The "New Science" of Wetland Restoration

The intricate workings of natural wetlands are slowly yielding their secrets to scientists applying a number of experimental approaches.

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The largest wetlands restoration project ever attempted is being planned for the Florida Everglades. The $685 million project involves 55 separate projects that scientists and engineers will develop and coordinate over the next two decades to try to reestablish the Everglades' unique wetland landscape.

This unprecedented effort has focused new attention and intensity on an issue that scientists working with constructed wetlands view as unresolved: Can humans create bogs, swamps, and marshes that fully duplicate all the complex functioning of natural wetlands? The Everglades restoration project as well as smaller scale efforts to restore habitat in San Diego Bay and studies under way at experimental wetlands aim to provide clues about how wetlands function.

"We do know some things about wetlands and how we can construct them," said Curtis J. Richardson, director of the Duke University Wetland Center. "But in terms of restoring them and in terms of understanding their function, this is a new science. We're just scratching the surface," he said. "Moreover, the relationship between wetland function and the value we derive from them is just now being understood," Richardson added (*1*).

The realization of the importance of wetlands, which ecologists often refer to as "nature's kidneys" for their water-cleansing powers, has grown since the 1960s. From the 1780s to the 1980s, wetlands in what are now the 50 states of the United States plummeted from an estimated 392 million acres to 274 million acres (*2*). The loss is now seen as damaging not only water quality in some areas, but also flood control and some parts of the economy.

Beginning in 1972, Congress enacted several laws that led to a wetlands policy often dubbed "no net loss" (*3*) and the controversial policy of "mitigation." This allows developers to destroy certain wetlands if they agree to return a former wetland to a close approximation of its original state (restoration) or build a new wetland where none had existed (creation), according to Tom Kelsch, acting chief of enforcement and regulatory policy at EPA's Office of Wetlands, Oceans, and Watersheds.

Failure of initial efforts

A surge in wetlands construction occurred in the early 1980s, and in the view of wetland scientists, many such efforts proved wasted and wasteful. Projects often failed to provide the proper conditions for wetlands to thrive (*4*). "People got into wetland construction and restoration without a clue as to how wetlands work," says William J. Mitsch, professor of natural resources and environmental science at Ohio

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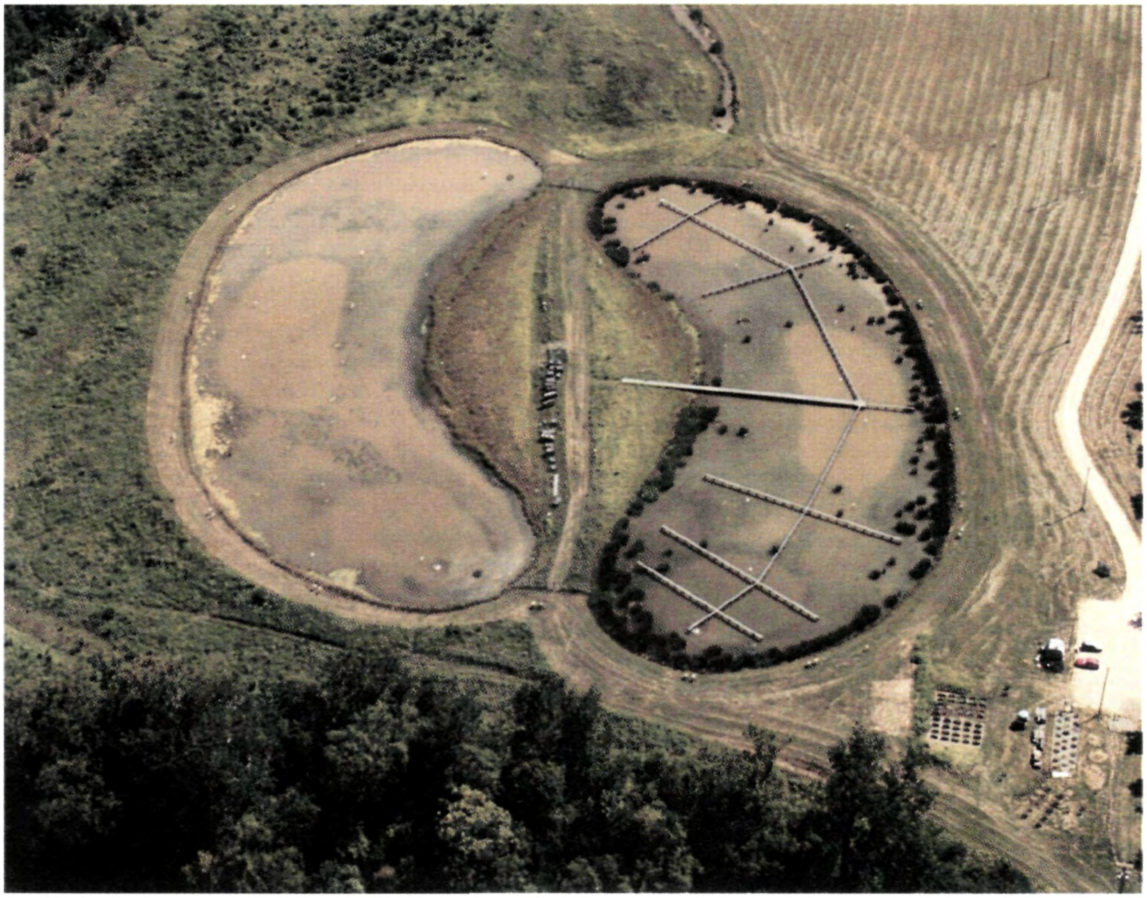


Experimenting with "nature's kidneys" on the Ohio State University campus allows researchers to probe the complex working of wetlands. The multiyear project at the 2.5-acre Olentangy River Wetland Research Park in Columbus includes a pair of constructed wetlands, one planted in 1994 (right) and the other an unplanted control. (Photo courtesy William Mitsch, Ohio State University)

State University. "It was engineers who did not know biology and biologists who didn't know engineering and hydrology."

Their failures left regulators and wetlands specialists with a strong message, one that has been increasingly expressed but not always heeded. "This is really complicated," says Edgar W. Garbisch, president of Environmental Concern, Inc., a nonprofit research corporation in St. Michaels, Md., that has constructed nearly 400 wetlands since its founding in 1972. "This isn't something that can be done simply by any general earth-moving contractor."

Constructed wetlands demand, and too seldom receive, an interdisciplinary approach, according to several researchers. "It seems simple; dig a hole and call it a wetland. But you really have to know quite a bit of both the biological sciences and the physical sciences," Mitsch says.

Among researchers today, the thrust is to better understand the importance of each individual wetland component—water, soil, plants—their interactions, and how best to integrate this knowledge to closely match natural wetlands.

By far, water is the most important of the three. "Wetlands are defined by their water; whether it's running, deep, shallow, turbid, acidic, or alkaline," said Donald L. Hey, director of the Des Plaines River Wetlands Demonstration Project, a 550-acre experimental station in Wadsworth, Ill., run by the nonprofit Wetlands Research, Inc. "In the past, people just planted wetland plants, figuring the hydrology was going to adapt to the plants."

Getting the hydrology right

Despite their great diversity, wetlands share a common feature: fluctuating water levels (5). A key requirement for any successful wetlands construction is getting the correct hydroperiod, the length of time and the time of year when the land is inundated or saturated with water. Some wetlands re-

Returning a wetland area to its original ecological function is an interdisciplinary challenge. When an endangered bird species did not occupy the constructed cordgrass wetlands at a wildlife refuge in San Diego Bay, researchers found the cause in the soil's inability to retain nutrients. The cordgrass canopy was too short to allow the bird to build its nest. Bonnie Peterson measures cordgrass in an area to be fertilized with nitrogen to remedy the problem. (Photo courtesy Kathy Boyer)

main wet for only a few weeks a year. Wetland species have adapted to these periodic fluctuations, and many will die off if the hydrology of their home changes significantly.

Yet Mitsch and Garbisch, among others, believe that with careful attention to detail in design, construction, and management, humans can duplicate much of nature's wetlands work. They note that a number of constructed wetlands have succeeded when targeted to a specific function such as wastewater treatment, wildlife habitat, sediment retention, erosion prevention, or reduction of acidity in mine runoff.

Researchers at Purdue University are studying how plants known to thrive in a wetland can be used to cleanse contaminated water. Sixteen small plots, each containing a single species of plant such as cattails or other grasses, were situated near hog pens on an experimental farm at the university. Each wetland received water containing a known concentration of hog wastes, delivered at a given flow rate.

Stephen B. Lovejoy, professor of agricultural and environmental policy at Purdue, and Paul Dubowy, now at Texas A&M, conceived the project as a way to assess the best mix of plants for cleaning water contaminated with nitrates and phosphorus from barnyard wastes. Lovejoy says the cattails might be perfectly suited for other cleanup operations, particularly if used to treat water before it is sent to a wastewater treatment system.

"Some plants will be more efficient at taking up certain pollutants," Lovejoy says. "So here we can start looking at the differential effectiveness of different plants. At the end of this project, we will have the information that will allow wetland specialists to do a better job of designing these facilities."

The "acid test" of restoration

In a project in San Diego, researchers are working to restore a wetland area to provide habitat for two endangered bird species and one endangered plant. Joy B. Zedler, director of the Pacific Estuarine Research Laboratory at San Diego State University, says her project illustrates the complex interrelationships within wetlands. "In Southern California, we have what I call the acid test of wetland restoration," she adds. "Agencies are trying to do what is the most difficult thing, namely to reconstruct endangered habitats and do it in an urban setting."

Zedler and her colleagues are working with two constructed cordgrass marsh areas in the Sweetwater Marsh National Wildlife Refuge in San Diego Bay, adjacent to a busy highway. A federal court ordered the creation of new marshes to compensate for damage inflicted by two highway projects on the habitats of two endangered birds—the light-footed clapper rail and the California least tern—and an endangered plant, the salt marsh bird's beak. A decade after construction of the first marsh, the project still falls short of some of the criteria set by the U.S. Fish and Wildlife Service, one of the federal agencies entrusted with the implementation of the Endangered Species Act.

"The more we study the species, the more we learn how complex their relationships are with the habitats they use," says Zedler, who works with the California Department of Transportation (Caltrans) and the U.S. Army Corps of Engineers, the two agencies responsible for restoring the marshes. Since 1989, she and her team have monitored the marshes to evaluate how closely they are meeting the Fish and Wildlife criteria and how successfully the habitat has been restored. The team has studied the ecology of the marshes, their soils and nutrients, the ability of certain plants to adapt and thrive, and the nesting habits of the clapper rail and the least tern. These studies helped produce recommendations for solving problems hindering the return of the species.

The project quickly met its goals for the least tern, and in November 1995 the Fish and Wildlife Service judged that the salt marsh bird's beak had reached an acceptable level of growth. The clapper rail, however, has not found the constructed marshes an acceptable habitat. The reasons for this rejection offer a classic and well-documented case study in the complexities and frustrations that can arise in building new wetlands.

The restoration effort began in 1984 when Caltrans contractors excavated 12 acres for the first marsh and transplanted vegetation there in 1985. By 1989, the marsh looked green and its plant composition and hydrology acceptable. Yet no clapper rails nested there. Zedler began searching for an explanation. "The problem we see with the clapper rail is that the canopy is too short to provide suitable nesting habitat," she says. The birds weave platforms of dead plant stems for nests, which they attach loosely to tall, upright stems so the nests rise with incoming tides, much as a floating dock does. The short canopy fails to provide the height the birds' need both to support their nests and provide protection from predators (4).

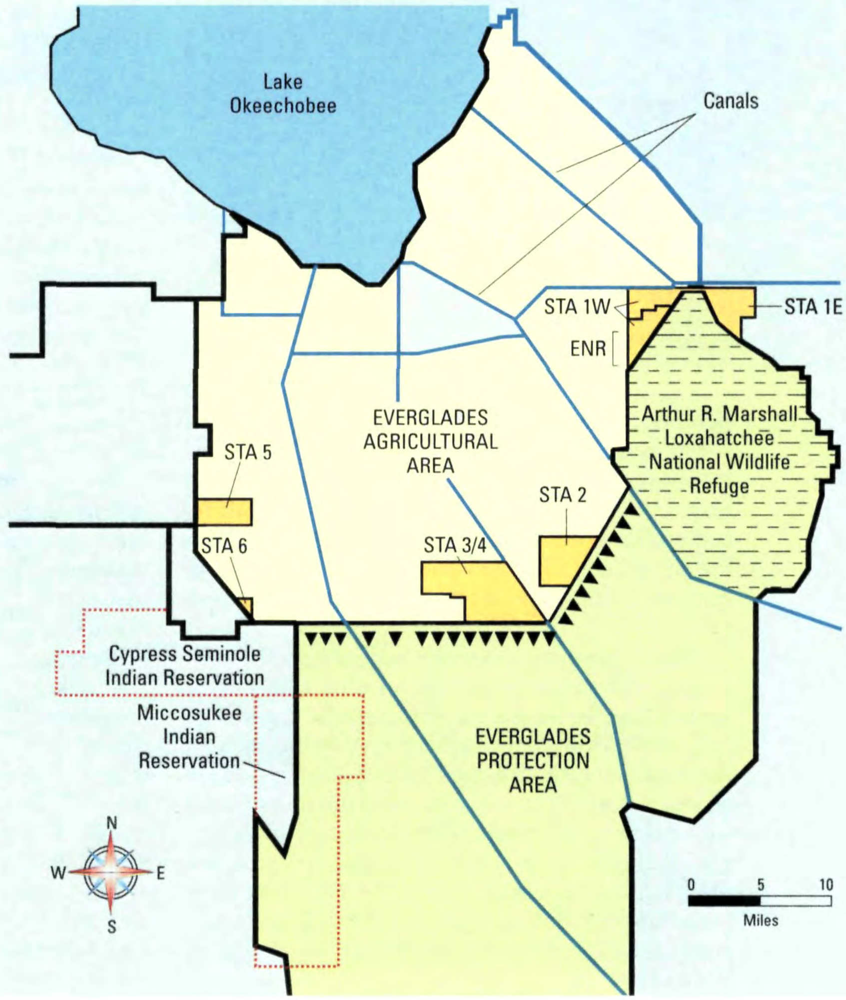
Zedler and her colleagues eventually solved this conundrum. The cordgrass received too little nitrogen to achieve full growth, a deficiency caused by the initial preparation of the marsh's soil base. The marsh bottom was created on top of several layers of sand dumped there after being dredged from the San Diego Bay. "The substrate is just too coarse; it's sandy," Zedler says. "Natural marshes have a high clay content; that gives them better potential for retaining nutrients. These sandy substrates don't hold the nitrogen."

Short canopies also allowed an infestation of a scale insect native to the marshes that devastated the cordgrass. This may have resulted because the insect's natural predator, a beetle, did not inhabit the constructed wetland although it thrived in the nearby natural marsh. "The beetle is terrestrial; it needs tall plants to hide out in when the tide rises," she explains.

Zedler believes the constructed marshes must grow to certain heights before the light-footed clapper rail and the predator beetle will find them acceptable. To reach and maintain this growth, the researchers will continually apply nitrogen fertilizers. "We have continued to monitor these areas for plants of that height, and without intervention on our part, they do not meet those criteria," Zedler says.

The Everglades: Wetlands restoring wetlands

A key component of the $685 million Everglades restoration project is a series of six constructed wetlands to be used as "storm water treatment areas" (STAs) to remove excess nutrients from the Everglades Agricultural Area runoff. Treated water from the six STAs will flow into the Everglades Protection Area (arrows). A prototype of these treatment areas, the Everglades Nutrient Removal Project (ENR), is in operation.



Water treatment in the Everglades

The Everglades restoration project was created by the Everglades Forever Act, passed by the Florida Legislature in 1994 and spawned by the settlement of a lawsuit filed by the federal government against the Florida Department of Environmental Protection and the South Florida Water Quality Management District for not meeting water quality standards. The act envisions a comprehensive cleanup and restoration designed to reestablish the Everglades landscape to the extent practicable, but falling short of recreating them in their entirety.

The 55 projects in the program are linked either to the act or a requirement of the settlement agreement. They are being carried out by the South Florida Water Management District, the Florida Department of Environmental Protection, the Seminole and Miccosukee Tribes, and numerous federal agencies including the Agriculture and Interior departments and the National Oceanic and Atmospheric Administration *(6)*.

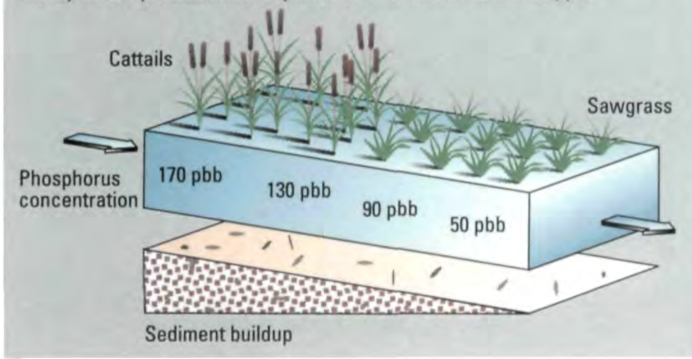
A key feature in this effort involves the construction of some 43,000 acres of wetlands, or storm water treatment areas, to the south and east of the rich farmlands around Lake Okeechobee (see map). In recent decades, runoff waters enriched in phosphorus from fertilizers used to grow sugar cane, rice, and vegetables have disrupted the flora and fauna that have thrived in the Everglades. The Everglades sustains its unique collection of plants and animals precisely because it is nutrient poor. Scientists have turned to the constructed wetlands to help remove the phosphorus.

West of West Palm Beach, abutting the Arthur R. Marshall Loxahatchee National Wildlife Refuge, lies the largest wetland ever constructed in the United States. Known as the Everglades Nutrient Removal Project (ENR), its 3681 acres serve as a "full-scale prototype" to "check the scaled-up fidelity of things that have been tested satisfactorily at a much smaller level," says Tom C. Kosier of the South Florida Water Management District, who manages the project. The results from the ENR will lead to the creation of the remaining six storm water treatment areas.

And so far, results are promising. In its first year of operations, the wetlands removed 28,000 pounds of phosphorus from the 120,000 acre-feet of water

A design for phosphorus removal

The Everglades Nutrient Removal Project is a 3600-acre prototype for six wetlands designed to remove phosphorus from agricultural runoff entering the Everglades. As water flows through cattails and sawgrass, phosphorus concentrations are expected to decline from 170 ppb to 50 ppb at outflow. Sediment buildup from decaying plants is heaviest at the inlet because the excess nutrient load spurs plant growth. Outflow concentrations during the first year of operation were reported to be between 20 and 40 ppb.



pumped into it. ENR's primary objective is to achieve a long-term average reduction of up to 75% in total phosphorus load; it achieved 83% in its first year. Also, officials seek to reduce phosphorus concentrations that run well above 100 parts per billion in the area's water to 50 ppb at outflow. In the first year, outflow concentrations ran between 20 and 40 ppb (*7*).

Some scientists, however, believe that the reliance on constructed wetlands in such a long-term project may be outpacing the scientific knowledge base. Duke University's Richardson specifically cites the restoration efforts in the Florida Everglades, where he and colleagues have carried out a number of studies looking at the effects of nutrients and water levels on plant communities. "We know certain types of wetlands that can be built," he says. "We have made phenomenal progress in the wetlands science field in the last 25 years. But we've got a lot of work to do."

Long-term performance questioned

Richardson's work indicates it would take 80,000 to 100,000 acres of new wetlands to reduce phosphorus pollution to the levels that Everglades officials have set for the project. "I think it's [a] 50–50 [chance] whether it will work with the acreage proposed," he says.

Indeed, wetlands' long-term nutrient removal rate has yet to be demonstrated, and concerns related to "wetland aging" and decreased removal rates have to be addressed. District officials recognize the limits of wetland restoration efforts aimed at reducing nutrient concentrations. As a result, the District is evaluating other water treatment and management methods as well as regulatory programs that either alone or in concert with the storm water treatment areas may be superior for nutrient removal. Proposals for new technologies are currently under consideration (*6*).

Richardson's team and others have sought to determine how much phosphorus the vast wetlands region, including Everglades National Park, can withstand and still prosper. "There is probably some threshold that is acceptable; we're not sure what that is at the moment, but we've put in a huge phosphorus dosage study down there to try to determine that," he says.

In conjunction with federal agencies, the district and the state Department of Environmental Protection are conducting the Everglades Nutrient Threshold Study, focusing on separating the effects of phosphorus from those of altered "hydropattern." The research will use large-scale field measurements, mesocosms for phosphorus-dosing experiments, and small-scale experiments conducted in greenhouses. The threshold will help establish a federal numerical threshold concentration for phosphorus in Class III waters (*8*).

As part of the effort to rehabilitate the Everglades, Florida and the Corps of Engineers plan to pump trillions of gallons of water back into the region to increase the flow through the Everglades by 28%. But that could prove an ecological disaster, according to Richardson, because there is insufficient research to forecast what effects the additional water will have on the ecosystem. Officials are "proposing one of the most massive construction projects in history without the proper ecological information to sustain the Everglades," he says. Currently, a series of tests is under way to determine the optimal timing and distribution of these freshwater flows that officials see as essential to revitalizing the region's ecosystem.

Despite the uncertainties remaining in wetland restoration projects such as the Everglades, the field is expected to grow. Constructed wetlands offer considerable promise in wastewater and storm water treatment (*8*), nonpoint source pollution control, and flood prevention. Donald Hey argues that an additional 13 million acres of wetlands in the Upper Mississippi River Basin would have prevented almost all of the $16 billion lost in the 1993 flooding (*9*). And as the science progresses and constructed wetlands are increasingly successful, wetland specialists see acceptance of constructed wetlands growing for a multitude of purposes.

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