USGS
science for a changing world

Belowground Dynamics in Mangrove Ecosystems

Mangrove Ecosystems

Mangrove ecosystems are tropical/subtropical communities of primarily tree species that grow in the intertidal zone. These tidal communities are important coastal ecosystems that are valued for a variety of ecological and societal goods and services (fig. 1). Mangrove wetlands are important filters of materials moving between the land and sea, trapping sediment, nutrients, and pollutants in runoff from uplands and preventing their direct introduction into sensitive marine ecosystems such as seagrass beds and coral reefs. Mangroves serve as nursery grounds and refuge for a variety of organisms and are consequently vital to the biological productivity of coastal waters. Furthermore, because mangroves are highly resilient to disturbances such as hurricanes, they represent a self-sustaining, protective barrier for human populations living in the coastal zone. Mangrove ecosystems also contribute to shoreline stabilization through consolidation of unstable mineral sediments and peat formation. In order to help conserve mangrove ecoystems, scientists with the United States Geological Survey (USGS) at the National Wetlands Research Center are working to more fully understand the dynamics that impact these vital ecosystems.

Sea-Level Rise, Peat Formation, and Habitat Stability

Early ecologists referred to mangroves as “landbuilders” based on observations that mangrove shorelines built seaward. Geologists, however, have criticized this viewpoint, offering evidence that mangroves do not actually build land, but instead respond to inputs of mineral sediment which creates the land upon which mangroves grow. Actually, mangrove soils develop through a combination of two processes: mineral sediment deposition and organic matter accumulation (fig. 2), but the relative contribution of these processes varies with geomorphology and other factors.

The mangrove islands of the Mesoamerican Barrier Reef System, specifically located in Belize, are isolated from inputs of terrigenous sediment and are thus dependent upon accumulation of organic matter for soil formation. Because mangrove soils are waterlogged and nutrient availability is low, decomposition of mangrove roots and other plant tissues is extremely slow (Middleton and McKee, 2001). These conditions lead to a slow buildup of organic material called peat that raises the soil surface a few millimeters per year over long periods of time. Mangrove islands are underlaid by peat deposits that may be

Figure 1. Mangroves are important coastal ecosystems valued for a variety of ecological and societal goods and services.

125 years of science for America ★ ★ ★ ★ ★ *1879–2004*

U.S. Department of the Interior
U.S. Geological Survey

Fact Sheet 2004–3126
August 2004

Figure 2. A coring device is used to extract soil from a mangrove ecosystem to help USGS scientists reconstruct the vegetation history of the site. The extracted core shows mangrove peat deposited beneath a sand layer.

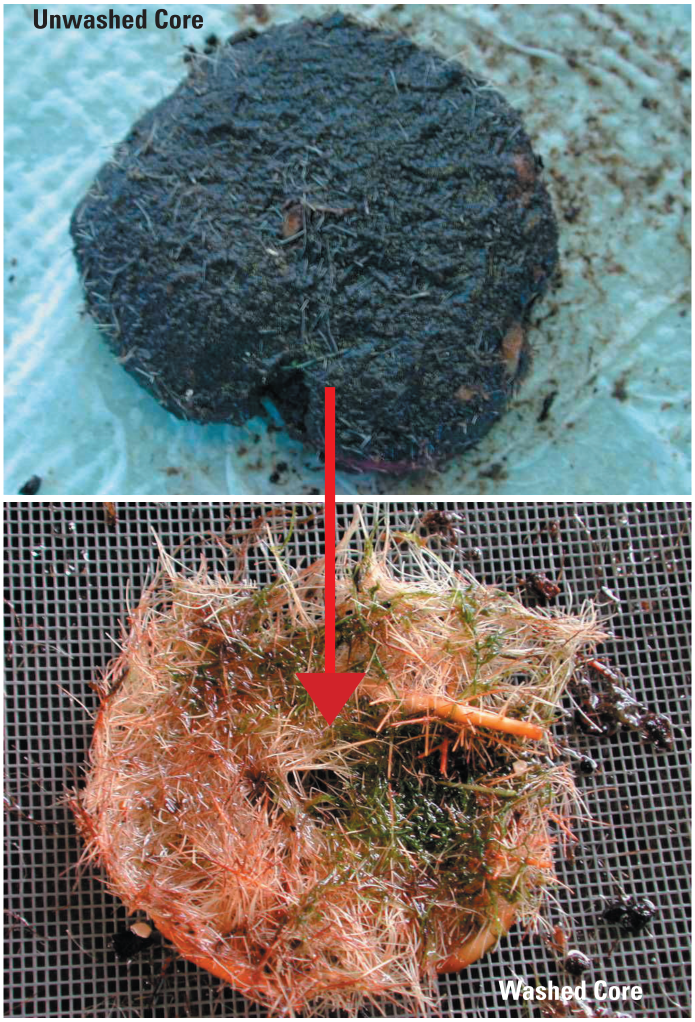

Figure 3. Contribution of roots to soil formation and vertical accretion in a mangrove ecosystem in Belize.

10 m in depth. These peat deposits are evidence that as sea level rose, mangroves have kept pace by slow deposition of plant parts (McKee and Faulkner, 2000). Mangrove peat is composed primarily of refractory roots (fig. 3), rather than leaf or wood material that decays more quickly or is removed by tides (Middleton and McKee, 2001).

Scientists are currently measuring surface and subsurface processes controlling soil formation and elevations in Florida, Belize, and other locations. They use surface elevation tables and marker horizons to quantify rates of elevation change and vertical accretion, respectively (fig. 4).

Mangrove Roots: The Unseen Half

Mangroves have two general types of roots: (1) aerial roots, which occur above the soil surface and provide a pathway for oxygen entry to (2) belowground roots that grow in the anoxic (without oxygen) soil. An intriguing growth pattern by mangrove roots was recently uncovered by USGS scientists working in Belize. Peat-based soils on mangrove islands were characterized by old root channels filled with living and highly branched roots of red (*Rhizophora mangle*) and black (*Avicennia germinans*) mangrove (fig. 5). Experiments indicated that root proliferation inside old, decaying roots may improve recovery of nutrients from decomposing tissues and may explain, in part, how mangroves persist and grow in nutrient-poor environments (McKee, 2001).

In spite of the importance of belowground processes to ecosystem productivity, nutrient dynamics, and ability to accommodate sea-level rise, very little is known about production and turnover of mangrove roots. Some information exists about root morphological and physiological responses to flooding, anoxia, sulfide, and nutrients (McKee and Mendelssohn, 1987; McKee, 1993; McKee, 1996), but few studies have examined belowground biomass or production rates in mangrove ecosystems.

Current work conducted by USGS scientists in Belizean mangrove forests is showing that root production rates vary across a tree height gradient from shoreline (tall trees) to interior (dwarf trees). Phosphorus additions to stunted red mangrove increased root production rates almost tenfold, whereas nitrogen enrichment had no effect on root production at any location. A relative measure of root production may be made by using in-growth bags filled with a standardized, root-free substrate. The bags are buried for a period of time to allow roots to grow, then retrieved and washed, and root biomass is measured. This technique is being used to compare relative rates of mangrove root production in Louisiana, Florida, Belize, Panama, Australia, and New Zealand. Information about root production aids in understanding controls on elevation change in mangrove systems occurring in different geomorphic settings. A greater understanding of mangrove systems will help to ensure that the most beneficial enviroments for their health are protected around the world.

Figure 4. Measurement of soil elevation change in a mangrove ecosystem in Belize using a rod surface elevation table.

Figure 5. A mangrove root channel formed by a refractory, dead root and containing living, highly branched roots that have grown inside. Root proliferation in such microsites may be a strategy by mangroves to capture limiting nutrients from decomposing tissues.

References Cited

McKee, K.L. and Mendelssohn, I.A., 1987, Root metabolism in the black mangrove, *Avicennia germinans* (L.) L.: Response to hypoxia: Environmental and Experimental Botany, v. 27, p.147-156.

McKee, K.L., 1996, Growth and physiological responses of mangrove seedlings to root zone anoxia: Tree Physiology, v. 16, p. 883-889.

McKee, K.L., 1993, Soil physicochemical patterns and mangrove species distribution- reciprocal effects?: Journal of Ecology, v. 81, p. 477-487.

McKee, K.L., 2001, Root proliferation in decaying roots and old root channels—a nutrient conservation mechanism in oligotrophic mangrove forests?: Journal of Ecology, v. 89, no. 5, p. 876-887.

McKee, K.L. and Faulkner, P.L., 2000, Mangrove peat analysis and reconstruction of vegetation history at the Pelican Cays, Belize: Atoll Research Bulletin, v. 468, p. 46-58.

Middleton, B.A. and McKee, K.L., 2001, Degradation of mangrove tissues and implications for peat formation in Belizean island forests: Journal of Ecology, v. 89, no. 5, p. 818-828.

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