Shovel ready. For conservationists in Rhode Island, restoring coastal marshes requires boots on the ground.

WETLANDS

Can Coastal Marshes Rise Above It All?

As climate change causes sea level to rise, wetland scientists are struggling to predict which salt marshes will drown—and which might climb out of danger

WESTERLY, RHODE ISLAND—Biologist Marci Cole Ekberg plunges her shovel into a particularly gloppy spot in a mucky salt marsh near the Atlantic Ocean. Her goal: to drain one of many shallow pools that are creating dead zones in the expanse of otherwise dense grasses, a phenomenon that she's recently observed in more than a dozen other marshes around the state. She fears that the pools are an early consequence of the sea-level rise that is being driven by global warming and an ominous "glimpse of the future" for marshes in New England. Rising oceans will drown the grasses, she worries, eliminating rich habitats and leaving coastlines bare.

Other researchers, however, are skeptical that the pockmarks are a result of climate change, saying winter ice or other causes may be to blame. And Rhode Island isn't the only place where researchers are debating what is really happening in salt marshes today and how the wetlands will fare in a future of higher seas. There's wide agreement that these salt marshes are among the ecosystems most vulnerable to rapid sea-level rise. But few researchers are ready to predict the fate of specific marshes; there's still too much to learn, they say, about how wetlands in different regions accumulate sediments that might allow them to outclimb rising waters and whether they can escape by migrating inland.

Wetlands scientists are mobilizing to reduce the uncertainty. By building improved forecasting models and better monitoring systems—and studying wetland regions already experiencing dramatic sea-level rise—they're hoping to bring some clarity to a murky topic and identify practical steps to protect marshes. The overarching goal, says wetlands researcher Susan Adamowicz of the U.S. Fish and Wildlife Service in Wells, Maine, is to help managers "give marshes the best possible chance to outpace global sea-level rise."

Wet benefit

Although they're not the most glamourous biomes, the United Nations estimates that wetlands are one of the world's most valuable providers of "ecosystem services," such as storm protection, water filtering, and seafood production. They also help lock up as much as 450 billion metric tons of carbon globally, absorbing warming compounds that might otherwise leak into the atmosphere.

Marshes have already experienced centuries of insults—such as pollution, overfishing, and draining for farming and development—that have disrupted the ecological systems that help keep them healthy. Now, rising temperatures are causing land-based ice sheets to melt and seawater to expand. Such changes have already helped push sea level up by an average of 1.4 to 3.7 millimeters per year since 1950, according to a 2010 study published in *Science*. (Other estimates vary.) Climate models predict that the trend will accelerate to 1 centimeter or more per year as Earth continues to warm. And even a few extra centimeters of water can mean the difference between life and drowning for marshes, which typically occupy a narrow coastal band that ends just above the high tide line.

Faced with rising water, marshes have three options, says geologist Matthew Kirwan of the U.S. Geological Survey (USGS) in Charlottesville, Virginia: build in place by trapping and piling up new sediments, migrate to higher ground inland, or die. Predicting which path a marsh might take, however, requires understanding the interplay of a host of factors, including the biological traits of different marsh grasses and how wetlands construct muddy yet firm foundations from grains of sand, silt, and organic litter.

A sinking laboratory

To get a glimpse of how these factors might shape marsh adaptability in the future, researchers have begun to scrutinize one wetland ecosystem already experiencing local sea-level rise: Louisiana's Mississippi delta along the Gulf of Mexico. There, natural and human factors are causing the land to sink relatively quickly, creating a natural laboratory that simulates a sea-level rise of 1 to 2 cm per year. That could be "what it's going to be like everywhere by the end of the century," says ecologist James Morris of the University in South Carolina, Columbia.

Some delta marshes are adapting better than others: While grasses in a spot named Old Oyster Bayou have thrived, for instance, those in nearby Bayou Chitique have been largely submerged. The difference, researchers say, highlights the important role that an adequate sup-

CREDIT: PETER HANNEY/SAVE THE BAY - NARRAGANSETT BAY

ply of fresh sediment can play in marsh survival. While Old Oyster Bayou receives some 70 mg of fresh sediment per liter of river water, allowing it to outclimb rising Gulf waters, Bayou Chitique's sediment infusions are largely blocked by upstream levees, reducing the load to just 20 mg per liter. The "natural process has been interrupted and there's not enough sediment," Morris says.

A 2010 modeling study that Kirwan and his USGS colleagues published in *Geophysical Research Letters* underscored the importance of sediment supply. In a scenario that included a rapid global sea-level rise of 1.25 m by 2100, the outlook for the 21st century was grim: "Most coastal wetlands worldwide will disappear," they concluded. But under slower scenarios, there was hope. Although marshes with low sediment availability fared poorly in the models, those with ample supplies often survived. A marsh's tidal range also played a role, the study found, with wetlands located in regions with larger gaps between low and high tide better situated to ride out sea-level rise, apparently because plants adapted for higher tidal ranges better withstand drowning.

Trench warfare

For conservationists, such studies suggest that it might be possible to help threatened wetlands adapt—for instance, by removing levees or dams to restore sediment, or even pumping in new mud. And in Rhode Island, the idea of ultimately aiding drowning marshes is what motivated Cole Ekberg, a biologist with the conservation group Save The Bay, to recently lug a shovel into a marsh here that is pockmarked with shallow grassless pools.

The origins and meaning of the pools is the subject of local debate, some fierce. Cole Ekberg and others say that their spread is a relatively recent development, documented in just the last few years in the higher-elevation parts of marshes in Rhode Island, Connecticut, Massachusetts, and Maine. And she's been running a restoration experiment of sorts, draining the pools to see if the grasses come back. "It's the best part of the day when water begins to move," she says.

Other marsh researchers are skeptical, blaming winter ice damage, invasive weeds, or geology. Mark Bertness, a marine ecologist at Brown University, sees "no evidence" of sea-level rise in the pools and says that the Save The Bay staff members are "well-intentioned but naïve."

Bertness also wonders whether the focus on sea-level rise is diverting attention from more immediate threats. His own studies, for instance, have shown that overfishing has resulted in a boom in a population of crabs that chow on marsh grass, sometimes causing severe damage. "I was just dumbfounded what these crabs have done over a 2, 3-year period," he says. "Sea-level rise is going to come along, but this is happening now."

No escape route

All sides, however, appear to agree that if a marsh doesn't have a sediment source that will allow it to build up, "then the question becomes will it be able to migrate," Kirwan says.

Increasingly, the answer is no. Marshes around the world are hemmed in by development that essentially blocks migration to higher ground. In many areas, the obstacles are concrete or stone sea walls built to protect seaside homes or industrial sites. In Europe and parts of Asia, studies have found that two-thirds or more of many shorelines have been "armored." Even sparsely populated sites can leave marshes little room: A 2000 study of Maine's lightly inhabited Casco Bay found that one-fifth of its shoreline was armored.

Some researchers are beginning to look at ways to clear such obstacles. Around the Blackwater National Wildlife Refuge near Maryland's Chesapeake Bay, for instance, a coalition of conservation and government groups has embarked on an ambitious effort to identify potential obstacles and protect possible migration paths. The group is even eyeing pine forests and farm fields that may have the right topography and soil types to be converted to future marshes. The Nature Conservancy has launched a similar effort on Long Island in New York state, while Rhode Island officials, scientists, and activists are working on a statewide assessment to map out risks to wetlands under different scenarios.

It could take decades to realize such forward-thinking efforts, planners say. In the meantime, scientists say that they need better ways to monitor how marshes are doing now. A good start, a team of USGS researchers argued in an April paper in *Nature Climate Change*, would be to create a global network of 14,000 relatively simple devices called surface elevation table markers. Secured to the ground beneath marshes, mangroves, and wetlands, they can register changes in the height of the marsh surface to an accuracy of 0.01 cm, more precise than surveys, LiDAR, or satellite readings. The authors say the network, which might cost $8 million to create, "would allow policymakers to prioritize wetland sites for intervention."

That's a goal that Save The Bay's Cole Ekberg supports. "Someone might ask what's the point of protecting salt marshes anyway, if they're doomed in the long run," she says. "My answer is if we can extend their lives 20 or 30 years, it's a valuable investment."

–ELI KINTISCH

Bayou blues. Louisiana's disappearing marshes offer a glimpse of how global wetlands may respond to rising seas.

CREDIT: P. R. HOAR/NOAA/NESDIS/NCDDC

Published by AAAS