A Whisper in the Reeds

Are Constructed Wetlands Luring Wildlife into Toxic Soups?

Douglas George
Class of 2001
Advisor: Marguerite Holloway

Sandwiched between Public School 56 and two dozen single-family homes, Porzio's Pond on southern Staten Island doesn't appear remarkable. In winter, the four-acre pool freezes and seven dead tree trunks stand pensively on the northern edge of the ice. Broken clumps of cordgrass and cattail outline where the water's shore is during sunnier, warmer months. Bevies of crows play endless games of 'Marco-Polo' in tangled shrubs that ring the pond. A squat concrete box, 20 feet long and four feet high, sits unobtrusively at the southern tip of the pond. Unobtrusive is exactly what the New York City Department of Environmental Protection wants, especially because this area has human fingerprints all over it.

In July 1998, the DEP started construction in and around the pond to improve storm water drainage. Porzio's Pond is the headwaters of Sandy Brook and chronic floods used to occur where the two met. Runoff heavy with the neighborhood's lawn fertilizers and oil residues swirled onto the main roads and choked the tiny stream valley. The pond-brook system was becoming a liability. Planners at the DEP tackled the flooding by building a riser box. This concrete structure acts like an overflow outlet of a bathtub – when the level of Porzio's Pond gets one foot above normal, the water pours down the box and into underground drains. The drains, which also collect polluted runoff from around the neighborhood, empty into a DEP-constructed marsh alongside the brook. The 1.2-acre marsh slows the crashing flood with a series of small pools and meandering channels. In this shallow marsh, pickerel weed and lizard tail purge the contaminants while mud and sand drops out of the water. The clean water then flows into Sandy Brook, purified by nature's premier scrubber – a wetland

system. Small constructed wetlands like this are cropping up throughout Staten Island as part of the DEP's ambitious Bluebelt program.

Dana Gumb, director of the eight-year-old program, said that the DEP has built wetlands to process water from 12,000 acres of the 38,000-acre island. Natural wetlands have been drained, bulldozed and paved in most areas of New York City, but the DEP is committed to saving what's left on Staten Island. "It's the last stand for freshwater wetlands in New York City," Gumb said.

The storm water wetlands that Gumb's group designs are multi-purpose. They combine flood control, pollutant removal and wildlife habitat with picturesque, emerald strips that increase nearby real estate values. Although the Bluebelt wetlands are relative newcomers to New York City, the idea of multi-purpose constructed wetlands is more than 30 years old. The Environmental Protection Agency estimates that more than 600 storm water and wastewater wetlands are in use nationwide. However, the possibility these systems could be toxic to wildlife is just now being considered.

Although constructed wetlands exist in landscapes ranging from the steamy lowlands of Florida to the dusty plateaus of northern Arizona and the blustery plains of Illinois, scientists and engineers admit they are not entirely clear about the processes that occur in their wetlands. Most basic premises are understood, such as which plants effectively remove certain chemicals and how much time is required for that removal. Treatment wetlands are designed to take advantage of the cleansing

nature of bacteria, algae and plants. Successful systems become attractive to fish, birds and small mammals and give people the opportunity to see nature up close.

As the country gobbles up land for development, city planners are utilizing constructed wetlands to attack many urban problems: loss of green space for recreation, degradation of water quality and lack of wildlife habitat. The San Francisco Bay area, for example, one of the nation's most densely populated regions, contains several projects totaling more than 300 acres of constructed wetlands, often squeezed among freeways or in narrow corridors abutting the bay. The wetlands are viewed as successes because they reduce damaging nutrients and heavy metals by as much as 80 percent before the water is discharged into the bay.

The removal of toxins by wetland systems is good news to water specialists, but not necessarily to the wildlife that reside there. Researchers are beginning to investigate the possibility that constructed wetlands could spell long-term disaster for many animals. Heavy metals that concentrate in the plants, such as lead and chromium, while harmful to people, are deadly to animals. Yet wildlife is attracted to constructed wetlands because they are often the only patches of greenery in an urbanized region. Some, such as the Hayward Marsh Expansion Project south of Oakland, Calif., have become major stopovers for migratory birds. The metals and other compounds could weaken immune systems and render the birds susceptible to disease, scientists say. But the science is not fully understood and scant, conflicting evidence muddies debate in the wetland community. Meanwhile, mallards, herons and terns build nests and hatch chicks in possible death traps.

The residents around Porzio's Pond weren't looking for a death trap when they approached the DEP to include the area in the Bluebelt program. They wanted to preserve the pond and creek for themselves and the animals. That request coincided with the DEP's plan to soften the impact of urbanization on Staten Island. Here, houses and businesses still use septic tanks, not sanitary sewers like the rest of New York City. The result: the absence of huge underground pipes that also provide storm water drainage.

Gumb said the plans for sanitary sewers have been delayed 30 years and will likely remain so for another 30 because of the billions of dollars required to construct them. In the meantime, officials are concentrating on flooding problems. Traditional storm drainage lines dry out wetlands by shunting any water – runoff or not – into concrete channels. Los Angeles channelized all of its rivers after the disastrous 1933 El Niño floods and today the city lacks any significant wetlands. Wanting to avoid the same mistake, the DEP decided to develop a drainage plan that took advantage of existing streams and ponds instead of eliminating them. By the late-1990s, many of these plans were becoming reality. The Porzio's Pond-Sandy Brook system was one of the earliest projects.

But the runoff that was now purposely directed into the streams brimmed with neighborhood pollutants and trash. Gumb said the DEP decided to take drainage to the next step with their storm water wetlands. "Rather than have pipes just sending water straight into the stream, these wetlands reduce the impact of the storm water discharge," he said. The added benefit was recovering lost habitat for wildlife.

Like forests, wetlands have borne the brunt of centuries of industrial and economic development. U.S. Fish and Wildlife Service researchers estimate that more than 53 percent of the lower 48 states' wetlands were destroyed between the late 1700s and mid-1980s: only 100 million acres remain today – an area the size of California. Some states, including California and Illinois, have lost more than 80 percent of these ecosystems to agriculture, residential encroachment and industrial development. Pollution furthered the demise of wetlands in the form of unfiltered storm water and agricultural runoff.

The impacts of this devastation to the environment are well documented. In the 1840s, Henry David Thoreau counted 22 species of orchids and over 1,000 ponds on Staten Island; today only six species survive around 28 ponds. In Indian River County, Fla., a study showed that the number of fish species dropped from 16 to five after a marsh was dammed for mosquito control. Development of the San Francisco Bay and Sacramento-San Joaquin River Delta, the West Coast's largest estuarine complex, has led to the listing of 60 plant and animal species as rare, threatened or endangered.

The 1972 passage of the Clean Water Act began to turn the tide in the favor of wetlands. The legislation defined what needed to be regulated to prevent water pollution and which agencies were responsible for water quality. During the 29 years since the passage of the act, attitudes and efforts have evolved. In the 1970s, government agencies and environmental groups focused on point source pollution problems, or sources where a single point of pollution, such as a discharge pipe, could

be identified. By the 1990s, with the vast majority of point sources removed or regulated, attention turned to non-point pollution sources, or those where pollution enters a system from a number of sources scattered over a large area.

Using wetlands to treat municipal wastewater, or household sewage, grew from the water protecting legislation. In state after state, more stringent measures on water quality forced small towns to invest in multi-million dollar centralized sewage treatment facilities or face the political and financial risks of not abiding by the law. Throughout the 1970s and into the 1990s, however, some communities opted to follow a greener, muddier path to create wetlands to purify their wastewater.

While wastewater was a single constant flow, storm water offered a special challenge because of how runoff enters the environment. Karen O'Brien, an environmental engineer at the EPA, said storm water is both a point and nonpoint source. "Wet weather events cause entry from all over the place," she said. Constructed wetlands emerged in the late-1980s as an attractive option to process storm water runoff and protect natural wetlands. They act as pre-wetland wetlands by filtering both point and nonpoint sources, cleansing the water and thereby protecting the health of nearby ecosystems.

As constructed wetlands spread around the nation, some people began to cautiously view them as an answer to the problem of disappearing natural wetlands. Towns built wetlands even in areas where they never existed before, such as Jacques Marsh in northern Arizona. This marsh was constructed in a shallow depression among the plateaus and soon became a bird haven. When wildlife appeared, usually the sign of a healthy environment, these unnaturally occurring marshes and ponds

became parks, wildlife sanctuaries and protected zones. One such dual-purpose wetland is in Arcata, Calif., in the heart of redwood country.

Nestled on the fog-laden North Coast, where World War II Navy pilots trained for raids on the foggy Japanese islands, the Arcata Marsh and Wildlife Sanctuary has become an international model for constructed wetlands. The 154-acre system opened in 1986 after almost 20 years of development. It treats municipal wastewater from 15,000 people. Visitors come because of its environmentally unique construction and its location on the Pacific Flyway – more than 250 species of migratory birds frequent the Arcata marsh. Because it is one of the world's pioneering successful projects, many wetland scientists use it as an exemplary system. It is widely studied for its innovative yet simple approach to treating wastewater, hosting researchers from countries including Mexico, Egypt, Australia and Croatia. At nearby Humboldt State University, several departments include the wetland system in their coursework. "It's used as a lab by us, fisheries and wildlife," said Robert Gearheart, an environmental engineering professor at the university. Gearheart was part of the original marsh design team in 1969 and has remained a prominent figure in the evolution of the system.

The Arcata Marsh and Wildlife Sanctuary encompasses many ideas fundamental to constructed wetlands. It is a collection of seven interconnected marshes, three ponds, a small lake and an assortment of low-tech waste screening facilities built on an old landfill. Mount Trashmore, the highest point at 10 feet, attests to the area's dumpy past. The system curls around the northern edge of Arcata Bay, where more than 50 percent of California's oysters are produced. The marshes

and ponds are separated from the bay by reed-covered berms. At high tide, though, the blue-gray waters of the Pacific Ocean surround the complex yet elegant system in which only two full-time employees toil.

Gearheart said operators track the purifying performance of the marshes and ponds by taking water samples from 16 sites. The samples are tested for suspended solids, nutrients, oxygen content and acidity, all common measurements for constructed wetlands. Each one of these categories indicates the health of the wetlands. Suspended solids, for example, measures the clarity of the water – high readings can mean that the water is not settling and the increased solids are placing fish and aquatic insects at risk of live burial. High amounts of nutrients, specifically nitrates and phosphates, commonly found in fertilizers, show that algal blooms are imminent. Algal blooms, what most of us know as "red tides," can be beneficial to the environment one moment and dole out destruction the next. On the one hand, algae produce vital oxygen from photosynthesis and suck harmful chemicals out of the water. When the algae die, however, their decomposition robs oxygen from the water, again placing fish at risk of death, this time from suffocation. As the fish die and decompose, larger amounts of oxygen are consumed. If the water stagnates, this self-perpetuating process, called eutrophication, can kill a wetland and leave a festering soup in its place. The chance of this happening at Arcata is slim though. "We have a general understanding of the relationship between plants, roots, sediments and the water column," Gearheart said.

Given the potential for such dismal deathly events, designers of the wetlands had to strike a balance between a flow of water fast enough to prevent eutrophication

but slow enough to remove chemicals and allow solids to settle. Compounding the dilemma were state and federal water quality standards and the demands of wildlife on water resources. Engineers decided that the water would spend 50 days being processed in seven stages.

In the primary stages of treatment, two giant corkscrews, which look like spinning troughs of sludge, lift the raw sewage 15 feet into a silo-shaped "headworks" building. Screens remove inorganic substances from the wastewater, which then flows into tanks where the sewage stagnates and solid separates from liquid waste. Solid waste is pumped to tanks, called digestors, to be decomposed by micro-organisms. Methane gas is bubbled through the tanks to mix the sludge; it can be recaptured and burned to heat the digestors, which facilitates the decomposition process. The sludge is rich in nutrients and, after being dried to kill remaining viruses and bacteria, is used as a soil conditioner by the city.

The liquid waste must undergo a longer, more arduous journey to purification. It flows first into three five-foot-deep oxidation ponds. Trees and plants are prevented from growing around the ponds so algae can thrive in unblocked sunlight. The algae-produced oxygen promotes the growth of bacteria and microbes. This microbial mix breaks down complex organic molecules, such as petroleum, and releases carbon dioxide – the stuff of life for algae.

Also in these ponds, 50 percent of the remaining suspended solids settle to the bottom. The microbial mix attacks the chemicals and heavy metals in the sediment. Close to the bottom, microbial oxygen consumption is so demanding that it exhausts the supply from the algae. Anoxic – without oxygen – conditions result and the

organisms use other chemicals in the sediments to survive, thus removing them from the environment. Anoxic conditions also help immobilize damaging zinc, silver and lead in the sediment. “There’s no uptake (of metals) in plants if conditions are anoxic,” Gearheart explained. If oxygen becomes available, the metals could dissolve into the water. The design of the ponds does not allow oxygen to reach the lower layers of water thereby preventing this from happening.

The water next flows into the two-foot deep treatment marshes, where thick vegetation strips nutrients from the water. Here, the algae shift from benevolent cleaners to antagonistic villains. Any living algae could cause blooms; dead algae would induce eutrophication. Hence, the water is filtered to remove dead algae, while trees and floating plants block the sunlight required for alga growth. Lush, native Humboldt Bay plants slow the water, causing more solids to settle, and ravishly consume nitrate and phosphate. After two days in the treatment ponds, the water is disinfected to extinguish any remaining life. The water is pumped into tanks, bubbled with chlorine gas for 60 minutes and then scrubbed with sulfur dioxide to remove the chlorine. But possibly damaging byproducts from the reaction are forcing changes to this method. “We are hoping to use ultraviolet radiation to kill viruses and pathogens in two years,” Gearheart said adding that the debate is just starting on how to implement the newer treatment.

Either way, the water at this point is legally clean but designers decided to take it one step further. It enters enhancement marshes named for the three major figures who helped establish the facility (one marsh is named after Gearheart). Thick grasses, willowy reeds and waxy waterlilies create verdant mazes with secret spots

for bird nests and muskrat burrows. Shrubs and trees lean over the water's edge and cast deep shadows into the meandering current. The water continues settling and losing nutrients for 10 days, but the real show is the ospreys, wrens and herons. Although birds and other wildlife frequent all parts of the marsh, the enhancement marshes are always teeming with fauna. The water is eventually released to Arcata Bay, five to six times cleaner than the water that comes out of most drinking faucets.

Gearheart said the Arcata Marsh and Wildlife Sanctuary shows how independent decentralized sewage systems are preferable to large central conglomerations. A central system for Arcata's population would have required a larger staff, more maintenance and cost $4 million more than the marsh did at $6 million. Although Arcata had the luxury of space when the marsh was being designed (the county is one of the most rural in California), the biological principles were established for a successful marriage between human needs and natural systems.

The situation is different in extremely urbanized zones where land comes at a high premium. For most of the nation's history, cities have grown houses and businesses on once healthy wetlands. Reintroducing marshes now usually involves pacifying eager developers, leading to the not-so-contemporary debate of environmental protection verses economic growth. The New York City Bluebelt program is a prime example of the viability of wetlands in one of the world's most urban cities.

When Maribel and Mike Sansone moved across the street from Porzio's Pond 21 years ago, southern Staten Island was a rural retreat from the steel and concrete canyons of the city. The Sansone's home was one of a dozen bordering the pond with

two horse farms behind the houses. The pond actually had no name. “We saw beautiful pheasants … and rabbits. We had an abundance of frogs; they were in our bathtubs when we first moved in!” Maribel said.

Frogs wouldn’t be the only infiltrators. Boom times came to Staten Island and the area around the pond blossomed. Between 1980 and 2000, 91,607 people moved to the island and the population rose 26 percent from 352,121 to 443,728. The open pastureland around the pond was sold and subdivided for houses. Roads were extended, shopping centers built and suburbia swept around Sandy Brook and the Sansones. Traffic increased on the winding country lanes, but the biggest change came in water control. The new roads and roofs didn’t absorb rainwater the way farmland did; they shuttled it into stream valleys with increasing force that scoured river banks, pulverized wetlands with polluted water and flooded the sprawling neighborhoods.

The bulldozers took aim at the pond in 1993. The area was zoned for multi-dwelling houses. When residents got word of the proposed development, they named it Porzio’s Pond after a farmer and formed the action group “Friends of Porzio’s Pond.” Sansome is the president of the organization. When the DEP established its Bluebelt program, the group lobbied the agency to purchase and protect the pond and creek from developers. The DEP acquired the area in 1995 and proposed building wetlands to control the floods and to clean the water before the natural wetlands along Sandy Brook choked in a toxic runoff stew.

But even as the pond and brook escaped the builders, animals were disappearing. “We used to be smothered by (red and blue robins) but now if we see

eight, we saw a lot," Sansone said. She hasn't seen pheasants in almost 10 years and even the pervasive frogs don't seem as abundant. She attributes the disappearances to the real estate growth and her group has made preserving the environment for the remaining wildlife a priority. "I'm trying to prevent them from all disappearing because we need them too," she said.

Although she was referring to the overall aesthetics, studies show that real estate values increase according to proximity to natural landscapes. "Wetlands add 10 to 20 percent in value," said Tom Schuler, executive director and founder of the Center for Watershed Protection. The Maryland-based organization compiled reports on the economic value (both perceived and actual) of wetlands. Some areas showed 24 percent increases for property adjacent to the wetlands and almost 11 percent declines if located farther away. When residents were asked to rank preferences on features common in suburban America, such as wetlands, cul-de-sacs, parks and dry plots of land, wetlands scored the highest. Even cul-de-sacs scored higher than dry land.

Back at Porzio's Pond and Sandy Brook, Sansone is eagerly planning for reintroduction of animals this spring. "We want to replenish it with fish," she said. The group is discussing plans to build birdhouses around the pond to encourage birds to become permanent residents.

Both the Arcata project and Bluebelt program specifically include wildlife habitat as vital components to the success of their wetlands. No one disputes the fact that healthy wetlands attract insects, fish, amphibians, birds and small mammals;

sometimes endangered species colonize the marshes and ponds. But toxic compounds that the wetlands are designed to remove may be affecting the immune systems and reproductive success of resident animals. If an avian disease, for example, then breaks out, wildlife managers have hundreds, even thousands, of sick and dying birds scattered across the wetland. These problems and their proposed solutions have begun to polarize scientists.

With many projects now well established, researchers are acquiring long-term data sets about animal populations. This information is being processed to analyze the effects of bioaccumulation and biomagnification in both plants and animals. Bioaccumulation refers to the buildup of harmful chemicals in plant or animal tissue. Biomagnification is the concentration of those chemicals in animals higher up the food web. Bioaccumulation and biomagnification of pesticides are responsible for the near extinction of the American bald eagle in the mid-20th century.

Habitat loss, toxic exposure and genetic homogeneity are all warning flags before an impending extinction. If researchers notice these flags, they can combat the disappearance of a species. But constructed wetlands complicate matters. They provide more habitats but, with all the toxins, they could be lethal havens for animals.

The Hayward Marsh Expansion Project on the eastern side of San Francisco Bay could be one of these traps. The 172-acre plot consists of a 145-acre marsh and a 27-acre mouse preserve. The marsh receives wastewater from several thousand people and performs second and third level treatment – similar to Arcata – before discharging water to San Francisco Bay. Operators test monthly for a collection of metals: arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver

and zinc. Slipped in among the rapidly growing Bay Area, it offers one of only two freshwater marsh sites in the entire region.

Migratory and resident birds, including the endangered peregrine falcon and Least tern, use this site by the thousands. Mark Taylor, a daily operator at the marsh, said the baseline population is around 30,000 but during spring and fall migrations it can reach 45,000 birds. “In our 145-acre marsh, we have more waterfowl than the entire 29,000-acre U.S. Fish and Wildlife Refuge in South Bay because we are the only freshwater zone in the East Bay,” he said. The Don Edwards San Francisco Bay National Wildlife Refuge he is referring to is about 15 miles south of Hayward.

The heavy concentration of birds in the Hayward marsh spells disaster when there is an outbreak of disease. Last year, avian cholera swept through the population, killing 1,500 birds. With an exposure-incubation-death timespan of only six hours, the disease struck the full spectrum of bird species. Taylor said operators had to vigorously respond to prevent wholesale slaughter of the birds. The outbreaks chronically happen in winter and baffle Taylor. “We’ve tested the sediments, water, and air. It’s not known why we keep having outbreaks,” he said. But he quickly pointed out that the deaths are not related to the presence of wastewater.

Herein lies the scientific conflict. Studies are inconclusive in determining if metals and pesticides weaken the birds’ immune systems, causing them to be more susceptible to pandemic events. A 1990 study by University of Wisconsin veterinary researchers showed that mallard ducks did not suffer from weakened immune systems after being fed a diet containing various levels of sewage sludge for almost two months. But they also found two to three times as much cadmium concentrated in

exposed birds' livers than in unexposed birds. The metal is known to have adverse effects on immune systems after prolonged exposure.

On the pesticide side of pollutants, Tom Schuler's group published a review of studies that examined concentrations in soil and various birds although none of the studies looked at wetlands specifically. All indicated that bioaccumulation and biomagnification were occurring. Three widely used residential insecticides – heptachlor, oxychlordane, and dieldrin – increased in concentration from the soil, through songbirds' diet of beetles and worms to the song birds, and ultimately, the raptors that hunted the songbirds. The lethal dose of dieldrin for songbirds is four parts per million; in some birds, the chemical was 20.5 parts per million.

Other research has focused on the uptake of metals by plants in constructed wetlands. André Sobolewski of Microbial Technologies conducted a 1996 study of heavy metal concentration in sediments and plant tissues exposed to water from mining operations. He concluded that plants in the wetlands were not consuming cadmium, copper, lead or zinc beyond existing natural levels. This implies, simply, that the metals are not entering the food web as a result of contaminated wetlands. However, Sobolewski's investigation was limited a total of only five plants from three wetlands.

Yet some scientists claim that plants are concentrating metals in root systems and leaves. In February of this year, Lena Ma, an associate professor of soil and environmental chemistry at the University of Florida, published in *Nature* her discovery that brake ferns could concentrate 200 times more arsenic in its fronds and stems than what was in the soil. The plant is able to store the metal in a form that

doesn't affect its functions or kill it. Although the study did not examine animal consumption of the ferns, arsenic kills slowly after prolonged exposure. Today's miracle plant could be tomorrow's death weed.

Meanwhile, Ari Ferro, president of Colorado-based Phytokinetics, Inc., a company that focuses on using trees to clean Superfund sites, said they analyze leaves for the original chemicals in the soil. "The parent compounds are not in the leaves," he said. "They are biodegraded into carbon dioxide, water and humic material in the roots and plant tissues." He went on to say that without strong evidence of risks, he is confident his company is not endangering wildlife.

Many in the field, though, on both sides of the issue, are unconvinced that there has been enough research and are digging deeper into the toxicity question. Much is riding on their findings. Bird populations are increasing at constructed wetlands across the nation. The Des Plaines River Wetlands Project north of Chicago recorded 165 birds in 1985, three years before the project was completed. In 1990, over 900 birds were counted, a 450 percent increase. Species richness also climbed, going from 45 to 77, a 70 percent rise. Four species of bird on the state's endangered list appeared: pied-billed grebe, black-crowned night heron, yellow-headed blackbird and least bittern. The Des Plaines River exemplifies two risks researchers have to contend with: not only could more birds be exposed to toxins, but more species of birds, which cuts into other food webs. Migratory birds can also transport local contaminants and diseases to distant biomes and spread the deadly impacts to other populations.

In these increasingly frequent debates, researchers sometimes appear to contradict their own work. “The ecological risks have been overblown,” Gearheart said. Taylor said that even with cholera outbreaks, the Hayward Marsh is cleaner than San Francisco Bay and dissections of resident muskrat livers do not indicate accumulation of heavy metals. And in the Bluebelt, routine testing of flora and fauna isn’t conducted, although officials are interested in what might be found. DEP planners say that because state and federal regulations do not require testing in storm water projects, funding is unavailable. Lynne Trulio, an associate professor of environmental studies at San Jose State University who worked at the EPA Office of Wastewater Management last year, summed up the feeling in the wetland community: “This is definitely an area of interest. There’s lots of opportunity to do this research but I don’t know of anyone doing any (studies).”

In the shrubs around Porzio’s Pond, academic debates are just distant grumblings. The constructed wetland along Sandy Brook came through two wet years to the satisfaction of its builders. People reminiscence about floods and muskrats now scamper among the cattails. Sansome and her group are gearing up for their annual clean-up of the pond this spring. She hopes to see more robins and ducks in the coming months. Thoreau’s Staten Island is permanently overrun with people, but in this little patch, nature and humans are attempting a revolutionary marriage. As with any union, listening is the key to success. Here among the reeds, people are tuning their ears to a new voice: the song of wildlife living in human residue.

-30-