxic chemical spills; and eutrophication. In many countries with mangroves, much of the human population resides in the coastal zone, and their activities often negatively impact the integrity of mangrove forests. In addition, eutrophication, which is the process whereby nutrients build up to higher than normal levels in a natural system, is possibly one of the most serious threats to mangroves and associated ecosystems such as coral reefs. Scientists with the U.S. Geological Survey (USGS) at the National Wetlands Research Center are working to more fully understand global impacts on these significant ecosystems.

Changes in climate and other factors may also affect mangroves, but in complex ways. Global warming may promote expansion of mangrove forests to higher latitudes and accelerate sea level rise through melting of polar ice or steric expansion of oceans. Changes in sea level would alter flooding patterns and the structure and areal extent of mangroves. Climate change may also alter rainfall patterns, which would in turn change local salinity regimes and competitive interactions of mangroves with freshwater wetland species. Increases in frequency or intensity of tropical storms and hurricanes in combination with sea level rise may alter erosion and sedimentation rates in mangrove forests. Another global change factor that may directly affect mangrove growth is increased atmospheric carbon dioxide (CO_2), caused by burning of fossil fuels and other factors. Elevated CO_2 concentration may increase mangrove growth by stimulating photosynthesis or improving water use efficiency, but the consequences of this growth enhancement for the ecosystem are unknown.

Climate Change and Extreme Events

Mangroves in the continental United States reach the northern limits of their range in southern Florida, Texas, and Louisiana where they intergrade with the temperate salt marsh grass, *Spartina alterniflora* (smooth cordgrass). Scientists at USGS are focusing on the ecotone between salt marsh and black mangrove (*Avicennia germinans*) in coastal Louisiana (fig. 1). Numerous populations of black mangrove occur in scattered stands across the deltaic plain (29° N latitude), typically dominating creekbanks where they have become established. In Louisiana, black mangrove is periodically damaged or killed by

Figure 1. Black mangrove-salt marsh community in coastal Louisiana. Brown areas are dead marsh, and green vegetation is healthy black mangrove. Photo by K.L. McKee, reprinted with permission of Blackwell Publishers.

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freezes, since mangroves are tropical species and susceptible to cold temperatures. Consequently, mangroves growing at their distributional limits do not reach the height or biomass attained by trees at tropical latitudes. In 2000, a historic drought and related factors led to extensive dieback of smooth cordgrass but left black mangrove undamaged (McKee and others, 2004). Scientists monitoring this unprecedented dieback event have documented the effects on the mangrove-salt marsh ecotone. In some areas where salt marsh was damaged, black mangrove has expanded (fig. 2). These periodic events suggest that vegetation shifts in these transitional communities may occur much more quickly than previously recognized.

On the other side of the world in New Zealand, a related species, gray mangrove (*Avicennia marina*) occurs near the southern limits of mangrove distribution (36° S latitude). Scientists with the USGS are collaborating with colleagues from the Smithsonian Institution and New Zealand's National Institute of Water and Atmospheric Research (NIWA) to study mangrove populations and controls on their structure and function. Like the populations of black mangrove in Louisiana, the New Zealand mangroves are stunted in stature (fig. 3). Mangrove cover in some estuaries, however, has expanded 50 to 75 percent between 1955 and 2000, possibly because of increases in sediment and nutrient inputs to estuaries (Nichols and Ellis, 2002). Field experiments to examine nutrient and disturbance effects on mangroves have been established at both Louisiana and New Zealand sites. Comparisons of these two sites will provide a much greater understanding of global

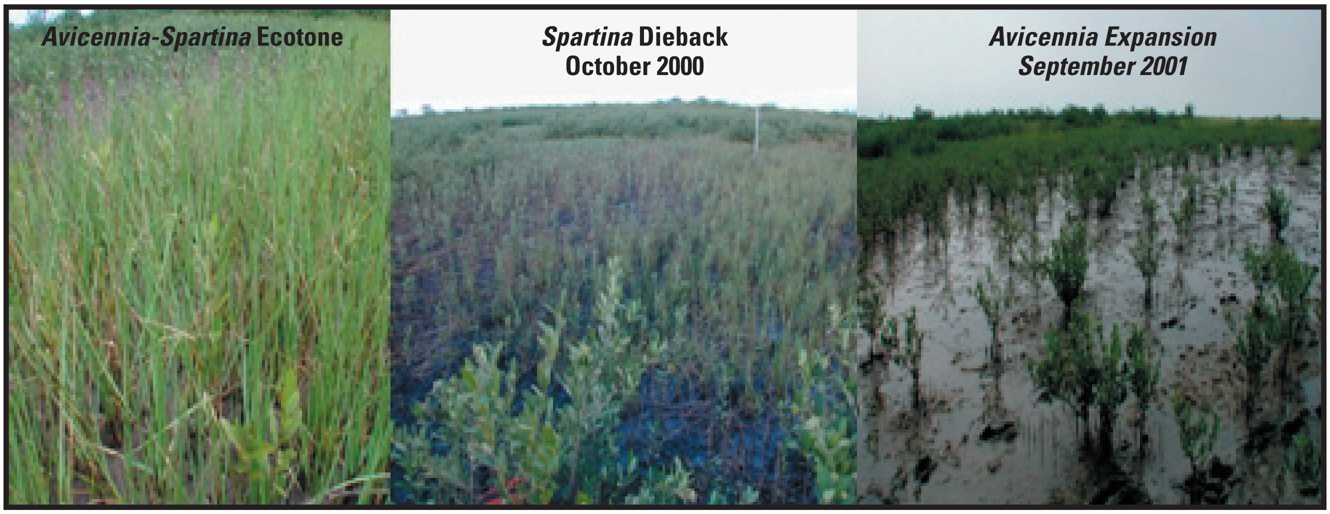

Figure 2. Expansion of black mangrove (*Avicennia germinans*) into salt marsh following sudden dieback of smooth cordgrass (*Spartina alterniflora*) in some areas of coastal Louisiana.

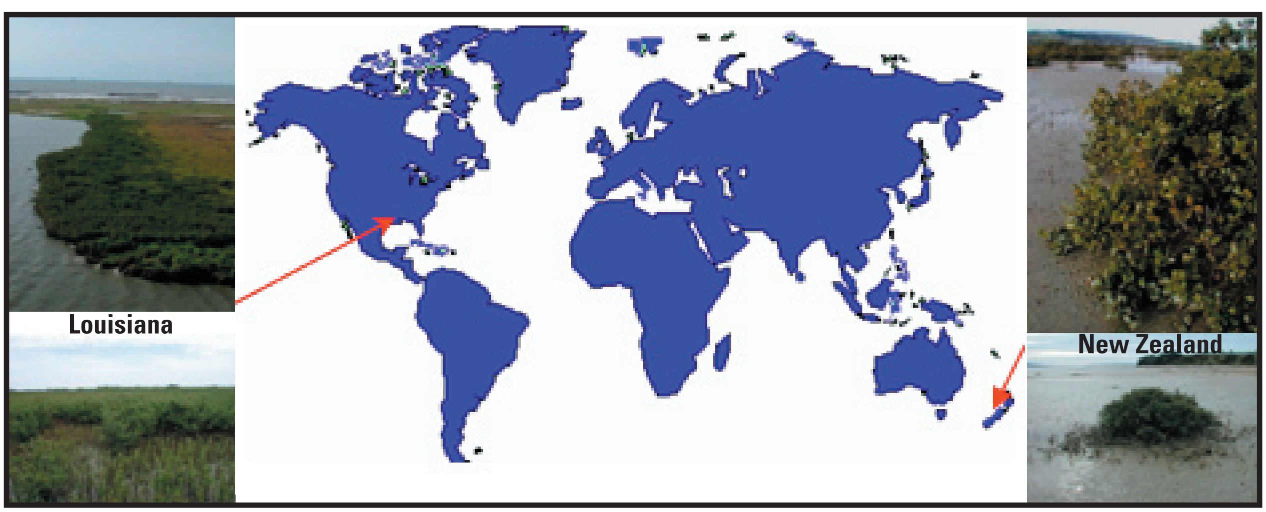

Figure 3. U.S. Geological Survey scientists are studying mangrove populations at the latitudinal extremes of distribution near Port Fourchon, Louisiana, USA, and at Waikopua Creek, New Zealand.

impacts on transitional plant communities than experiments conducted in single geographic locations.

Elevated Atmospheric Carbon Dioxide

Carbon dioxide concentration in the atmosphere has increased about 21 percent from 280 parts per million (ppm) in preindustrial times to approximately 370 ppm today and is predicted by some models to double within the next century. Effects of elevated CO_2 and climate change will likely be apparent first in geographic areas where major vegetation types meet. With funding from the USGS Global Change Program, investigators are conducting experiments to determine the relative responses of this mangrove-salt marsh community to CO_2 enrichment and interactions with local factors such as nutrient regime (fig. 4). Preliminary results indicate that vegetation shifts from salt marsh to mangrove-dominated communities will not occur by increases in CO_2 alone, especially where soil conditions promote growth of smooth cordgrass which suppresses expansion of black mangrove; however, where smooth cordgrass is stressed or eliminated, for example by climate extremes, black mangrove may invade salt marsh (fig. 2).

Figure 4. An experiment to determine effects of elevated carbon dioxide (CO_2) and other factors on a mangrove-salt marsh community.

Accelerated Sea Level Rise and Peat-forming Mangroves

Scientists from USGS have collaborated with Smithsonian Institution scientists to understand how peat-forming mangroves keep pace with rising sea level. Mangrove islands in the Mesoamerican Barrier Reef System are isolated from inputs of terrigenous sediment and are thus dependent upon accumulation of organic matter for soil formation. Here, mangroves have built vertically through peat formation, which occurs when decomposition of organic matter is slow. Soil waterlogging and low nutrients, which slow decomposition of mangrove tissues, naturally lead to a buildup of peat that raises the soil surface a few millimeters per year over long periods of time. Mangrove peat is composed primarily of refractory roots, rather than leaf or wood material that decays more quickly or is removed by tides (Middleton and McKee, 2001). Mangrove islands are underlain by peat up to 10 m in depth, and radiocarbon dating indicates that mangroves established in these sites 7,000 or 8,000 years before present. As the sea level rose, mangroves kept pace by deposition and slow turnover of roots (McKee and Faulkner, 2000).

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