Predicting Future Mangrove Forest Migration in the Everglades Under Rising Sea Level

Mangroves in the Everglades

Mangroves are highly productive ecosystems that provide valued habitat for fish and shorebirds. Mangrove forests are universally composed of relatively few tree species and a single overstory strata. Three species of true mangroves are common to intertidal zones of the Caribbean and Gulf of Mexico Coast, namely, black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*), and red mangrove (*Rhizophora mangle*). Mangrove forests occupy intertidal settings of the coastal margin of the Everglades along the southwest tip of the Florida peninsula (fig. 1).

Figure 1. Study area of mangrove communities in the Florida Everglades.

Current Status and Stresses of Mangrove Ecosystems

The flat slope and near sea-level elevation of the protected Everglades system account for one of the largest contiguous tracts of mangrove forests found anywhere in the world; these factors also, however, punctuate the vulnerability of mangrove forests to rising sea level and other climate changes. Global climate change has been projected to increase seawater temperatures and accelerate the rise in sea level which may further compound ecosystem stress in mangrove-dominated systems. These forests are subject to coastal and inland processes of hydrology largely controlled by regional climate, disturbance regimes, and human decisions about water management.

Mangroves are halophytes, meaning they can tolerate the added stress of waterlogging and salinity conditions that prevail in low-lying coastal environments influenced by tides. While early researchers attributed zonation patterns to salinity gradients, more recent field and laboratory studies indicate that mangroves have adapted wide tolerances to salinity and may be influenced to a greater degree by local hydrology and episodic disturbance events. Increases in relative sea level will eventually raise saturation and salinity conditions at ecotonal boundaries where mangroves are likely to advance or encroach upslope into freshwater marsh and swamp habitats.

SELVA-MANGRO Landscape Model of South Florida Mangrove Forests

The wide range of environmental settings and mangrove expanse in the Everglades coastal margin warranted the application of a landscape ecosystem model to predict potential habitat changes from sea-level rise. An integrated landscape model, SELVA-MANGRO, was developed to simulate the dynamics and distribution of mangrove communities of south Florida.

SELVA is a Spatially Explicit Landscape Vegetation Analysis model that tracks predicted changes in the biotic and abiotic conditions of each land unit (1 sq ha) on an annual basis for the entire simulated landscape. Each land unit is defined by habitat type (forest, marsh, aquatic), land elevation, water level, and salinity conditions. SELVA also calculates probability functions of disturbance for each forest unit relative to potential sea-level rise, lightning, and hurricane strikes. Intertidal forest units are then simulated with the MANGRO model based on unique sets of environmental factors and forest history.

MANGRO is a spatially explicit stand simulation model constructed for mangrove forests of the Neotropics (fig. 2). As an individual-based model composed of a set of functions predicting

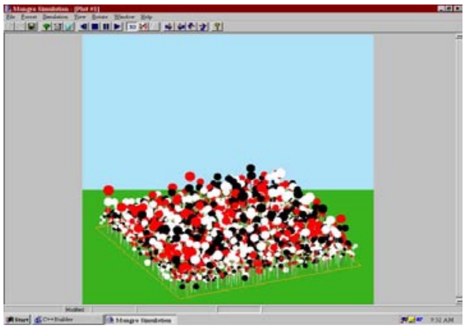

Figure 2. Sample graphics interface of the MANGRO model and a recruitment phase of mixed mangrove species composition (red = red mangroves, white = white mangroves, black = black mangroves).

the growth, establishment, and death of individual trees, MANGRO predicts the tree and gap replacement process of natural forest succession influenced by stand structure and environmental conditions.

The SELVA-MANGRO landscape model hierarchially integrates the scale and functions of the SELVA and MANGRO models into a single framework by coupling model parameters at the landscape and forest scales, respectively.

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Development of an Everglades Digital Elevation Model

A high resolution model of surface topography was developed for SELVA-MANGRO to predict the rate and fate of coastal inundation from projected sea-level rise scenarios. The ability to predict landward migration of mangroves caused by sea-level rise depends on the relationship between landward slope and elevation in relation to tide range and extent. Historic topographic and drainage maps (Davis, 1943) with 1 ft (0.3048 m) contour intervals across the south Florida Everglades were rectified and digitized into a geographic information system and spatial template of SELVA-MANGRO.

Forecasting Sea-Level Rise and Mangrove Migration across South Florida

SELVA-MANGRO applications forecasted mangrove migration under projected climate change scenarios of sea-level rise and saltwater intrusion for the Everglades coastal margin. Sea-level rise was modeled as a function of historic sea level conditions at Key West, Florida, based on mean annual tide records (1940 to present) projected into the 21st century with the addition of curvilinear rates of eustatic sea level expected from climate change. The data record was extended into the next 100 years for sea-level rise scenarios of 15 cm to 1.1 m by year 2100 based on low, mid, and high projections obtained from global climate change models.

SELVA-MANGRO results show that species and forest cover will change over space and time with increasing tidal inundation across the simulated landscape for all sea-level rise scenarios. The degree of mangrove migration compared with contemporary distribution and selected sea level scenarios (low, moderate, high) expected by the year 2100 are contrasted in figure 3. The model shows that freshwater marsh and swamp habitats will be displaced as the tidal prism increases over time and moves upslope. The greater the rate of sea-level rise, the faster or more extensive will mangroves encroach onto the Everglades slope. Figure 4 shows the predicted land area that mangroves may gain over the next century at the expense of other freshwater habitats. While scientists are evaluating various freshwater alternatives for restoring the natural hydrology of the Everglades, sea-level rise of even conservative estimates must not be ignored given the potential for saltwater intrusion and mangrove migration.

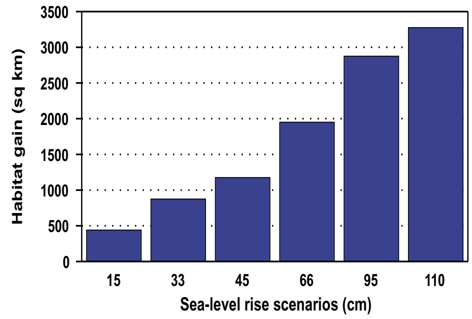

Figure 3. Contemporary and predicted distributions and species composition from inland mangrove migration under selected sea-level scenarios, low (15 cm), moderate (45 cm), and high (95 cm), expected by

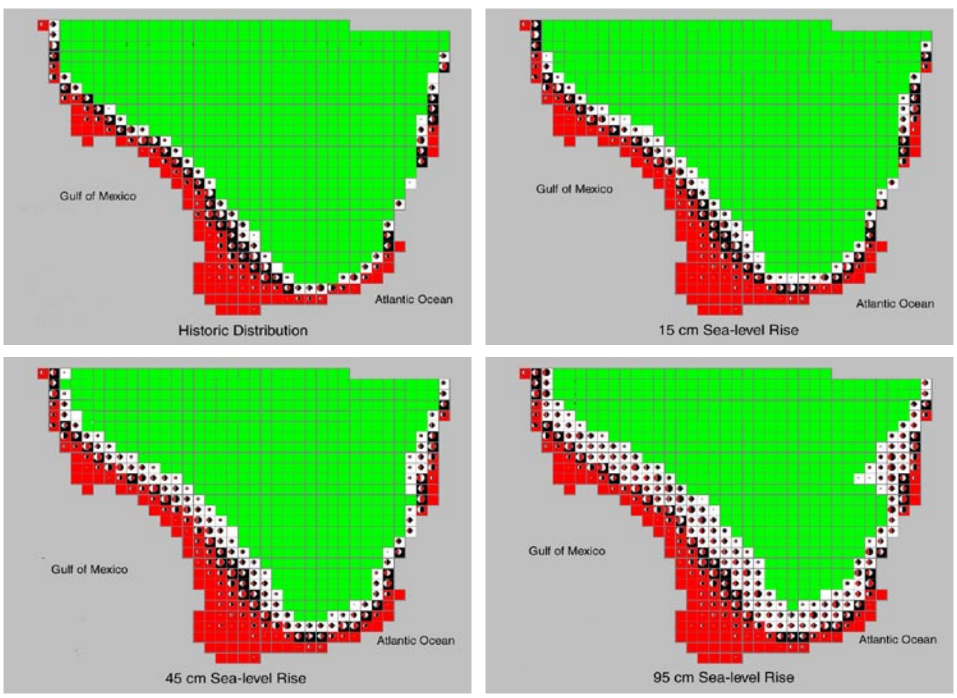

Figure 3. Digital elevation model (DEM) of south Florida based on spatial interpolation of elevation contour and proxy zonation heights taken from historic vegetation and topographic maps. NOTE: Modified from vegetation map of southern Florida by J.H. Davis, Jr., 1943.

References Cited

Davis, J. H., 1943, Vegetation map of Southern Florida, Bulletin 25: Tallahassee, Florida Geological Survey, scale: 1: 400,000.

For Further Reading

Doyle, T.W., and Girod, G., 1996, The frequency and intensity of Atlantic hurricanes and their influence on the structure of south Florida mangrove communities, *in* H. Diaz and R. Pulwarty, eds., Hurricanes, Climatic Change and Socioeconomic Impacts: A Current Perspective, pp. 111-128: New York, Westview Press, pp. 325.

Doyle, T.W., 1998, Modeling global change effects on coastal forests, *in* G. R.Guntenspergen and B. A.Vairin, eds., Vulnerability of coastal wetlands in the southeastern United States: Climate change research results, 1992-97: U.S. Geological Survey, Biological Resources Division Biological Science Report USGS/BRD/BSR-1998-0002, pp.105.

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