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Ecologist David Kaplan surveys dying coastal trees in the Withlacoochee Gulf Preserve in Yankeetown, Florida. ROGER DROUIN/YALE E360

GHOST FORESTS

How Rising Seas Are Killing Southern U.S. Woodlands

A steady increase in sea levels is pushing saltwater into U.S. wetlands, killing trees from Florida to as far north as New Jersey. But with sea level projected to rise by as much as six feet this century, the destruction of coastal forests is expected to become a worsening problem worldwide.

BY ROGER DROUIN • NOVEMBER 1, 2016

On a recent afternoon, University of Florida watershed ecologist David Kaplan and Ph.D. candidate Katie Glodzik hiked through the Withlacoochee Gulf Preserve, on the Big Bend coast of northwestern Florida. Not long ago, red cedar, live oaks, and cabbage palms grew in profusion on the raised “hammock island” forests set amid the preserve’s wetlands. But as the researchers walked through thigh-high marsh grass, the barren trunks of dead cedars were silhouetted against passing clouds. Dead snag cabbage palms stood like toothpicks snapped at the top. Other trees and shrubs, such as wax myrtle, had long been replaced by more salt-tolerant black needlerush marsh grass.

Saltwater, flowing into this swampy, freshwater-dependent ecosystem as a result of rising sea levels, is turning these stands of hardwoods into “ghost forests” of dead and dying trees.

“The loss of these islands changes the landscape from a mosaic to one dominated by a single habitat – salt marsh,” said Kaplan, noting that the change means reduced habitat for some species of wading and migratory birds, as well as for turtles and snakes.

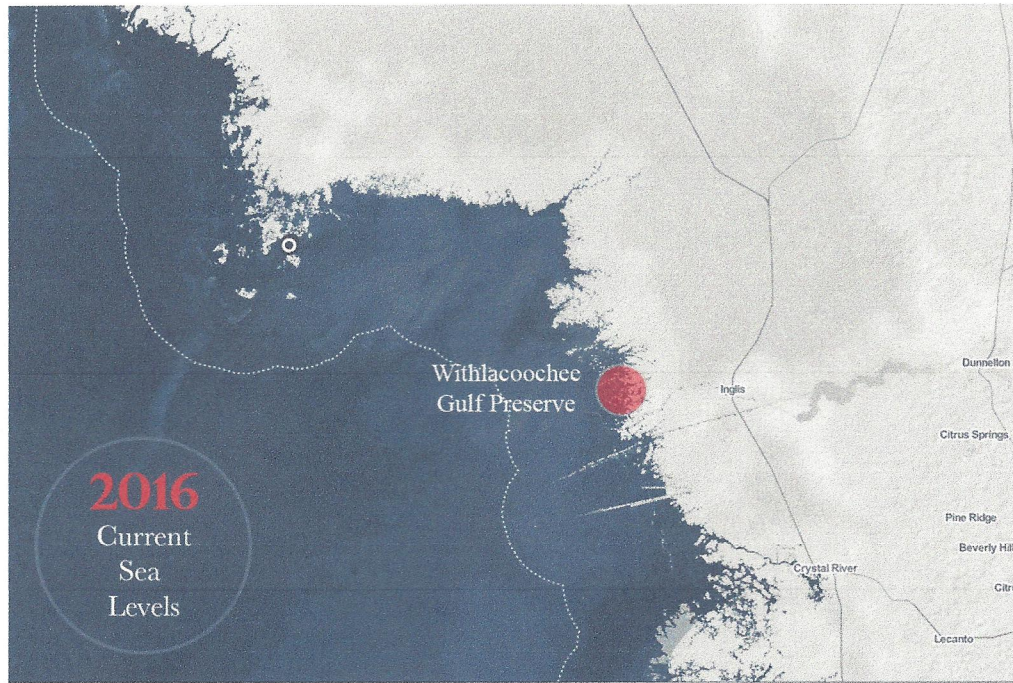
A similar transformation is occurring in coastal floodplains across the southeastern and mid-Atlantic regions of the United States, representing what scientists say is the leading edge of climate change in what were once largely freshwater ecosystems. From Florida’s hammock islands to North Carolina’s swamp forests, rising sea levels, often compounded by regional water management practices, continue to push saline water further inland, wiping out swampy woodlands.

“Ghost forests are a dramatic expression of climate change,” says Gregory Noe, a research ecologist with the U.S. Geological Survey who has been studying the impacts of dying cypress in the iconic swamps along the Savannah River, which forms much of the border between Georgia and South Carolina.

In addition to killing off bottomland forests, saltwater intrusion is affecting wetland habitats in places along the U.S. East Coast like the Delaware Bay estuary, where encroaching sea levels are inundating the salt marsh and killing a line of forest fringing the coast – allowing a non-native, invasive strain of reed to colonize.

While many of the ecological consequences of saltwater intrusion are still unknown, important swampy habitats for threatened species, such as the endangered red-cockaded woodpecker, are in peril, according to Marcelo Ardón, assistant professor of ecosystem ecology at North Carolina State University. Fisheries for species such as drum and catfish that are dependent on healthy wetland forests are being affected, as well.

Because of the low elevation and flat or gently sloping characteristics of the southern U.S and mid-Atlantic coastal forests, these regions are among the most vulnerable globally to saltwater intrusion, experts say. But other wetland and estuarine ecosystems are threatened worldwide by increasing salinity. China’s Pearl River estuary on the South China Sea is experiencing the agricultural and ecological effects of saltwater intrusion. Drought and rising sea levels are allowing saltwater to spread as far as 50 miles into Vietnam’s Mekong Delta, affecting ecosystems and rice production.



Predicted sea level rise along Florida's Big Bend coast over the next century. Mapping and data courtesy of Climate Central and NASA. GRAPHIC BY YALE E360

The rate of global sea level rise has increased significantly over the past several decades, a trend linked to climate change. According to the U.S. National Oceanic and Atmospheric Administration, during most of the 20th century sea levels were rising at 0.6 inches per decade. Since 1992, however, sea level has been rising at 1.2 inches per decade. Experts predict, for example, that by 2100, global warming will cause sea level to rise by as much as four to six feet worldwide, including from 3.3 to 6.6 feet along Florida's Big Bend coast.

Before bottomland hardwood forests disappear, the subtle signs of saltwater intrusion take place in the soil. Plant growth halts, trees and plants produce fewer seeds, and the seeds that do drop to the ground have a harder time germinating. "Even with relatively low levels of salinity, trees slow their growth," Ardón says of swamp trees such as water tupelo and pond pine. Cypress trees are often the last to die, since they are among the most salt-tolerant of coastal forest trees.

Saltwater also begins breaking down peat – partially decomposed vegetation – faster, which can have drastic consequences in places like North Carolina's Albemarle-Pamlico Peninsula, where elevation on average is only two feet or less above sea level. The loss of peat causes land to subside, enabling saltwater to move farther inland. Forest habitat can then transition to marsh and, eventually, open water.

In Florida's 413-acre Withlacoochee Gulf Preserve, Kaplan says there has been a steady decline in the raised hammock island forests, demonstrating how sea level rise is dynamically "re-shaping the coastal landscape in this region." The cabbage palms and cedars rooted atop the flat, limestone substrate are resilient to occasional periods of salt exposure during storms. However, recent annual rates of sea level rise have upped the duration and intensity of salt-water exposure – the two factors that trigger tree die-off, says Kaplan, an assistant professor in the University of Florida's Department of Environmental Engineering Sciences.

Kaplan and his colleagues categorize the hammock island forests of the preserve into three groups: "healthy," "stressed," and "remnant" (or relic) stands. The forests, says Kaplan, are increasingly grouped in the latter two categories.

On my recent visit to the Withlacoochee preserve, I pointed to a forested hammock island that appeared to be healthy. But Kaplan prompted me to take a closer look; barren cedar branches and an understory choked with marsh elder and other salt marsh shrubs became visible within the stand. "I would group it in 'stressed,'" he says.

Along the Savannah River, the coastal floodplain swamp is beginning to lose a footrace with rising seas. As mineral sediment combines with dead plants and roots to form peat, wetland forest soils build annually at the rate of about tenth of an inch, says Noe, the research ecologist with the USGS. This is a natural accretion that typically takes place in some southern swamps. But the accretion is not fast enough to keep up with recent annual sea level rise.



The stump of a red cedar in Withlacoochee Gulf Preserve [left]. Dead and dying trees on the shores of the Albemarle Sound in North Carolina [right].

Noe says that scientists and land managers are especially concerned about the appearance of ghost forests within the Savannah National Wildlife Refuge and other wildlife refuges, including preserves in Florida, South Carolina, North

Carolina, Virginia, and Maryland.

Although factors such as recent port dredging and local drought have accelerated the recent conversion of swamp to ghost forest along the Savannah River, Noe cites sea level rise as the main cause of the change. “We know sea level rise is happening, and we have confidence it will continue to keep happening,” Noe says. “These swamps are bellwethers of change.”

Both Kaplan and Ardón are investigating possible practices to stem the proliferation of ghost forests and are seeking to expand awareness among land managers and policy makers of the complex interactions that threaten coastal habitats. Kaplan believes that strategic land preservation could help slow the loss of imperiled coastal areas, allowing some wetland forests to migrate inland as sea levels rise, Kaplan explains.

As part of a National Science Foundation-funded, \$1.5 million collaborative project among North Carolina universities, researchers are working on mapping a vulnerability index for ecosystems prone to saltwater intrusion. Ardón, a member of the research team, hopes the maps will raise awareness among residents, water management planners, and local officials about how regional decisions can alter the ecosystem in the 2,300-square-mile Albemarle-Pamlico Peninsula and pinpoint areas that will be most threatened. “We hope these tools can be adapted to use in other areas,” Ardón says.

At the Palmetto-Peartree Preserve, on the tip of the Albemarle-Pamlico Peninsula, however, the forests continue to die. “There are a good number of places where the forest has gone to marsh and other areas where the forests have been replaced with open water,” says Ardón.

Ardón and Emily Bernhardt, a biogeochemist at Duke University, have already discovered that wetlands that normally improve water quality by retaining nutrients in soil – thus acting as a nitrogen sink – can quickly become a nitrogen source, releasing nitrogen and, in some cases, phosphorus, when they are affected by saltwater intrusion.

Along the Delaware Bay coast, there is historic evidence of coastal forest boundaries shifting slowly, going back thousands of years, says Beth Watson, assistant professor of wetlands science at Drexel University in Philadelphia. Recent accelerations in the rate of sea level rise, however, now have the potential to drown both marsh and coastal forest habitats. “I’ve seen a lot of these dying forests,” says Watson, adding

that in some areas “there are bands, about a kilometer wide, of dead trees.”

Over the past several decades, in places such as Cumberland and Cape May counties in southern New Jersey, encroaching sea levels have been inundating salt marsh and killing forest flora such as tupelo, Atlantic white cedar, and shrubs fringing the coast. In some instances, a non-native, invasive strain of a reed, *Phragmites australis*, is taking root – thus preventing the marsh from retreating inland, according to a 2013 study. The transition to ghost forest here “creates an opportunity for colonization of these vacant areas by *Phragmites*, which is better adapted to the resulting brackish conditions,” reports ecologist Joseph A. M. Smith.

Carol Collier, senior advisor for watershed management and policy at The Academy of Natural Sciences of Drexel University, worries about the impacts of shifting coastal wetlands on the region’s fisheries, water supply – and perhaps most vexing for coastal populations – the ability to buffer storms. Marshes and bottomland forest provide natural buffering against storm surge.

“Climate change is having a major impact on the region, with sea level rise and the intensity of storms,” said Collier, the former executive director of the Delaware River Basin Commission.

In the coming century, as sea level rises dramatically and human impacts on coastal ecosystems increase, scientists say the toll on wetland forested areas and bottomland hardwoods will be severe. “What little research has been done in forested coastal wetlands suggests that they will not be able to keep up with sea level rise,” says Ardón.



Roger Real Drouin is an author and journalist who covers environmental issues. His articles have appeared in *Scientific American*, *Ensa*, *Grist*, *Mother Jones*, and other publications. He was named the 2018 John Ringling Towers literary arts grant fellow, for a book he is writing on Florida’s native landscapes. **MORE →**