An ambitious $14 billion plan aims to restore Louisiana's wetlands, which are disappearing at record pace. But the scientific and political hurdles are huge

Louisiana's Vanishing Wetlands: Going, Going ...

What do you do if you are one of the poorest states in the nation, have a projected budget shortfall of more than $200 million, and are losing Rhode Island–sized swaths of land every 50 years? If you are Louisiana, you propose the largest, most expensive environmental restoration project on the planet —and hope the federal government picks up the tab.

The $14 billion plan known as Coast 2050 attempts to protect more than 10,000 square kilometers of marsh, swamp, and barrier islands, an area nearly twice as large as Florida's Everglades—the nation's most beloved swamp and the former record holder for an environmental salvage project. Although the plan has yet to be funded by Congress, current legislation sponsored by Senator Mary Landrieu (D–LA) would tap royalties from federal oil and gas leases on the outer continental shelf to help pay for more than 500 projects ranging from replanting marsh grasses on barrier islands to building locks on the Mississippi River. A $6 million feasibility study of wetland restoration projects designed for Barataria Basin, just east of the Mississippi River, is already under way; state leaders hope it will spur on the larger project.

"This is the major delta system on the North American continent, and it is dying," says biologist Bill Good, director of the Coastal Restoration Division of Louisiana's Department of Natural Resources (DNR) and one of the driving forces behind Coast 2050. "It has a tremendous impact on the overall ecology of the Gulf of Mexico. I mean, God bless the Everglades, but God bless the Mississippi Delta, too."

Disappearing treasures? A heron swoops down into a lush cypress marsh in the Atchafalaya Basin, one of the few places in Louisiana where marshes are actually expanding.

Coast 2050 is the latest and by far the most ambitious of a series of coastal management and restoration plans that date to the early 1970s, when scientists first measured dramatic rates of land loss in Louisiana's coastal zone—roughly all lands lying south of Interstate 10, which stretches from Slidell to Lake Charles. Between 1956 and 1990, some 3460 square kilometers of coastal wetlands reverted to open water. The state continues to lose between 65 and 91 square kilometers each year, one of the highest rates of land loss in the world. Louisiana alone contains 40% of the wetlands in the contiguous United States, yet accounts for 80% of wetland loss in the Lower 48 states. At this rate, even with current conservation projects under way, another 1800 to 4500 square kilometers will vanish under the Gulf in the next 50 years—and that area could conceivably include the city of New Orleans. The loss of public resources, including fisheries, wildlife habitat, navigation, flood control, and hurricane protection, has been estimated at more than $37 billion.

Previous attempts to help the state's wetlands led to passage of the 1990 Coastal Wetlands Planning, Protection and Restoration Act, which was sponsored by Senator John Breaux (D–LA). The "Breaux Act" currently funnels about $40 million to $50 million annually into the state for wetlands restoration projects.

Yet wetlands advocates contend that the program, which has funded mostly small projects equally distributed throughout the state, has served as little more than the proverbial finger in the dike. In the mid-1990s the Coalition to Restore Coastal Louisiana, an influential advocacy group, pushed for a single, overarching restoration and management plan that would meld federal, state, and local efforts with public participation to create a focused blueprint for saving the state's beleaguered wetlands. With the support of Louisiana Governor Mike Foster and Secretary Jack Caldwell of the DNR, Good led dozens of state, federal, and university scientists in an 18-month effort that selected projects from previous plans and also included new techniques. Those include methods for predicting future land loss, the first coastwide assessment of subsidence rates and patterns, and the first comprehensive look at changes in fish and wildlife populations. Public hearings were held in the 20 coastal Louisiana parishes, all of which eventually passed resolutions supporting the plan, which was released in December 1998.

"We have a chance to plan and design a major natural system—a world-class system—that produces renewable resources and that can sustain itself and sustain human activity," says coastal geologist Sherwood Gagliano of Coastal Environments Inc., one of Coast 2050's architects and the researcher

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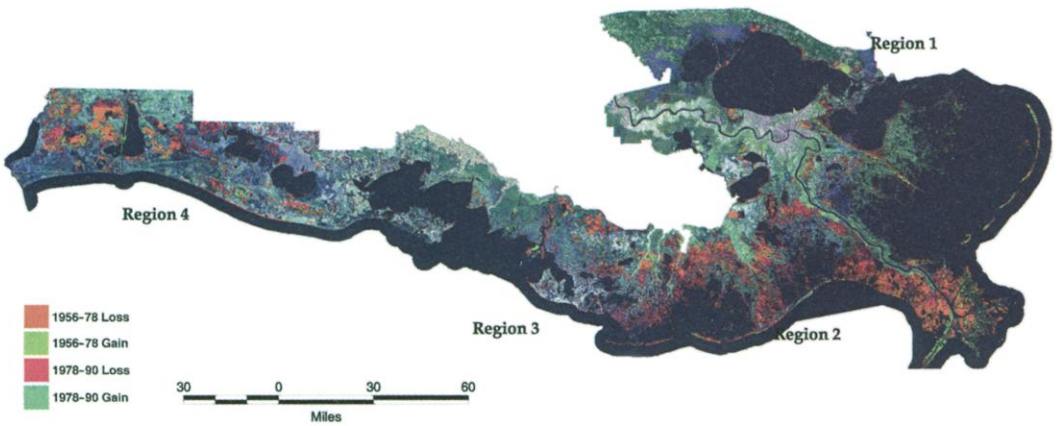

Win some, lose most. As coastal wetlands revert to open water, Louisiana is losing up to 90 sq. km. of wetlands each year.

who first raised the alarm about coastal land loss in the early 1970s. "I'm not sure that's been done anywhere, not on this scale." Other wetlands experts aren't as optimistic about the ability of the U.S. Army Corps of Engineers to correct the damage they largely helped create. "The Army Corps' reputation is not good," says ecologist Stuart Pimm of Columbia University. "They like highly managed systems. My rule of thumb when it comes to ecosystems is larger is better than smaller, connected is better than fragmented, and natural is better than managed."

Sinking and slumping

To succeed, coastal scientists have to overcome three major obstacles that are fueling wetland demise, according to Gagliano. The first is called concentrated margin gravity slumping, or fault-induced sinking. Geologists working for the oil and gas industry have long known that the entire delta region is chopped up into thousands of pieces by subsurface fault zones that crisscross the delta from east to west. The seaward block, consisting of about 4100 square kilometers, has been slipping southward since the turn of the century. As it slips, the Gulf of Mexico invades. Gagliano estimates that such slumping may have caused as much as 60% of the land loss that has occurred since the 1890s.

The sinking rate began to accelerate in the 1960s, largely because of the second major obstacle: the levying of the Mississippi River. Unlike the crisis in the Everglades in which a naturally low-energy freshwater system is suffering from nutrient overload, Louisiana's wetlands are starving for nutrients, sediments, and water. Big Muddy was once the greatest land builder in the world, dumping an estimated 400 million tons of sediment a year on the delta. It created six different delta lobes during the last 7000 years, jumping its bed every millennium or so in its rush to find the path of least resistance to the Gulf. As the old deltas withered, leaving fringing barrier islands, new ones formed, nourished by spring floods. The natural overflow of fresh water, sediments, and nutrients kept the wetlands fresh and aggressive, according to Gagliano. Marshes were able to overcome their natural sinking and dewatering by constantly increasing their vegetative surface.

The devastating flood of 1927 that drove nearly 1 million people from their homes and inundated more than 70,000 square kilometers led to the Depression-era construction of high concrete levies that now line the banks for nearly 2000 kilometers. The levies did end the spring floods, but with a cost. Meanwhile, four major upstream dams built on the Missouri River trapped more than half of the river's sediment load. Most of the remaining 150 million tons of clay, silt, and sand that could sustain the delta now scour out the river's ship channel before flowing into a deep offshore trench in the continental shelf.

Navigation channels and canals comprise the third major problem. More than 13,000 kilometers of canals lace Louisiana's marsh, along with nine major shipping lanes that have made the state the nation's leader in shipping tonnage. The canals—built primarily by the oil and gas industry—and shipping lanes are directly responsible for up to 30% of the state's current wetland loss. They are indirectly responsible for even more, because they have drastically changed the hydrology of the marsh. Driven by winds and tides, salty Gulf water that was once relegated to the coastal fringe now flows up the human-made waterways far inland, causing massive "brownouts" or marsh die-offs along the way.

"Essentially, you are bringing salt water and tidal action into a freshwater regime," says Good. "We're trying to reduce that tidal energy and marine influence in those fresh and brackish water systems."

One of the worst offenders has been the Mississippi River Gulf Outlet (MRGO). Built in the 1960s to give large container ships access to New Orleans, the channel is now lined with forests and marshes killed by saltwater intrusion. Moreover, ship wakes are eroding a 60-kilometer stretch of the northern bank at an average of 5 meters every year.

Heavy lifting

To combat these problems, Coast 2050 would plug some canals and close MRGO as soon as another container facility is completed farther downstream. More controversial, however, are plans to relocate the Mississippi River Navigation Channel from the lower river to capture the bed load currently lost to the deep waters of the Gulf. This would entail building a new channel to the east or west of the current river entrance with at least two locks—a plan that is anathema to powerful shipping interests along the river because of the potential delays and the possi-

Worst offender. The Mississippi River Gulf Outlet *(above)*, built to provide large ships access to New Orleans, has turned freshwater marshes brackish, resulting in massive die-offs of cypress trees *(left)*.

CREDITS: (TOP TO BOTTOM) USGS NATIONAL WETLANDS RESEARCH CENTER/COASTAL RESTORATION PROJECT OFFICE; U.S. ARMY CORPS OF ENGINEERS; USGS NATIONAL WETLANDS RESEARCH CENTER

ble shoaling of the main navigation channel.

In the more immediate future, however, Coast 2050 depends largely on water diversions, both large and small structures, that scientists hope will recreate at least part of the river's former natural functions by spilling water back into the marshes. The prototype for such efforts is the Caernarvon Freshwater Diversion, a $26 million opening in the levy built by the Army Corps about 16 kilometers south of New Orleans. Authorized by Congress in 1965 but not funded until the mid-1980s, the gated concrete culvert can divert up to 240 cubic meters of river water per second into a canal that feeds into the marshes behind Breton Sound, an area that had been losing up to 400 hectares a year. After 3 years of operation, Good's staff measured a 6% annual increase in marsh within the study area and a sevenfold rise in the population of freshwater marsh plants. Oyster numbers in the public seed grounds of Breton Sound jumped by more than three orders of magnitude, while waterfowl, alligators, and muskrats flourished in the rejuvenated marsh. An even larger diversion known as Davis Pond is scheduled to come online this year. Coastal planners estimate that the two separately funded diversions, combined with current Breaux Act projects, will prevent up to 22% of the projected loss by 2050.

Necessary diversion. Planners hope to stem the loss of wetlands by spilling water from the Mississippi River back into the marshes. A prototype is the Caernarvon Freshwater Diversion, 16 km south of New Orleans; since it began operation, some of the marshes of Breton Sound have rebounded *(inset)*.

"From what we know about how the marshes are naturally formed and from research that's been done at Caernarvon and other areas, the use of sediment diversions appears to provide a feasible means of large-scale marsh restoration," says Irving Mendelssohn, a coastal ecologist at Louisiana State University (LSU) in Baton Rouge who has studied the region's wetlands problems for more than 20 years.

Louisiana's barrier islands, the state's first line of defense against hurricane storm surge, are another matter. After comparing 130 years of data depicting shoreline positions, geologist Randolph McBride of George Mason University in Fairfax, Virginia (formerly of LSU), found that some islands are eroding at up to 20 meters per year. Others have lost half of their land area over the last century. According to McBride, several islands, including Isles Dernieres, Timbalier Island, and the Grand Terre islands, will disappear within the next 20 to 50 years if left to their fate. This would leave large swaths of wetlands exposed to the direct erosive force of the Gulf. Although the exact buffering effect of the barrier islands on storm surge is unknown, Joseph Suhayda of LSU's Department of Civil and Environmental Engineering, using computer modeling, estimated in 1997 that certain configurations of islands and inlets along the coast could reduce storm surges inland by more than 1 meter.

Under Coast 2050, Louisiana's barrier islands would be restored or maintained using the most cost-effective means. This would most likely i beach nourishmen dredged material combined with marsh creation projects on the bay side of the islands, although hard structures such as sea walls and groins are also being considered. Such hardening of the shoreline worries Orrin Pilkey, a coastal geologist at Duke University, who specializes in barrier island migration.

"Two sea walls on East Timbalier Island are already out to sea," says Pilkey. "In the context of rising sea levels, I don't see how they'll be able to stop the islands from disappearing. We have to look at this realistically and recognize that we're going to lose a lot of stuff." Pilkey thinks the best chance of success lies with a plan to replant marsh grasses on the inland side of the islands and then pump dredged material behind them to give them a platform on which to migrate.

Competing interests

A number of unanswered questions swirl around the plan. Scientists still don't know how much fresh water, sediment, or nutrients a marsh needs to thrive or when it needs them. Nor do they know if diversions such as Caernarvon and Davis Pond will funnel too many nutrients into the marshes, leading to eutrophication and algal blooms. And the jury is still out on the exact rates of subsidence and sea level rise.

"Sometimes you can't wait until all the answers are in," says Mendelssohn. "You have to start the management process, but you have to be able to change that management approach and modify those procedures when new information becomes available." Such "adaptive management" and monitoring components have been built in to many Coast 2050 projects.

Nonetheless, Mendelssohn believes nature has provided scientists with a good model of how large diversions will work: the Atchafalaya River. Capturing some 30% of the Mississippi River's flow at the Old River Control Structure near Simmesport, the Atchafalaya River is producing the healthiest marshes in the state as well as a small but growing delta that appeared after the 1973 flood. It's one of the few places in Louisiana where marshes are actually expanding.

"We've been studying these wetlands for 30 years," says James Johnston, chief of the Spatial Analysis Branch at the U.S. Geological Survey's National Wetlands Research Center in Lafayette and co-chair of the Coast 2050 monitoring program. "A lot of what needs to be done is just common sense."

The scientific questions may be the easiest to resolve. Currently, the state is involved in five lawsuits related to reduced oyster harvests allegedly caused by the Caernarvon Diversion, which has pushed the freshwater gradient farther toward the Gulf. Political opposition has kept Caernarvon running at roughly half of its capacity. Shrimpers, farmers, the petroleum industry, shipping interests, and low-lying municipalities are heavily vested in the status quo, which could change dramatically if Coast 2050 accomplishes its goals. Some towns, for instance, may be forced to relocate to avoid the risk of flooding. Nonetheless, President Clinton recently threw his support behind the Landrieu bill, known as the Conservation and Reinvestment Act, which seems to be gathering momentum in Congress. The bill would return most of the federal royalties on outer continental shelf oil and gas leases to states where offshore drilling is allowed. Coastal states such as Alaska, Mississippi, and Louisiana would

CREDITS: (LEFT TO RIGHT) U.S. ARMY CORPS OF ENGINEERS; UNIVERSITY OF LOUISIANA, LAFAYETTE

receive the lion's share of the money, although other states that are landlocked would benefit as well. The House of Representatives approved the bill in May with a two-thirds majority, but it faces a stiff floor fight in the Senate.

Coast 2050's staggering price tag alone is enough to raise a red flag for ecologist Pimm, who has been a vocal critic of the Everglades restoration. "Water projects in the U.S. have a reputation for embodying the worst excesses of pork-barrel spending," says Pimm, and Coast 2050 may be no exception. "What we'd really like for the Mississippi is to take out all the dams and levies and diversions and let the damned thing flow free."

Even if the big money doesn't arrive, the delta's defenders say they will not be deterred. They contend that the government will either spend billions now to save the marshes or many more billions later to bail out New Orleans, half of which already lies below sea level. "We'll do whatever we can," says DNR's Good. "Even if we have to fill sand bags and throw them into the breach." **–JOEL BOURNE**

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COMPUTER SCIENCE

Flushing Out Nasty Viruses In the Balkans

Bulgaria created a pioneering center to tackle the threat that its homegrown viruses pose to the world; now the lab is struggling to stave off obsolescence

SOFIA—Shortly before its corrupt Communist regime toppled a decade ago, Bulgaria was overrun by a spate of devastating infectious agents that went by names such as Dark Avenger, Anthrax, and Evil. Cooked up by shadowy figures in the besieged country, these plagues were not the errant concoctions of Soviet-era bioweapons labs. They were the scribbles of computer geeks.

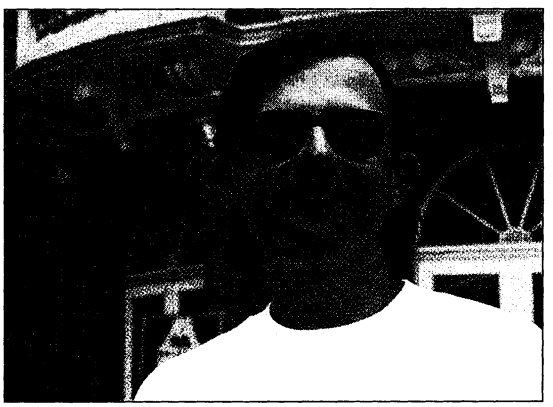
How this mostly rural Balkan country with a frayed telecommunications infrastructure became a "virus factory" is a tale wrapped in Cold War intrigue. Just as compelling is how the Bulgarian Academy of Sciences responded to the crisis. The academy established a National Laboratory of Computer Virology, where antivirus hunters match wits with unseen virus creators. The laboratory has been a major force in reining in Bulgaria's viral threat, says Lars-Olof Stromberg, a virus expert with the Royal Institute of Technology in Stockholm.

While Bulgaria's significance as a computer virus reservoir has waned, the virology lab continues to serve as a training ground for antivirus experts, including a few who made major contributions during recent efforts to disarm high-profile scourges such as the ILOVEYOU virus. Despite a ludicrous budget—the government gives the lab roughly half of what a single Western whiz kid fresh out of college might earn in a year—the facility remains a force to be reckoned with. "They are certainly good at looking at emerging viruses and analyzing them quickly," says Fred Cohen, a researcher at Sandia National Laboratories in Livermore, California, who in 1983 coined the term "computer virus."

A Balkan Silicon Valley

No one knows where the first viral-type programs came from; they may have originated in instructions given to early computers to fill memory space by copying bits. In the late 1970s, some malignant codes infected Russia's Rijad mainframe computers. Then a few years later a virus known as the "Xerox worm" (so named because it made copies of itself) blighted a U.S. computer network.

It was not until the late 1980s that the public at large became acquainted with the destructive powers of viruses. That's when a rapidly proliferating virus from Israel dubbed Jerusalem bogged down computers around the world, and Brain—a "boot-sector infector" from Pakistan that hit MS-DOS systems—went on a rampage. Bulgaria then put itself on the map, unleashing a slew of globe-girdling viruses in the late '80s and early '90s. In the years since, the rogues' gallery has swelled to nearly 50,000 known viruses worldwide, with 10 to 15 new ones popping up every day. This proliferation has turned antivirus and computer security R&D into a multibillion-dollar business (see table).



Early antidote. Bulgaria tapped a young star named Veselin Bontchev to lead its antiviral campaign.

CREDIT: R. KOENIG

Bulgaria's contributions to this global scourge trace their roots to the 1970s, when Soviet planners designated the loyal satellite as the lead East Bloc country for producing computers and software. Implementing that decision, Bulgarian Communist Party leader Todor Zhivkov decreed that personal computers would be manufactured in his hometown of Pravetz, which lent its name to two generations of PCs. Unable to import user-friendly Western software, a cadre of computer-literate Bulgarians soon became intimately familiar with the code that runs computer programs—knowledge that helped them understand how viruses operate, says Klaus Brunnstein, who founded the University of Hamburg's pioneering "Virus Test Center" in 1988.

Several theories have been put forward to finger who among the Bulgarian population turned their hands to virus writing. Some say the culprits were a handful of talented but frustrated young computer experts who were looking for an escape from the economic and social turmoil of the late 1980s and early '90s. Others see more insidious forces at play. Stromberg, for one, asserts that Bulgaria was a center of the once top-secret "InfoWar" effort, initiated by the KGB in the late 1970s to develop software and viruses that could be sicced upon the West. After the Soviet Union dissolved, he contends, some of those highly trained experts left the government "to freelance and to hack Western computer systems"—sometimes for organized crime rings.

Bulgarian experts contacted by *Science* demur, insisting that viruses sprang from the brows of amateurs, not spies. Thousands of computer-savvy teens cut their teeth in neighborhood "computer clubs" set up by the government in the 1980s. Although most of their activities were benign, some learned how to pirate Western software, and a few dallied in viruses. "The first viruses created here in Bulgaria were innocent things—just kids who experimented," claims computer scientist Eugene Nickolov, who runs the Sofia lab.

If that's true, it didn't take long for some computer jocks to lose their innocence. By the late 1980s, Bulgarians "certainly displayed more aggressive virus examples than many of their contemporaries" in viral hot zones elsewhere, Cohen says. Notorious