The Lost Snail of the Yangtze and Other Essays

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Preface

This book contains essays that I wrote on various ecological topics for general audiences between 2000 and 2022. Many of these essays came either from the *Poughkeepsie Journal*, where Cary Institute staff under the leadership of Bill Schlesinger wrote a column every other week for several years, or the *Great Lakes Echo*, which published a monthly series of pieces in 2022 about natural history in the Great Lakes. One of the essays ("Alien Invasions") has not appeared previously.

Lori Quillen and Bill Schlesinger encouraged me to write these essays. They, Judy Bondus, and many of my colleagues at the Cary Institute offered helpful comments on early drafts of many of the essays, and Jen Read, Alex Haddad, and Dave Poulson helped me with the "A Year in the Kingdom of Ice" series. I thank them all.

Dave Strayer, December 2022

Thoughts on Ecology

Predictions for the Next Millennium

As we consider what the environment might look like in 2050, we might think about how well we could have predicted the current state of the environment from the vantage point of 1950. Leading environmental issues of the day included air and water pollution and concern over declining game populations. A forecaster sitting at my desk in 1950 might have predicted that the world of 2000 would be increasingly fouled by toxic air and water pollution, and that Dutchess County would be incorporated into the New York City metropolis, so that wild habitats and populations of wild game would all but disappear from the region.

These predictions have only partly come to pass. We do have serious problems with pollution, but have made great strides in controlling "end-of-the-pipe" pollution through the Clean Air Act, the Clean Water Act, and other state and federal programs. The Dutchess County landscape has been transformed by a growing human population and shifting economic forces. While some wild populations in the area have declined, others (especially deer and Canada geese) have grown to nuisance levels in ways that could not have been predicted in 1950 (the first record of a Canada goose nesting in NY was 1949!). Our seer probably would not have predicted any of the leading environmental issues of the late 20th century: global climate change, acid precipitation, stratospheric ozone depletion (the "ozone hole"), the outbreak of Lyme disease, the global extinction crisis, and the proliferation of exotic species (including zebra mussels, hemlock wooly adelgids, and now apparently the West Nile virus locally). So some of the problems that would have been foreseen in 1950 have come to pass, some have not, some problems were dealt with by society and so are less serious than predicted, and many new problems have emerged unforeseen.

What do we learn about the future from this look at the past? First, environmental quality is set by complex ecological, economic, and social systems that we only partly understand, so precise prediction is difficult. What can we say about the future? The most important trend that will continue unless the human population or economic system collapses is that our use of natural resources is growing rapidly. This trend leads to the following predictions.

Demands of human populations will strain the capacities of ecosystems to support us

Nature provides products that sustain us (food, water, clean air, construction materials, etc.) and absorbs our wastes. As the human population grows and per capita demands rise with increasing prosperity, the ability of the environment to provide for humans may be overwhelmed. We already see evidence of this in the depletion of global fisheries, accelerating extinction rates, deposition of acid, nitrogen, mercury and other harmful substances even in the most remote areas of the globe, and the beginnings of human-caused global climate change. As the human population grows both locally and globally, we can expect to see more cases where both ecosystems and humans suffer because humans demand too much from ecosystems. Some likely problem areas include provision of water to Dutchess County as well as to dry regions worldwide, accelerating climate change from emissions of carbon dioxide and other greenhouse gases, undesirable fertilization of estuaries and the coastal oceans through increased nitrogen use, and continued acceleration of extinction rates.

Environmental problems will increasingly extend over large areas and long periods of time

For the first time in history, human activities are now so large that they routinely affect large regions or the entire planet. The natural forces that regulate these large ecosystems often are slow, working over decades to centuries or even millennia. Thus, a few decades of acid precipitation may affect forests and lakes in the Northeast for many decades even after we stop producing pollutants, and the effects of carbon dioxide on climate will continue for decades after emissions are eliminated. Thus, many human actions have consequences that extend over large areas and last for many years. This leads to the difficult situation where environmental problems may have to be anticipated and solved decades before they reach their peak; in fact, before we are certain about how severe they will become. We will be increasingly challenged to think over the long term.

Solutions to environmental problems will require international cooperation

As human impacts on the environment have grown, the nature of effective solutions has changed. Many environmental problems that affect us locally (e.g., acid precipitation, invasive species) cannot be solved by local actions. Thus, environmental regulations have moved from local ordinances or state laws banning noxious activities to interstate pacts or federal laws regulating activities such as water withdrawals from interstate waters and industrial emissions. Many environmental problems (global climate change, ozone depletion, movement of invasive species, extinctions) cross national borders, and require coordinated action by several countries. Learning to develop effective and fair international agreements on environmental matters is an important challenge for the future.

We will be surprised

No one foresaw the emergence of Lyme disease in North America. Similarly, acid precipitation and the depletion of stratospheric ozone were well along before they were discovered by scientists, and even further along before they were addressed by policy-makers. As human impacts on ecosystems grow, we can expect even more important surprises. We must not be so arrogant to think that we can predict how the environment will change in the future, and be prepared to work hard to identify and solve new and surprising environmental problems.

Poughkeepsie Journal, 1 January 2000

Lost Worlds

Few themes in literature are more alluring than the lost world. Places like Atlantis, Shangri-La, Conan Doyle's "Lost World", and now the bestselling "The Lost City of Z" conjure up images of strange landscapes, exotic civilizations, and hidden treasures. Their mysteries continue to fascinate readers and movie-goers. Given the high profile of these fictional lost worlds, it is ironic that the Earth's real lost worlds get so little attention.

Consider Mussel Shoals. A 53-mile long series of rapids in the Tennessee River (a river three times the size of the Hudson), Mussel Shoals was a complex world of islands and winding channels, shallow enough during the summer to drive a wagon across. Little side-channels filled with minnows and miniature catfishes hiding in the riverweed alternated with whitewater and deep green pools. The shoals contained hundreds of species of shellfish and fishes, large and small.

Named for its immense beds of freshwater mussels, Mussel Shoals was one of the richest sites on the planet for freshwater life. The shoals were drowned in 1927 behind Wilson Dam, built to improve navigation and provide hydropower and flood control for residents of the Tennessee Valley. Even if the dam were removed and the acres of accumulated mud cleared away, dozens of species that lived on the shoals are now extinct because of Wilson Dam and other impoundments. Mussel Shoals truly is a lost world.

The great tallgrass prairies of the Midwest are another lost world. Cleared to grow corn and soybeans for us, our livestock, and now our cars, these magnificent grasslands once extended from Indiana to Nebraska, and from Texas to Manitoba. People always described these prairies as being a "sea of grass." The only time I ever saw enough tallgrass prairie to make an impression – an 81-acre patch in West Branch, Iowa – it was indeed impossible not to think of the sea. It wasn't just the way the wind rippled through the grass like a breeze over water – it was the color too. The prairie was green the way the sea is blue. Just as the sea changes from deep blue to turquoise to shimmering silver and white with the wind and waves, the prairie restlessly changed from bright grassy green to silver to sullen dark grey-green as winds and clouds passed. Floating in this sea of grass were countless whirring insects and bright prairie flowers.

Few habitats on earth have been lost the way that tallgrass prairie has been lost. Of the 167 million acres once in North America, only 3% remains, much of that degraded and damaged. When the prairie is lost, the animals it supports are lost, too, which has led to the decline of the prairie chicken and the upland sandpiper. More seriously, the soils held in place by the prairie are lost, too – about half of Iowa's topsoil has washed away since its prairies were plowed, and more is lost with each rainstorm.

The Earth abounds with lost worlds – the Three Gorges of China's Yangtze River, drowned to provide hydropower for China's growing economy; the great wetlands of California's Central Valley and our own Orange County, drained to grow vegetables and fruits for our tables; the Aral Sea in Russia, turned into a shrunken briny pool when its tributaries were diverted into irrigation ditches for Soviet cotton fields; and countless others.

Worlds are lost when we consume the resources we need to support our growing human population and swelling appetites for prosperity. Every time the human population grows, houses get bigger, or we buy fuel-inefficient vehicles, we lose another world.

Don't misunderstand me. I'm not scolding humans for using resources – all life requires resources. And I'm not even suggesting that we should feel guilty about the resources we do consume. The world is filled with wonderful opportunities, and it seems unreasonable to insist that people never take a trip to Hawaii, have a child, drive a car, or eat a fine meal, just to avoid consuming resources. We have just one life to live and most of us would be unhappy spending it eating gruel in an unheated mud hut.

But I do think it's useful to think about the worlds that we lose when we consume resources, and make mindful choices about our lives. Of course it would be nice to drive a bigger car, or have the steak instead of the pasta, or have a big house in the country, but is it worth losing another world? What names do we want to add to the list of worlds that have already been lost?

Poughkeepsie Journal, 29 March 2009

Breathing Lessons: Living Without Oxygen (with Jon Cole)

Most of us learned in school that plants produce oxygen and consume carbon dioxide, while animals (like us) consume organic matter (like carrots and burritos) and oxygen and produce carbon dioxide. These relationships keep our planet in a nice balance for both plants and animals. They are easy to remember, but leave out some interesting parts of the story.

Living things need energy to maintain order – blossoms, membranes, beating hearts – in the face of the forces of entropy and chaos. Plants get energy from the sun, producing oxygen and consuming carbon dioxide in the process. We get energy from the food that we eat, which ultimately comes from sunlight by way of plants.

But these are not the only sources of energy that living things can use. In the Earth's many secret places, like swamp soils, deep lakes, and ocean sediments, there is no oxygen at all, but bacteria, fungi, and even a few animals still are able to consume organic matter – dead bits of plants, animals, and other bacteria. Instead of taking in oxygen, they "breathe" nitrate, or sulfate, or iron. They produce carbon dioxide, too, but also substances like nitrogen gas, or sulfide, or methane.

You may never have heard of such species, but you are familiar with their work. The rotten-egg smell of pond mud and the wine that we drink are products of organisms that live and work in habitats without oxygen.

What is essential for life is not that there is oxygen to breathe or organic matter to eat, but that there is some source of energy. The list of possible chemical reactions that could be exploited for energy capture is long, and enterprising organisms make their living using dozens of chemical reactions other than the simple oxygen-carbon dioxide reactions of the typical biology textbook. Some bacteria can "breathe" iron, and manganese, and arsenic, and a lot of other stuff. (And not all photosynthesis produces oxygen, either, but that's a story for another time.)

It seems odd to think that life can exist without oxygen, but the earliest forms of life on our planet did not need oxygen. In fact, there wasn't even any oxygen in the Earth's atmosphere until about 2.5 billion years after life arose. When oxygen first began appearing on Earth, as a product of photosynthesis, it was a deadly poison to early forms of life. However, through the long process of natural selection, most living things have evolved to tolerate oxygen, and even benefit from it. Organisms that don't need oxygen are now confined to special habitats, usually in wet soils and sediments.

Here are two important lessons about the versatility of life. First, these unfamiliar organisms that live without oxygen are essential to the persistence of life on Earth. If all consumers required oxygen, then all of the dead material that made its way into the Earth's many oxygen-free zones would simply pile up there, unable to decay. This would lock up valuable organic matter and nutrients, and impoverish the rest of the planet.

Second, you should be able to see now why it is so hard to tell whether there is life on another planet. What would you look for? Living things don't necessarily produce oxygen or carbon dioxide, and they don't necessarily need water or carbon, or any other single substance. They need to be able to capture energy to maintain some kind of order against the relentless chaos of the universe. The ways in which they capture this energy could be fantastically varied, depending on the opportunities offered by some alien planet and the idiosyncrasies of evolution.

Life is so complex and varied that it is unreasonable to think that we could learn all about it in school. But it does seem a pity that many textbooks leave out some of the best parts.

Poughkeepsie Journal, 3 January 2010

Remembrance of (Some) Things Past

Memories can inspire or betray us. When the great storehouse of our memory is opened, even by something as commonplace as the aroma of a cookie, the powerful emotions evoked by the memory of happiness or injustice can inspire us to write a great novel, or demonstrate to block the demolition of a beloved building, or go to war.

Memory sometimes betrays us because we don't always accurately recall an event that occurred. But it also betrays us because we can't remember events that happened before we were born. The powerful emotions called forth by memory cannot be inspired by ancient events, or by phenomena that change too gradually to have dramatic effects within one lifetime.

Ecologists Karin Limburg and John Waldman describe a particularly striking example of such a slow slide into oblivion. They analyzed all available records on populations of diadromous fishes (species such as salmon and shad that migrate between fresh waters and the sea) in the North Atlantic. They found that 33 of the 36 stocks had declined, very dramatically in most cases. Populations of 25 of these stocks now stand at less than 10 percent of their historic levels, and 10 are at less than 1 percent of their historic levels. As bad as these figures are, they probably *understate* the severity of decline, because in many cases fisheries monitoring did not begin until well after populations started to fall.

These fish stocks may have begun to decline by the early nineteenth century as a result of dams that prevented these migratory species from reaching their spawning grounds, overfishing, and pollution. More recently, climate change, invasive species like the zebra mussel, and cooling-water withdrawals may have intensified the losses.

Most of our local migratory species have declined, including Atlantic sturgeon (now at 9 percent of historic levels throughout the Atlantic), American shad (3 percent), alewife (1 percent), blueback herring (0.6 percent!), American eel (28 percent), and smelt (1 percent throughout the Atlantic, and gone entirely from the Hudson).

Losses of our local fish have been so severe that the New York State Department of Environmental Conservation has completely closed the commercial and recreational fishery for American shad in the Hudson River. This species sustained

Native Americans, colonists, and modern New Yorkers alike, with landings from the Hudson at times exceeding 1 million pounds a year. As local fisherman John Mylod has observed, 2010 is the first spring in thousands of years in which humans won't go down to the banks of the Hudson to fish for shad. This is not our proudest moment as stewards of the earth.

So why aren't people up in arms about the catastrophic losses of nearly every diadromous fish species in the North Atlantic? At least part of the answer must be that no one alive can remember the original state of the fish populations, when rivers on both sides of the Atlantic ran silver with shads, and docks were stacked high with sturgeons. Instead, each generation has seen only a small part of this long slide into oblivion as our natural resources were nibbled away.

Because our memory is limited by our life span, we don't feel personal sadness or indignation arising from the memory that each fish now returning to the Hudson used to be accompanied by 10 or 100 of its fellows. We don't *feel* the void left by their absence.

In a more practical sense, because we can't remember the great historic fish populations, we are less inclined to feel outrage when someone proposes a project that might damage fish populations just a little, nor demand the aggressive management of our fish stocks that would restore them to more than a shadow of their historic greatness.

Maybe the best we can do in such circumstances is to remember that if we rely solely on memory to guide us, we will always underappreciate the importance of long-term changes to our natural resources. Instead, we need to use other tools, such as scientific analysis, even if data don't have the evocative power of memory.

Poughkeepsie Journal, 9 May 2010

Scenes From a Vanishing Planet

Once there were big stands of hemlocks in the ravines and on the steep creek-banks. Their shade was so deep that hardly any underbrush could survive, so the ground was clear between their big trunks. It really did remind you of a green cathedral. Where there were openings along the creek or where a tree had blown over, bright shafts of sunlight would slice down to the forest floor, like in paintings. The ground was covered with a thick mat of needles, making it so soft underfoot that you could walk through the woods without making a sound. The needles made the air a little fragrant, not as sharp as under pine trees, but distinctly aromatic. During the winter, when a breeze shook the branches, motes of snow would sparkle in the air.

The street I grew up on was lined with elms. There was a little median strip with weeping mulberries and gnarled crabapples, and high above it all, the vaulted green canopy of elms. I didn't know it at the time, but the elms gave the street an air of quiet elegance. (And there was little in this small Midwestern city of stamping plants and paper mills that you'd call elegant.) The huge elm tree that spread over the intersection of Macomb and First Street made it seem quiet and civilized. When the blight finally got that tree, we saw that the corner really was common--hot, and noisy, surrounded by parking lots and sagging old houses. Those elms are gone now.

We'd sit outside on summer evenings as the heat drained out of the day and the sky turned to deep, smooth blue. The bats came out just before the first stars, skittering through the sky on their crazy flight paths. I knew that they were mammals, but they always looked more like little jagged birds. If you threw a pebble up into the air, sometimes they'd veer over to investigate before swooping back to their business catching bugs.

These scenes are vanishing from our world, or have already vanished, because we have been careless about moving species around the world. The elms fell victim to Dutch elm disease, which we brought from Europe on diseased logs. The hemlocks are dying because we imported nursery stock contaminated with a deadly new insect (the hemlock wooly adelgid) from Asia. Now it looks like the white-nose syndrome that is killing many of our bats may be from a fungus that we accidentally imported from Europe, harmless to European bats but lethal to our species.

These are just three of literally thousands of non-native species that we've brought into the United States, which have caused ecological destruction and billions of dollars in economic damage. Although we've known for decades that moving species carelessly around the globe causes countless problems, we still aren't taking the problem seriously. Species still move freely around the world on human coattails, leaving a trail of new problems in their wakes.

I hate having to polish my stories to keep these scenes alive in my mind after they have vanished from the world. I hate knowing that I'll fail – that my stories never will be good enough to bring the missing pieces of our world back to life, any more than the old stories that I read about chestnut trees or passenger pigeons make me feel like I am standing in those lost forests or hearing the whirr of a million wings. Most of all, I hate knowing that we're still making the same careless mistakes that cost us so many pieces of this beautiful world.

This world we live in, and often take for granted, is too valuable to ruin through neglect. We can do better. It starts with people caring enough to encourage policies that prevent invasive species from entering the United States in the first place. We should be protecting our natural heritage for future generations. On day they will wonder why we did so little.

Poughkeepsie Journal, 13 March 2011

Seeing Ghosts

Is it good or bad to be able to see ghosts? I've been wondering about this since I recently realized that I've been seeing ghosts ever since I began to study freshwater mussels about 30 years ago.

There's nothing special about being able to see ghosts – all mussel ecologists can do it. Our native mussels make thick shells, some weighing more than a pound, that can last for decades or centuries, especially in places where the water is hard (rich in calcium). This means that when you visit a river, you can see the ghost shells of mussels that lived in 1940, or 1840, along with the shells of mussels that are living in the river today.

So mussel ecologists can see the past and present at the same time. Each of the 300 species of freshwater mussels in North America has its own habitat preferences, and uses its own set of fish species to carry its larvae. Thus, mussel ghosts tell you not only what kinds of mussels used to live in a river, but also what the habitat was like and what kinds of fishes could be found there.

Let me give you an example. One of the first places I visited as a young ecologist was the mouth of Macon Creek in Michigan. The day I visited, I saw a nearly stagnant stream filled with warm water having the temperature and odor of fresh urine. Algal scum covered the stream bottom, and construction debris tumbled down its banks. Not surprisingly, I didn't find a single living mussel in the creek. The scene was unappealing in the extreme.

But the ghost shells of 18 species of mussels (the most I have ever seen at a site) showed me a different scene. At the same time that I was seeing the squalid scene in front of me, I was also seeing the creek mouth as it must have been before the land was cleared in the 19th century.

A small, clear creek overgrown with willows swings through broad loops before entering the river. The sandy spit where the two streams meet is covered with hopeful young sycamores and the tracks of sandpipers. Upstream of the creek mouth, the river flows in a foam-flecked green pool shaded by the graceful parents of those little sycamores. Downstream, a bright riffle sparkles in the sun. The water is filled with minnows and sunfishes and multicolored darters, and the air is filled with waxwings and warblers and black-winged damselflies.

You can imagine the emotions that these ghosts evoked in me – delight in discovering that such a lovely spot once existed in the monotonous landscape of southeastern Michigan, mixed with sadness at its demise.

I wonder how we would feel if we could see all of the ghosts around us. What if we saw the shadows of great flocks of passenger pigeons flickering on the ground each year during the migration seasons? Or the thin trails of wood smoke rising from Indian encampments along the creek every time we drove past I-84 and Route 9? Or, looking down from the Walkway Over the Hudson, saw both the empty muddy water of 2012 and the clear water of 1750, alive with the backs of numberless shads swimming up the river in huge schools?

I really don't know if it would be a good thing or a bad thing if we could see all of these ghosts. But I do know from my own unsettling experiences as a mussel ecologist that being able to see ghosts forever changes the way that you think about the world and our role in it.

Poughkeepsie Journal, 29 January 2012

The Dirty Truth about Unpaved Roads

Paving rural roads is one of the local issues that can get people in Dutchess County worked up. Some people like the rural look of unpaved roads, and that they restrict the volume and speed of traffic. Others think that paved roads are safer and more comfortable to drive on. And then there is cost – it's said that paved roads cost less to maintain, but are very expensive to build.

I'm not going to discuss any of these important issues today, but will focus on the ecological impacts of unpaved roads. I often hear the claim that unpaved roads are "greener" than paved roads because they are permeable (they allow rainwater to percolate instead of running off).

In fact, the dirty secret about unpaved roads is that they have a poor ecological record. To begin with, even unpaved roads are so compacted that they allow very little water to soak in, unless they are specifically built and maintained to allow water to infiltrate. So rainwater just runs off of unpaved roads, as it does for paved roads, and the supposed ecological benefit of unpaved roads is illusory.

The chief problem with unpaved roads is that they are subject to erosion, which can generate a lot of sediment that runs off into watercourses. This problem is so bad (and so well known to ecologists) that unpaved roads and poorly managed construction sites often are identified as the worst hot spots on the landscape for sediment generation.

This sediment is a problem for several reasons. First, it can smother stream habitats and their inhabitants, reducing biodiversity and eliminating sensitive species from our streams. In particular, it can clog stream gravels and prevent spawning and rearing of trout.

In addition, adding sediment to streams can cause them to become unstable and change their courses. This instability can pose a problem for plants and animals that live in or along streams, as well as for humans that live near streams.

Perhaps of greater interest, by accumulating in streams, this sediment can raise streambeds and make flooding worse. In the wake of last year's flooding, there have been many suggestions to "clean out" local streams to prevent future flood damage. Such campaigns by themselves will cost precious tax dollars and are likely to damage stream habitats without providing long-term relief from flood damage (see "Flood mitigation requires care", *Poughkeepsie Journal*, 23 October 2011).

Instead, if any program to reduce future flood damage is to be effective, it must focus on reducing sediment inputs to streams, as well as any "cleaning" of the channels that might actually be required. This includes sediments generated from unpaved roads.

Unpaved roads may generate a lot of dust during dry periods. This dust can alter roadside vegetation, and has been considered to harm human health. In addition, any chemicals that are applied to unpaved roads to keep down dust may themselves have ecological or health effects.

It is worth noting that some of the benefits of unpaved roads in slowing traffic may also be achieved by using road designs that incorporate alternative "calming" measures that do not have the negative ecological effects of unpaved roads. See the "New Greenway Guide: Rural Roads", at http://www.co.dutchess.ny.us/CountyGov/Departments/Planning/planonit03042010.pdf for a good introduction to these measures. Another good resources is http://www.dirtandgravel.psu.edu/.

So whatever their merits, unpaved roads are not especially "green", and have some ecological effects that are distinctly negative. I'm not saying that this means that we should go out and immediately pave all the roads in the county. Certainly all of the issues that I raised at the beginning of this article should be considered. However, in any comprehensive discussion about the values of paved vs. unpaved roads, we should consider the real and substantial negative ecological effects of unpaved roads.

Poughkeepsie Journal, 20 May 2012

The Real Hunger Games

Everybody seems to know about food webs these days – how primary producers capture the energy of the sun, and pass it along to consumers and then on to predators – but I'm not sure that most people really understand what food webs are about. Food webs are not like the pleasant diagrams you see with cute little mice and clever foxes happily playing their roles in nature's balance. They're the scariest places that you can imagine.

...It was my turn to go for groceries, which I suppose was only fair – the Thompsons had given me Brandon's good bike after that grizzly got him last month. And we really needed the groceries. We hadn't dared to go out the last three nights because the scent of big cats had been so strong. But tonight was going to be a good night – just the hint of a moon, and no wind to drown out the sound of stalking paws. I was just going to the crummy neighborhood store, so there really shouldn't be a problem anyway. I'd like to be able to go across town to the big supermarket – the food was so much better there – but Mom wouldn't let me, not since the wolves had gotten Dad and Sarah on the other side of town. I spread lampblack over my face and hands as I waited for it to get good and dark. I knew that I would be nearly invisible in the faint moonlight, and I had done what I could to disguise my scent (you don't want to know the details), but I was afraid that my constant cough would give me away. It had been so damp in our underground home lately that it seemed like we had colds all the time. I wished that we still had a house above ground, but no one built old-style houses since the rocs had moved in and begun to pluck carpenters off of the roof beams...

Does a food web sound pleasant to you now?

You may think that this little story is overblown, but it is an accurate description of life in the food web. Most animals are confronted with predators that are numerous, efficient, and deadly. For instance, when we freshwater ecologists have tried to figure out how the invertebrates that live in lakes and streams die, we find that predators kill most or nearly all of them.

In response, prey have evolved a wide range of tactics to avoid getting eaten, or more precisely, to avoid getting eaten before they reproduce. Zooplankton have become nearly as clear as the lake water they live in to avoid the fatal gaze of fish. Speckled moths fade away against lichen-covered tree bark. Little animals grow costly and ungainly spines when the water smells like predators, or hide away in dark crevices or deep water until the sun sets. They avoid the places where predators live, even if that means forgoing the richest feeding grounds. Mayflies exposed just to the smell of fish grow to adulthood and emerge to lay eggs more quickly than those grown up without their fishy predators. Animals become vigilant and skittish when the wind carries the scent of predators, or a moving shadow (a shadow means sudden death) passes. And still most of them die in the maws of their predators.

I suppose this is an obvious point, but being in a food web means that, while you're out gathering your food, you are being stalked by your own predators. So the next time you see those little mice and clever foxes, think a little about what it is really like to be part of a food web. But don't think about it too much – it may give you nightmares.

Poughkeepsie Journal, 2 December 2012

Considering the Evidence about Climate Change

Some of my friends and relatives don't believe in climate change, so I regularly get emails containing evidence that climate change isn't real. The "evidence" contained in these emails usually falls into one of two categories.

Some of the evidence is just bogus – "facts" that are not true or that have been willfully misinterpreted or distorted. There isn't much to say about this, except shame on those who spread such baloney.

The other thing I find when I click on the links in these emails are reports of studies that seem to contradict the dogma of climate change. I'm sure you've seen these – studies showing that an ice sheet is expanding, or that temperatures have been dropping at a weather station somewhere.

Indeed, such studies do exist, and sometimes they are scientifically valid. They do not necessarily threaten ideas about climate change, however, a point that often is misunderstood by non-scientists. Instead of staking everything on any single study, scientists consider the weight of all evidence when reaching their conclusions, whether about climate change or any other subject.

A new study in *Geophysical Research Letters* by a team led by NOAA's David Anderson illustrates this point nicely. There has been some concern about whether direct measurements of temperatures (using thermometers at weather stations) fairly represent global warming over the past century or two, because these stations are not evenly distributed across the planet, often are near cities (which are heat islands), and so on. Of course, climate scientists are pretty smart, so they have tried to correct the temperature record for these biases, and it is this corrected temperature record that serves as one of the foundations for the conclusion that the Earth has been warming recently.

But what if this corrected temperature record is somehow wrong? Is there some other way that we can tell if the planet has been warming?

It turns out that the chemical make-up of structures such as coral reefs, glacial ice, and mussel shells records the temperature at which the structure was built. Furthermore, the growth rates of living things and the timing of plant leaf-out also can be used to infer past temperatures. One of the advantages of using these indirect records of past temperatures is that they can be collected around the world, not just near cities, getting around one of the possible problems with direct measurements of temperature.

Anderson and his team combed through the scientific literature and found 173 separate studies where temperatures since 1880 had been estimated by these indirect methods. Reassuringly, they found that estimates of global temperature using these indirect measures agreed very well with the corrected temperature records measured at weather stations. This study provides yet more evidence that global warming can't be written off simply as a result of biased measurements by climate scientists.

One very interesting finding of the Anderson study is that 13 of the 173 studies they reviewed found evidence of cooling rather than warming. Should we interpret these studies to mean that the global climate has not been warming?

Such a radical interpretation is hard to defend. Remember that Anderson's team found that the average of the 173 studies clearly showed that temperatures have been increasing around the globe since 1880. Furthermore, let's not forget that the direct measurement of temperatures, made at numerous places around the globe, and carefully vetted by countless climate scientists, show this same warming trend. And other kinds of evidence, not even considered by Anderson's group, like shorter periods of ice cover and shifts in distributions of plants and animals towards the poles and high elevations, also confirm the warming trend. I just don't see how you could throw out all this evidence just because a few studies go against the trend.

Instead, it seems most logical to interpret these scattered contradictory results as a result of imperfect scientific methods being applied to a complicated natural world whose pieces do not always move in lockstep. These interesting contrary results certainly would repay closer investigation, but do not invalidate the general conclusion that the Earth has been warming.

The next time you get an email claiming to invalidate some scientific claim, remember that one swallow does not make a summer. Consider all the evidence.

Poughkeepsie Journal, 5 May 2013

How Green is Your Grass?

How green is your grass? You might think that growing marijuana would be environmentally benign, based on how many times "pot-smoking" and "tree-hugging" appear in the same sentence. But an upcoming scientific study in *Conservation Letters* by Craig Thompson of the US Forest Service shows that illegal marijuana farms can have serious environmental impacts.

Dr. Thompson's team studies fisher populations in the mountain forests of northern California in the hopes of understanding why this large weasel-like animal is still so rare, despite recent conservation efforts. One day, one of the fishers they were tracking turned up dead, an otherwise healthy animal whose body cavity was filled with blood. The animal had bled to death from eating rat poison (technically an "anticoagulant rodenticide"). Prompted to examine tissue samples from other fishers recently found dead in the region, they that found 83% of them contained rat poison, suggesting that many fishers are being poisoned. Where are these animals finding rat poison in the largely pristine Sierra National Forest?

From the hundreds of illegal marijuana farms that are carved out of the national forest. The marijuana growers use lots of rat poison, as well as other pesticides (including some that are banned in the US), to protect their valuable crop. Little animals get into these poisons, then the fishers eat the little animals and die.

But these marijuana growers do more than kill a few weasels. Although careful scientific studies of marijuana growing are scarce (ecologists are easily discouraged by shotguns and booby traps!), it appears that these marijuana farms are anything but green. They illegally draw large volumes of irrigation water from local streams during the summer dry season, endangering populations of trout and salmon already threatened by dams, climate change, and human encroachment. To get to their hidden farms in the forest, growers build lots of roads and stream crossings that are poorly designed and maintained, leading to severe erosion. They tend to use lots of fertilizer, which ends up polluting local streams, and leave trash, spilled fuel, and human waste around their farms.

Nor is indoor marijuana production environmentally friendly. Indoor marijuana growers use a surprising amount of electricity, contributing to large carbon emissions (2 lbs. of CO_2 per joint). One study estimated that indoor marijuana production consumes 1% of all US electricity, and that its electricity use could be cut by 75% if growers adopted more efficient practices.

I draw two conclusions from these studies. The narrow conclusion is that, unless you can somehow tell your neighborhood dealer that you want to buy only marijuana that has been sustainably grown ("Humboldt Green" instead of Panama Red or Maui Wowie?), the current system of marijuana production isn't environmentally benign. I don't know about pot smokers, but many pot growers aren't tree huggers.

The broad conclusion is that unregulated industries don't often voluntarily adopt safeguards to protect the environment, even if such safeguards might benefit the greater good, if it is against their own self-interest. The marijuana growers are trashing the environment because it's easy and profitable for them to do so, regardless of what it might mean to you, me, or the unfortunate fishers.

We have seen this same sort of behavior by many industries, which did not voluntarily control their pollution either, leading to widespread problems with poor air and water quality in the mid-20th century (remember the flaming Cuyahoga River?). Despite what might seem to be enormous differences between California marijuana growers and companies like General Motors, they share this fundamental characteristic.

However, General Motors, and all other legal enterprises, have been forced to consider the public good by laws such as the Clean Water Act and Clean Air Act. The impacts of the illegal and unregulated marijuana industry remind us of the limits of the free market system to protect public goods like wildlife and water quality, and of the value of regulations in safeguarding these public goods.

Poughkeepsie Journal, 30 June 2013

The Road from Eden

I often hear that ecologists should stop being so gloomy. After all, the world isn't coming to an end – the sky is still blue, the grass is still green, and the birds are still singing. But this critique of ecology misunderstands three essential matters – the nature of ecological apocalypse, the good reasons why ecologists might feel gloomy, and the central motivations of ecology, which are fundamentally optimistic.

We are familiar with apocalypse through a recent spate of post-apocalyptic novels and movies – *The Hunger Games*, *World War Z*, the *MaddAddam* trilogy, and *The Road*, to name just a few. In most popular portrayals, the apocalypse is sudden and definitive, whether it comes from atomic war, disease, or zombies. There is the period before the apocalypse and the period after the apocalypse, and never any doubt about which period you're in.

In contrast, ecological apocalypse is gradual and insidious, and there is a long period that is neither clearly pre-apocalyptic nor post-apocalyptic. What had been the most abundant bird species in North America disappears entirely; vast runs of migratory fish vanish from our rivers; lakes around the world fill with toxic algae; invasive diseases sweep the planet, driving amphibians around the world into an unparalleled spasm of extinction, and killing our bats and iconic forest trees (chestnuts, ashes, hemlocks, and elms so far); millions of acres of soils in our most populous nation become too badly polluted to grow safe food; some of the world's greatest rivers dry to their dusty beds during dry seasons, their waters entirely consumed to slake human thirsts; the very climate of the planet changes. OK, it's not the end of the world, but it's obvious that we've come a long way from Eden. These changes took place not in the flash of a nuclear explosion, but over many human lifetimes. We moved down the road from Eden toward Dystopia so gradually that few of us even noticed.

But ecologists notice, because we know what the world used to be like, and watch how the world is changing today. It is the gift and burden of ecologists to be able to see these changes, in Edna O'Brien's phrase, with a ruthless clarity. We also think that we can see where today's actions may take us, and what additional damages to our ecosystems and our own health and quality of life will result if we continue down the road we're on. It is frustrating, then, to hear that we should lighten up because everything is fine. Clearly, everything is not fine, and there is a very good chance that it will get worse. In part to counter the argument that everything is fine, and in part to motivate the action that we think is needed to improve the world, we recite these damages that we see, leading to our reputation for gloominess.

Now here's the optimistic message of ecology. We can't choose the road that brought us here and so damaged our natural world, but we do get to choose the road ahead from this point. Contrary to our image of pessimism, most ecologists I know are optimists, in the sense that we believe that gathering and applying knowledge about ecosystems will let us choose a better road forward. We work every day to better understand how ecosystems work, how human activities affect them, and how to reduce and even repair ecological damages from human activities. It would be hard to get out of bed every day to do this work if we weren't at some level optimists. It's just that we struggle to articulate our twin message of apocalypse and optimism, urgency and empowerment.

Every day, individually and collectively, we make the decisions that determine where we go next on this road from Eden. To a place where our grandchildren and their grandchildren will prosper, or to one of the Dystopias? To find a good way forward, we will need wisdom and nerve, a clear understanding of where we are along this road, and a map that shows us where different roads lead. This is where ecologists, even gloomy ones, can help us.

Poughkeepsie Journal, 10 August 2014

Reflections on a Man of Merritt

I'd like to beg your indulgence to share a few personal thoughts today that were inspired by the recent passing of my friend Scott Meyer. Scott ran the Merritt Bookstore in Millbrook, and was one of the most inquisitive and optimistic people I've ever met.

Scott loved science, so reflecting on his life reminded me first about how wonderful and mysterious our world is. Over the centuries, scientists, naturalists, and regular people have figured out how our planet was formed, where hummingbirds go in the winter, how diseases harm us and how they might be prevented, where to look for iron ore, how spiders catch their prey, and a million other things that improve and enrich our lives. Bookstores and libraries are filled with wonderful books by writers like Mary Roach, Steven Jay Gould, and John McPhee that share this knowledge with us.

A reader of these books might be excused for thinking that the era of scientific discovery is over, and that every detail about our world has now been set down in a book (or maybe Wikipedia) somewhere. But there is so much that is still unknown. Scott's enthusiasm for science arose not just from the discoveries that have been made, but for the knowledge that great discoveries remain to be made. I always had the impression that Scott woke up every day thinking that today might be the day when the next great discovery about our world would be made – a new dinosaur, or a subatomic particle, or a tiny lemur deep in the forests of Madagascar. It could be anything!

Scott also was a great optimist, and believed that it was always possible to make the world better, and that the way to do so was to join hands and work together as a community. Sometimes, his ideas for getting people together and improving Millbrook didn't bear fruit, but I never saw him decide not to try to fix something because it looked hopeless.

Sometimes when we look at the state of the environment, it is easy to believe that the world is being run (and run into the ground) by Big Oil and corrupt politicians. Certainly, books like *Merchants of Doubt* show the powerful and corrosive influence of money on environmental management. It would be easy to give up on the environment as a lost cause. What can one person do?

But of course that is just what Big Oil and corrupt politicians are counting on. If we decide not to engage, then their money and insider's knowledge of politics will always carry the day. But if we cannot match them dollar for dollar, or scheme for scheme, we can outnumber them in votes and good hearts. But this can only happen if we get up off of the couch and engage.

It may be correct to think that it's hard for just one person to solve a big environmental problem, but as Scott understood, you never actually have to solve these problems by yourself. If you don't like the way the environment is being managed, get out and join with others who share your concerns. There are many such groups, from your town's Conservation Advisory Commission to big groups like the Union of Concerned Scientists or The Nature Conservancy (and there are lots more).

So in this humdrum world of jaded cynicism, Scott's passing has reminded me that it is our rare privilege to live on an endlessly fascinating planet that has not yet given up all of its deep secrets, and that it is always possible to take action to protect it. Of course, we will be up against powerful interests, and of course we will lose some battles. But I think that Scott would have reminded us in the end that the world is filled with good people and that joining together can magnify our strength ten-fold.

Poughkeepsie Journal, 11 October 2015

De-Extinction is a Risky Ecological Experiment

De-extinction (bringing extinct species back from the dead) has been riding a wave of enthusiasm, fueled by Steward Brand's TED talk and several prominent books and articles. But for a project that aspires to use materials from the past to build a better future, de-extinction is doing a poor job of using past experience with biological invasions to temper that enthusiasm.

The basic idea of de-extinction is to use bits of genetic material salvaged from an extinct species (museum specimens, frozen mammoths) in cutting-edge biotechnology to create living animals in the lab, and use these lab-created specimens to re-establish populations of the extinct species in the wild. Actually, as Beth Shapiro described in her excellent book *How To Clone a Mammoth*, the end product isn't literally the extinct species, but an animal with some of the genes of the extinct species (the passenger pigeon) and some of the genes of a living relative (e.g., the band-tailed pigeon), which hopefully looks and acts something like the extinct species. We might call this new species "passenger pigeon v.2.0".

I don't need to explain the appeal of "de-extinction". Besides using our powers to bring back charismatic species, de-extinction could restore vital functions that these lost animals performed, and thus benefit other inhabitants of their ecosystems. De-extinction is also almost irresistibly cool (come on! Bringing mammoths back from the dead?).

Much of the discussion about de-extinction has focused on the technical challenges of resurrecting extinct species, the problem of choosing which species to revive, and the danger that de-extinction could divert attention and resources away from badly needed programs to prevent further extinctions. These serious problems deserve careful consideration, and are well treated in Shapiro's book and elsewhere. But focusing on these problems can distract us from what may be the central risk of de-extinction: that its ecological effects could be large, and hard to predict and manage.

We have learned from biological invasions that putting new species into ecosystems can have large economic and ecological effects, sometimes positive and sometimes negative, but almost always difficult or impossible to predict or control. Familiar examples include rabbits in Australia; or zebra mussels, emerald ash borers, and chestnut blight in the US, among many others. The combination of large effects, low predictability, and irreversibility makes putting new species into ecosystems, including de-extinction, a risky enterprise.

As for any human activity that poses risks to the environment, proponents of de-extinction should be able to provide good answers to three questions: what are its likely effects?; what is the plan to prevent or repair unexpected damage?; and why should this project be done now, instead of being deferred?

The usual answer to the first question is that the species is being returned to the ecosystem in which it lived for many years, and will simply resume its former ecological roles. This answer fails on two counts. First, because we've been changing our world so rapidly, a de-extinguished species *won't* be restored to its former ecosystem, but to a different, sometimes radically different, ecosystem. Since the passenger pigeon was last abundant, its home in eastern North America has been transformed from forests to industrial farms, superhighways, and megalopolises; its human population has increased 5-fold; we've poured huge amounts of nutrients and toxins into the landscape; thousands of species from other parts of the world have become established, while others (like American chestnut) have dwindled or disappeared; and we are in the process of changing its climate.

Ecologists know that the setting into which a species is placed strongly affects its roles and impacts, so there is no reason to expect that passenger pigeon v.2.0 (or any other de-extinguished species) would simply re-assume its former roles. Experience with native North American species like white-tailed deer, Canada geese, coyotes, and Colorado potato beetles shows that the roles that these species play (and human valuation of those roles) changed radically as ecological and societal contexts changed.

The second objection to the naïve answer that a de-extinguished species would simply resume its former roles is that v.2.0 isn't the same as the extinct species. In all but a few of the cases that are being discussed, the organism to be released won't literally be the species that was lost, but rather a human creation that in some ways looks and acts like the lost species. This match might be pretty close, or merely superficial (e.g., a cold-hardy, hairy elephant in place of a woolly mammoth). Even small differences between v.2.0 and the original could cause large differences in roles and effects.

Again, experience with biological invasions shows that this isn't just a theoretical possibility. When two similar species of sparrow were released in North America, one spread quickly and became a widespread nuisance (the house sparrow), while its cousin never left the St. Louis area or caused problems (the Eurasian tree sparrow). The example of the common reed (*Phragmites*) is even more striking. Native strains of this species were a widespread but minor part of North American wetlands. When nearly indistinguishable Eurasian strains were introduced, they formed impenetrable thickets all across North America, crowding out native plants, damaging wildlife habitat, and disrupting nutrient cycles. Wetlands managers now spend millions of dollars each year to burn, herbicide, mow, dig up, and otherwise kill Eurasian *Phragmites* in North America. Organisms that look like one another and share genetic material aren't necessarily interchangable.

It is therefore wholly inadequate to assert that a de-extinguished species will merely resume its former roles, and not cause problems. Furthermore, research on biological invasions shows that it is very difficult to accurately predict the abundance and impacts of newly introduced species. Consequently, we can expect some predictions about the effects of de-extinctions to be wrong, so that some de-extinctions anticipated to be benign will cause harm. It is therefore important that a plan for controlling or repairing damage be in place before these new organisms are released. We routinely assess the likely impacts of oil wells, and require that they be built and operated responsibly, but also require spill-response plans, because we know that some spills will occur despite our best efforts. De-extinguishing species will be far less certain than drilling and operating oil wells, so "spill response" plans will be essential.

Again, the usual response given to this concern is naïve and unsatisfactory: "we removed the species before, and if it becomes a problem, we can simply remove it again". Recall how we removed the passenger pigeon the first time: by felling millions of acres of forests and slaughtering countless birds for market. Does anyone really think that society would allow immense tracts of forest to be cut and millions of birds to be killed (for a market that doesn't even exist today) if passenger pigeon v.2.0 turned out to cause problems? Today's (and tomorrow's) world is vastly different from the world from which these species were removed, so the mechanism of their original extinction probably won't be available as a control method.

Instead of the glib answer that "we did it before, so we can do it again", we need a credible plan to remove problematic de-extinguished species or manage their impacts. Who will decide whether control or eradication is necessary? At what point in the de-extinction process will this decision be made? What tools or methods will be effective in controlling the species or its problems? And who will pay for these efforts? We know from experience with invasive species that control or eradication of nuisance species can be costly and difficult (or impossible), so developing such "spill" plans will be challenging. However, they will be as indispensible for de-extinction as for oil drilling.

Finally, we should ask why de-extinction needs to be done as soon as possible, and not deferred. It is natural that we are eager to bring species back from the dead as soon as we can. This eagerness generates nearly irresistible momentum, but we should resist this momentum and deliberately choose the best time (if ever) to pursue de-extinction. This may mean waiting until we gather information needed to assess the benefits and risks of releasing these new organisms into nature and develop a control plan.

The recent debate about whether to allow fracking in New York is instructive. This new technology can provide large benefits (formerly inaccessible natural gas), but rushing into fracking led to large environmental problems. One approach is to defer fracking. There is no hurry in getting the gas out of the ground (it will still be there tomorrow!), and we can expect to develop better technologies and environmental controls if we wait a bit. Not "no fracking ever", but "no fracking today".

A similar argument could be applied to de-extinction. There is no urgency to most of the cases that are being discussed, apart from the personal desires of some people; no greater difficulty in bringing back a species in 2100 rather than 2030. On the other hand, rushing headlong into de-extinction exposes us to unnecessary risks just as rushing headlong into fracking exposed us to unnecessary environmental damages. So we deserve a good answer to the question not only of why we should bring back the passenger pigeon, but why we should bring it back today.

As an invasion biologist, it's hard not to hear echoes of old enthusiasms in the arguments for de-extinction. ("The introduction of a few rabbits could do little harm and might provide a touch of home…[to Australia]", "but that so fine a plant as this [water-chestnut], with its handsome leafy rosettes, and edible nuts, … can ever become a nuisance, I can scarcely believe".) Over and over, naïve proponents of introductions seduced us with stories about how new species would improve ecosystems and benefit humans in myriad ways, their enthusiasm unchecked by any rigorous assessment of possible impacts or control plans. Some of these introductions did bring benefits (although rarely the full benefits that were promised), but many caused large, lasting ecological and economic problems. This bitter experience should have taught us to be wary of the alluring stories now being told about de-extinction. If de-extinction is to proceed, we need serious consideration of its ecological effects, not romantic appeals to the imagination. Let's not repeat old mistakes with new species, no matter how technologically advanced their pedigrees.

Ecotone, 19 Feb 2016

The Beauty of the Earth

Theme and Variations on the Ocean

If you ran a tourist agency for time-travelling, intergalactic visitors, what attractions do you think would bring aliens to the Earth in 2010? As humans, I suppose that we'd think that our great buildings and art would attract visitors. And because ours is the blue planet, I'm sure that the oceans would fascinate tourists from the arid planets.

But I also think that our lakes would be a big draw. We live in a time when lakes are more numerous than at nearly any other time in the Earth's history – there are 300 million ponds and lakes on the planet, ranging from little weedy ponds to inland seas like the Great Lakes.

Why is this the Age of Lakes?

Lakes are the children of catastrophe. Given enough time, nature will fill a lake with debris, or drain it, so we can have lakes only if something, usually a disaster, creates new basins or blocks valleys. Landslides create lakes, as do earthquakes, volcanoes, and sinkholes. But the biggest manufacturers of modern lakes have been glaciers and people. The glaciers that covered the Hudson Valley (and much of Europe, Asia, and North America) scoured deep basins, bulldozed earth to dam river valleys, and scattered huge chunks of ice that left landscapes pocked with holes when they melted.

It is largely a result of glaciers that we live in the Age of Lakes. But in the last few hundreds of years, people have dug so many ponds and built so many dams that we now rival the glaciers as lake-builders. Today's abundance of lakes is only a temporary condition - many lakes have already disappeared since the glaciers began to shrink 18,000 years ago, and most of today's lakes will last for just a few thousand years more.

Three hundred million lakes, all of them a little like the ocean, yet each different from all the others – a sort of Theme and Variations on the Ocean – entice the human (and perhaps the alien) mind. Analyzing Theme and Variations may be the central purpose of any intelligent mind trying to make sense of a complicated world, and it is as fascinating to scientists as to musicians, painters, and poets.

A lake. A pond. An inland sea. A lake with water, brighter than air, over rippled sand. A quiet lake with bulrushes and water the color of weak tea. A pond with bulrushes and water lilies, its still surface shivered by a passing breeze. Crashing whitecaps and stinging, wind-driven sand along the shore of an inland sea. The hypnotic sway of bulrushes rocked by gentle waves in a small lake. Water lilies on a quiet bay.

This variation among lakes that attracts the artistic mind is also a valuable scientific tool. To see how algal production affects fish communities, we find a set of otherwise similar lakes that differ in greenness, and then count fish. If we want to know how land use affects lake productivity, we measure water clarity in lakes surrounded by different mixes of forests, farms or suburbs. Using this deliberately comparative approach, the first great centers of freshwater ecology sprang up a century ago in the lake districts of Wisconsin, and Sweden, and northern England, and built the foundation for modern freshwater science and management. Even though scientists now routinely use information collected by satellites and sophisticated laboratory equipment, and analyze data with powerful computers, we still rely on the old, dependable method of contrasting different kinds of lakes with one another.

So here's the deal I can offer you, for a limited time only (the next 10,000 years). Visit the intergalactically famous Age of Lakes without having to buy an expensive rocket ticket, endure the inconveniences of time travel, or suffer through a 3-million-year layover in a dingy spaceport near Alpha Centauri. Spend a morning watching the light and wind change the complexion of a nearby lake. Or spend a week every year on a different Finger Lake so you can discuss these marvels with a visitor from Pluto. Savor the Age of Lakes.

Poughkeepsie Journal, 18 July 2010

The Beauty of Ice

When my friend Natasja was talking about her recent trip to Antarctica, I was surprised to hear her say that she didn't know that ice was beautiful. Of course ice is beautiful – it's one of the most beautiful things that we get to see in our daily lives. It's just that most people only see ice in ice cubes. Looking for the beauty of ice in an ice cube is like looking for the majesty of the sea in a glass of water.

Ice is beautiful in its many forms. Probably the most familiar kind of ice (other than the ubiquitous ice cube) is pond ice. (Be careful if you're planning to go out and look at pond ice after reading this – you can fall through and get miserably cold or even die. I like to have at least 4 inches of good black ice under my feet before venturing out, or know that the water is so shallow that I can walk away if I fall through).

"Black ice" contains no air bubbles or snow, and forms on clear, cold nights. It isn't black at all, but so perfectly clear that nothing blocks your view of the inky darkness of the deep water beneath your feet. Walking on thin black ice is both unsettling and enchanting. Because the ice is so clear, it feels as though you're walking right on the glassy-calm water. This is unsettling because you know it's impossible, and you expect to wake from this dream and plunge into the cold water at every step. It's enchanting because you can see right down into the water and look at the plants and fishes swimming under your feet (a friend once watched a beaver swim between his feet). When you chip through black ice, it comes up clear and bright, like huge sparkling gems.

Not all lake ice is so benign. Late in the season, ice forms long vertical crystals the size and shape of a pencils or candles. This "candled" ice easily breaks along the junctions between the crystals, so it has no strength and is very dangerous. I once chopped through 18 inches of rotten candled ice near a creek mouth with just 3 strokes of an ice spud before retreating gingerly to a safer place.

What about streams? I often hear people say that moving water can't freeze, but moving water will freeze like any other water when it hits 32 degrees. Once it gets below 39 degrees, water actually gets lighter as it gets colder. As a lake cools on a still winter night, the coldest water floats on the top, where it gets colder and colder until it freezes. For a lake to freeze on a still night, only that top skim of water needs to cool to the freezing point. The water movement in streams keeps such a skim of cold water from forming, so all the water in the stream needs to cool to 32 degrees before it freezes.

When streams do freeze, they present a most unearthly scene. If you go down to a stream the morning after a bitter cold night, you'll see the water steaming. Long needles of ice crystals (called "frazil ice") will be forming all through the water. These crystals are sticky, and pile up like frigid pillows on stones and logs in the riffles, instead of forming a solid sheet on the water's surface.

Although you may not think of it as ice, the frost that forms on windows is one of the most beautiful forms of ice. When I was in college, a building on campus had a 2-story glassed-in lobby. On the coldest mornings, those panes would be frosted with feathery plumes taller than a man, as if the lobby had been paneled in etched silver plate. You can see smaller versions of such striking scenes on your own windows.

I think what surprised Natasja about the ice she saw in Antarctica was that it was bright blue, not white or dull grey like an ice cube. Pure ice is optically very much like unfrozen water, so if you see thick, pure ice (like in a glacier or an iceberg), it will be disconcertingly blue, just like the sea.

You may not be lucky enough to see a blue glacier this winter, but you can get out some fine cold day this winter to look at a frozen pond, or a steaming stream filling with frazil ice, or even just the frost on your window. Ice is too beautiful to ignore.

Poughkeepsie Journal, 15 January 2012

See the World

We see so little of the world that we live in. I was reminded of this yesterday when I visited Tivoli, where 17-year cicadas have emerged in great hordes. The sounds of the cicadas filled the air, and fat, red-eyed bugs clung unsteadily to leaves or wobbled through the air. These insects emerge, take over the world for a few weeks, and then disappear for another 17 years.

Except that they don't. These insects are with us all the time, it's just that they spend 16.9 years in hordes underground, living with the blind worms in the secret life of the soil, dreaming their cicada dreams of sunshine and flight. They don't disappear, they just drop out of our field of view.

They're not the only parts of our world that flicker into view for a little while, and then "disappear". For a week or two in late April, the forests of the Hudson Valley seem just filled with shadbushes, lit up like Christmas trees with their white flowers. Once they're done blooming, though, it's hard to find a shadbush – it's as if they have vanished.

When it was really wet a few summers ago, my wife and I went into the woods looking for mushrooms. And boy did we find them – dozens of kinds of mushrooms in all sorts of colors and shapes that I would have said weren't found in nature. Graceful jet-black oars, cinnabar funnels, cheerful lemon yellow jelly-balls, broad fawn parasols, yellow mushrooms that bled blue ink when you touched them. It was as if a candy designer on LSD had chosen the fungi for this woods. Although we rarely see them, these bizarre fungi are here all the time, growing quietly in the soil and waiting for just the right conditions to pop up and startle us.

Thinking about all of the pieces of the world that come into our view for just a brief time made me reflect on the pieces that never come into our view. There are many such pieces – things that are too small to see, like the innumerable creatures of the soil; things that come out only at night, like the flying squirrels that are so common locally, but which most of us never get to see; things in places where we never go, like the strange life of the ocean trenches; things that are altogether invisible, like the greenhouse gases emanating from a soil; and perhaps most common, things that we just never bother to look at.

One of the privileges of being a scientist is that we have a license to look for all of the unseen parts of our world. (This sounds exciting, but doing science doesn't always feel that exciting. My friend George McManus once described scientific research as "Long periods of tedium broken only by occasional episodes of intense disappointment".)

When scientists see what no one has ever seen before, sometimes we see things that are fundamentally important to people, like rising carbon dioxide concentrations in the atmosphere, or the spirochete that causes Lyme disease. Sometimes, we see things that are just plain fascinating, like the 7-foot long tube worms that live along deep-sea vents, and which have no digestive tract, but are fed by symbiotic bacteria that in turn feed on hydrogen sulfide, a chemical that is a deadly poison for most life (what writer of fiction could think of such things?). And sometimes, as suggested by George's quote, we see things that aren't especially interesting or important. But unless we look, we don't know what our world actually looks like.

But you don't have to be a licensed scientist to expand your view of the world, and see the unseen. Anyone who wants to can see a little more of the world. Wade into a creek and look under the rocks. Go into the woods after a rain. Look really closely at a handful of soil. See the world.

Poughkeepsie Journal, 21 July 2013

Sycamores

I always have a hard time choosing my favorite tree, but today I think it must be the sycamore. When I see the winter sunlight shining on their lovely white trunks and arms, all flecked with tan and brown and olive, it's hard to think of a more beautiful tree.

But it's not just what I see when I drive by these trees – it's what I know I would see if I took the time to get out of my car and walk through the sycamores. Sycamores are lovers of creeks and rivers, so where there are sycamores, there are flashes of spotted trout in cool green pools, ranks of deep scarlet cardinal flowers standing on the river bank, quiet V's made by swimming muskrats and minks, and shrubs full of bright migrating birds. And because these are just about my favorite parts of the world, I think that sycamores must be my favorite trees.

Sycamores are such faithful friends of creeks and rivers that it is easy to trace the course of streams just by following lines of sycamores that snake across the landscape. In the Midwest, where I grew up, twisting lines of sycamores ran behind the straight lines of fields and barns before fading off into the distance, thin veins of wildness in an otherwise domesticated countryside.

Young sycamore trees as slender and graceful as young girls sprout on the banks and sandbars of streams. Although there is plenty of sunshine and water in these streamside nurseries, there is also deadly peril. Most of these young trees will be killed when the sandbar or stream bank in which they root is washed away by the next flood, or they are battered to pieces by logs or ice driven by these floodwaters.

But for a lucky few of these young sycamores, the stream will shift its course to nibble away at the opposite bank, or redirect its floodwaters into a new channel and leave the young tree alone. Spared from the destructive power of the stream and nourished by the rich soils of its floodplain, sycamores are one of our fastest-growing trees, and can reach an enormous size. Along with the tulip tree, the sycamore is the largest hardwood in our eastern forests, reaching more than 150 feet tall, with a span of 200 feet and a trunk almost 15 feet in diameter. Large trees often are hollow, and the early European settlers in the Ohio Valley sometimes set up their first homes in large, hollow sycamores before they built proper houses.

These big, beautiful, spreading sycamores can visually define a landscape, whether the downtown of a small village, the back boundary of a farm field, or a riverbank. And I'm not the only one who has been impressed by sycamores. All across the range of this tree in eastern North America are place names like Sycamore, Illinois, Sycamore Creek (of course), and Buttonwood (a reference to the characteristic pom-pom-shaped fruits of the sycamore).

But what good are sycamores? Unlike the sugar maple or apple, they don't produce food for us. Although sycamore wood is used for butcher blocks, furniture, musical instruments, and other purposes (and the quarter-sawn wood has a beautiful lacy pattern), it isn't especially valuable or widely used when compared to local timber species like black cherry, red oak, or black walnut.

So I suppose that the main "good" of sycamores to us is their beauty. And just as I sometimes prefer the useless beauty of poetry to the utility of a dishwasher repair manual, sometimes I prefer beautiful trees to useful ones. And today I think I prefer the sycamore.

Poughkeepsie Journal, 13 March 2014

The Other Blue Planet

Like many freshwater scientists, I suffer from Cousteau envy. To me, fresh waters are fascinating, but they get no respect from the public. No one talks about the hour-long TV special they saw about freshwater life ("Alors, now Philippe lowers ze bathyscaph into ze creek"), all the little kids I meet want to grow up to be marine biologists (not stream ecologists), and as far as I know, Pixar has no plans for "Finding Wabash", the touching story of a small catfish's journey to reunite with his family in a Midwestern river.

And it is true that there are no coral reefs in fresh water, nor any octopuses, squids, starfish, or sand dollars, and hardly any whales, dolphins, or sharks. These and many other captivating creatures live only in the ocean, so we must go to the ocean to see them.

It may surprise you to learn that fresh waters contain a rich diversity of life, by some measures even greater than the ocean's. Even though fresh waters cover only 1% of the Earth's surface (compared to the ocean's 71%), they support almost 10% of all known species on our planet, and fully one-third of known fish species. In terms of numbers, this is 125,000 known animal species in fresh water, and probably tens of thousands more that haven't yet been discovered and named.

This great diversity of species arose in part because of the great diversity of freshwater habitats, from icy mountain streams to woodland pools to underground streams and caves to wide muddy rivers to the Great Lakes. Each of these diverse habitats supports its own distinctive set of species.

But even more important, fresh waters are "islands" surrounded by a sea of land. Fish and many other kinds of freshwater animals cannot easily cross from one river system to the next, meaning that different species have evolved in different river systems. In ancient landscapes like the American Southeast, each river system has its own species of fish and shellfish, adding up to a very large number of species worldwide.

But this focus on numbers can distract us from what is really interesting about freshwater life – the species themselves. What sorts of things live in fresh waters? To begin with, fresh waters contain quite a few creatures that you probably thought lived only in the ocean. Sponges are common in our lakes and streams, and jellyfish even crop up in local ponds and lakes from time to time. And although we may think of shrimp and crabs as ocean-dwellers, hundreds of species live in fresh waters, mainly in the tropics.

Whales and dolphins do live mainly in the ocean, but there are a few freshwater species, and they are interesting ones. My favorite is the Irrawaddy dolphin, an endangered animal that has learned to fish cooperatively with people. Burmese fishermen call these dolphins over to their boats; the dolphins then chase fish towards the boat where the fisherman nets them, sharing the catch with their dolphin helpers. Another freshwater dolphin, the baiji, just went extinct because its only habitat, the Yangtze River in China, has been so badly degraded by people.

Fresh waters also contain 700-pound stingrays, 12-foot-long catfish, 10-foot long armored garfish, mussels that seduce fish into carrying their larvae, lily pads large enough to support the weight of a child, hundreds of kinds of turtles, electric eels, archer fish that spray water onto leaves to knock bugs into the water and archer mussels that make a fountain of water to attract fish, 7-pound crayfish, freshwater "oysters" that cement themselves to river stones and are called "crocodile eggs" by locals, crocodiles, a nearly countless variety of tiny, bright fish, and about a thousand other things that are as interesting as anything you'd see on a coral reef.

So by all means, go snorkeling around coral reefs, and enjoy those fascinating TV documentaries about the oceans. The ocean is magnificent and full of amazing, beautiful life. But also try to take some time to appreciate freshwater life. Locally, my favorite spot for a refreshing summer snorkel is the Delaware River between Narrowsburg and Port Jervis, which is a fine, clear river full of life, including lots of fish, aquatic insects, shellfish, and freshwater sponges. And no sharks!

Poughkeepsie Journal, 25 Oct 2015

New Insights about an Old Fish

In books and movies, it's common to discover that someone who we thought of as a good guy is really a villain, or vice versa – think of Severus Snape, who appeared to be Harry Potter's nemesis, turning out to be his most loyal protector, for example. When this sort of thing happens in real life, it can be a little disorienting.

As a long-time angler and ichthyology student, I thought I knew a lot about the bowfin. But recent developments have shown that much of what I knew about this fish was wrong. I learned as a kid that bowfins are "trash fish" – not good for eating or anything else. They are supposed to taste like "mud-soaked cotton". What's worse, bowfins are voracious predators, so we always imagined they were eating all of the best fish before we could catch them. Like many other anglers, I was taught to kill any bowfins that I caught, to protect valuable sport fish populations. If ever there was a useless fish, it was the bowfin.

A bowfin. Credit: Unknown author, Public domain, via Wikimedia Commons.

I learned in ichthyology class that the bowfin is a "living fossil", the single surviving member of a line of fishes that was already around more than 100 million years ago. Something very like our modern bowfin was swimming around in prehistoric swamps between the legs of dinosaurs. Bowfins also have a number of interesting traits: they can breathe air, they ferociously guard their young, and they have a skeleton unlike any other modern fish.

But it turns out that I didn't know the bowfin very well. A careful analysis of bowfin DNA and anatomy that was just published shows that there isn't just a single species of bowfin, as has been so long assumed, but two, or maybe even four. The different species, though similar in appearance, each live in different parts of the United States and Canada. Probably only one of these species (*Amia ocellicauda*, which doesn't yet have a common name) lives in the Great Lakes region. We don't yet know whether the different species have different habits or abilities, or perform different roles in their ecosystems.

This discovery reminds us that we still have a lot to learn about the natural world. There still are secrets waiting to be uncovered, even about a large, familiar fish that lives in one of the best-studied regions of the planet. So it's best to be a little humble about our understanding of the natural world. No matter how sophisticated, our knowledge usually isn't the final truth.

The other recent news about the bowfin is that this most useless of fishes has turned out to be very valuable. How is this possible? Although bowfin meat is unpalatable, their eggs are now being made into delicious caviar. Bowfin caviar (sometimes dressed up as "Cajun caviar" or "choupique caviar") costs about $10 an *ounce*, and is at the forefront of a movement to develop a sustainable American caviar industry from our native fishes.

As the bowfin shows, the value of a species can change dramatically from one time to another. If we had found in 1975 a way to kill all of the bowfins, probably nearly everybody (except for a few wild-eyed ichthyologists) would have been in favor of doing just that, and we never would have discovered the value of bowfin caviar.

The answer to "what is species X worth?" depends as much on human ingenuity and current fashions as on the species being judged. We may think that we know what a species is worth today, but there is no way to know what it will be worth tomorrow. This means that we should be very cautious when making irreversible changes to the natural world, like destroying habitats or extinguishing species.

So as we learned for Snape, don't judge the bowfin (or any other species) too quickly.

Great Lakes Echo, xx December 2022

Fresh Waters and Their Conservation

The Ingredients for Making a Flood

Last week, heavy rainfall and wet soils combined to create floods throughout the mid-Hudson Valley. Standing water closed more than 60 roads, including parts of the Taconic Parkway. According to the United States Geological Survey, it was the 3rd largest flood on Wappinger Creek since 1928, and the 5th largest on the Ten Mile River since 1930. At its peak last Monday evening, Wappinger Creek had risen 13 feet above typical summer levels, and was carrying 87,000 gallons of water over the dam at Red Oaks Mill *every second*. Last week's flood was impressive, but it didn't set a record. Based on past records, we can expect to see a flood of this size every 15-30 years.

The ten largest floods in Wappinger Creek at Red Oaks Mills since 1928. Data courtesy of the United States Geological Survey.

Date	Peak flow (gallons per second)
August 1955	139,500
September 1938	119,250
April 2007	87,000
June 1973	78,000
October 1955	61,275
May 1984	58,725
January 1949	57,975
March 1940	53,175
March 1936	51,600
October 2005	49,440

What determines the size of a flood? To begin with, the harder it rains, the bigger the flood. However, peak flows last week were almost twice as large as in the flood of October 2005, even though we had much less rain (5.2 inches in two days) than in

October 2005 (8 inches in a day, and 13 inches in a week). Rainfall alone doesn't determine the size of a flood.

Several other factors contribute to flood severity. Actively growing plants take up about half of the rainfall in a typical summer. As a result, it takes more rain to cause a flood in summer than in winter or spring. The weather preceding a storm can also impact flooding. Lack of growing vegetation and wet ground from earlier rain and snow contributed to the severity of last week's flood.

Human activities also contribute to flooding. Impervious surfaces such as parking lots, roadways, and roofs cause water to run rapidly into streams and intensify flooding. When careless construction or land management causes excess sediment to enter streams, stream beds fill up and become more prone to flooding. As was apparent to anyone who was out driving in last week's flood, artificial barriers to water flow (inadequate culverts, roadways) can cause local flooding.

It is normal for streams to flood. Streams mold their channels to carry the water and sediments that they receive from the landscape. A typical stream in our region has a floodplain that contains water periodically during wet periods. Streamside plants benefit from the rich soils deposited by floodwaters. Fish and other animals that use floodplains for feeding or breeding also depend on this regular cycle of flooding. Preventing streams from rising into their floodplains can cause ecological damage and increase flood severity downstream.

Floodplains and wetlands help insure against severe floods. By absorbing then slowly releasing water, these areas allow floodwaters to soak in and work their way downstream gradually, instead of arriving in a single devastating pulse. Economic damages from flooding can be reduced if homes and businesses are kept away from floodplains and streambanks. Uses such as hiking trails, pastures or recreational fields may be appropriate for floodplains, as long as we recognize that they will occasionally flood.

Although it might seem logical to head off floods by dredging or straightening stream channels or building levees, such projects can actually worsen future flooding. By preventing water from spreading out onto the floodplain and speeding the movement of water downstream, these projects can worsen downstream flooding – helping you but hurting your neighbors. These projects can also destabilize stream channels, causing erosion, sediment problems, and ecological damage for years.

Problems are not limited to the project area, but can extend for long distances up and downstream.

Preventing flood damage thus requires management of entire watersheds, not just stream channels. Dutchess County is fortunate already to have management plans for Wappinger and Fishkill Creeks, which could serve as the basis for such planning.

Poughkeepsie Journal, 22 April 2007

The Source of the Hudson River

One of the best known and least helpful facts about the Hudson River is that its source is Lake Tear of the Clouds in the Adirondacks. Although it's true that Lake Tear of the Clouds is the source of the Hudson in the geographers' sense of the word (the highest-elevation stream that feeds into the river), it isn't the source of the Hudson in the way that most of us think of "source" (the place where its water comes from). The true source of the Hudson is the myriad of tiny streams that arise in the forests of the Adirondacks and the Catskills, in the farm fields of Orange County, in the malls along Route 9, and in your back yard.

These little streams, collectively known as headwaters, play a major role in shaping the character and value of the larger streams and rivers that they feed. Most of the water in the Hudson got there by passing through headwater streams. Between the time that a raindrop falls to the ground and the time that it reaches the open ocean, it spends a great deal of its time in headwater streams. As a result, these little streams not only provide the water that fills the Hudson and other large streams and rivers, but they also change the quality of that water. Undamaged headwater streams can remove nutrients and other pollutants, retain sediments, slow down flood waters and thereby reduce flood severity, and keep streams cool during the summer. On the other hand, drains and pipes that run from parking lots swiftly carry rainwater, oils, and other pollutants downstream, thereby contributing to floods and pollution in larger streams and rivers.

In addition to protecting the ecological value of larger streams, undisturbed headwaters are themselves important habitats. They support a rich community of plants and animals, many of which live only in headwater streams. In our area, plants like watercress and the peculiar red alga *Batrachospermum*, and animals such as brook trout, sculpins, and two-lined salamanders make their homes in headwater streams. Many other species of fish move into even the tiniest of headwaters from larger streams for part of the year to take advantage of rich feeding grounds, nursery areas, or cool water. Animals living in the surrounding landscape, such as various birds and mammals, find food, shelter, and dispersal corridors along headwater streams.

Despite their ecological value, headwater streams often are neglected or damaged. They typically receive little legal protection, and many headwater streams don't even appear on maps. As a result, they are subject to "the death of a thousand cuts" as people straighten their channels, dump trash into them, pave their banks and surrounding areas, remove streamside vegetation, and use harmful chemicals in and near them. Damage to these tiny streams inevitably leads to problems in larger streams and rivers, as sediments choke their channels, nutrients and warm waters lead to outbreaks of undesirable plants and animals, and floods become more severe downstream.

We can protect these little streams and the larger rivers that they feed by taking a thousand small, simple actions in our own back yards and communities. We can try not to disturb the beds or banks of streams, and keep construction activities and impervious surfaces – such as blacktop, concrete, or paving – away from the immediate vicinity of the stream channel. We can plant or protect vegetation along small streams, and keep potentially harmful chemicals such as pesticides and fertilizers out of the streams and surrounding areas. And we can begin to take even the smallest streams into account when we make local planning decisions.

Abundant, clean fresh water is a valuable resource. We can try to clean it ourselves at great expense, or we can let nature clean it for us at little cost. But if we want nature to do this work for us, we have to protect the headwater streams that are her tools for the job.

Poughkeepsie Journal, 2 September 2007

No Free Lunch with Hydropower

Many people make the mistake of thinking that hydroelectric power is an environmentally benign source of energy. It is renewable (unlike oil), doesn't generate noxious waste (unlike nuclear power), and wouldn't seem to produce harmful greenhouse gases (unlike coal). As a result, hydropower is often featured in packages of "green" energy offered to concerned consumers, and conferences like the one recently organized by Congressman Hall (*Poughkeepsie Journal*, 18 November 2007) frequently tout the potential of hydropower as a clean energy source for the future.

But hydropower, like most energy production, causes serious environmental problems. A river that has been cut to pieces by hydropower dams acts no more like a wild river than a bucket of The Colonel's Extra Crispy acts like a living chicken. Hydroelectric dams prevent fish and other species from moving freely along rivers, and isolate populations of river-dwelling animals into small segments between dams. The magnificent salmon runs of the Pacific Northwest have been decimated by hydropower dams, and attempts to restore these runs have been politically acrimonious, expensive, and so far unsuccessful. Similar problems, although less widely publicized, have occurred wherever dams have been built, damaging or destroying populations of sturgeons, shads, and other valuable migratory fish. Once dams are in place, attempts to undo the damage they cause by installing fish ladders, altering dam operations, or even removing the dams altogether have been complicated and expensive, have caused their own environmental problems, and ultimately often have been unsuccessful.

Hydroelectric dams also change habitat conditions for long reaches up- and downstream of the dams. The sediments that formerly nourished floodplains and deltas below the dam are trapped in the reservoir, leading to channel and coastal erosion for many miles downstream. The unnatural flows created by hydropower plants stress or even eliminate the animals that were adapted to the natural rhythms of river flows. And of course, the pond-like habitat provided by reservoirs is unsuited to most river-dwelling species, and has aided in the spread of undesirable invasive species. As a result of these ecological changes, dams have led to the extinction of more species in the continental United States than any other single cause.

A further problem with hydropower is that it may actually cause worse climate change from greenhouse gases than burning fossil fuels to produce an equal amount of electricity. This surprising result occurs because the ooze that accumulates at the bottom of the reservoir above a hydroelectric dam provides ideal conditions for bacteria to make methane, a greenhouse gas that is 21 times more potent than carbon dioxide. It has been estimated that the methane produced by some tropical hydropower reservoirs produces 3-4 times as much greenhouse warming as would have been produced simply by burning fossil fuels to produce electricity! So in addition to destroying habitat, hydropower produces greenhouse gases.

Of course, other methods of energy production cause serious environmental problems too, and hydropower certainly will be part of our energy mix in the future. However, when we evaluate the potential of various energy sources to contribute to this mix, we should take a hard look at their environmental costs, and not overlook the real costs of supposedly green technologies. When we consider the full environmental costs of any method of energy production, whether for hydropower, nuclear power, ethanol production, or coal-burning, I suspect that we will see that energy conservation is by far our greatest bargain.

Poughkeepsie Journal, 9 December 2007

The Mussel in the Rainforest

I.

This past summer, we unexpectedly found a very rare freshwater mussel in one of the small tributaries of the Housatonic River basin – a species that hadn't been seen in the region since 1843. When a reporter asked me how I felt when we found the mussel, I was of course completely unprepared for the question, and stammered out some sort of weak response. But now that I've had the time to consider the question, I guess I'd say that it felt like we had unexpectedly come across a little piece of the rainforest still standing amid the farm fields and suburbs of southeastern New York.

II.

When Europeans first came to the streams and rivers of eastern North America, they would have seen dozens of kinds of catfish, some as small as your finger and some as large as your uncle, an armored needlefish that grew up to 10 feet long, which they would call the alligator gar, shoals of silvery shads, and dozens of kinds of darters and minnows – tiny fish so colorful that they would look at home on a coral reef. If they had looked closely, these early explorers might have noticed that the rivers contained hundreds of species of freshwater mussels, some as large as a dinner plate, and as many kinds of crayfish. None of these animals would have been familiar to the Europeans, because with just a handful of exceptions, none of these animals lived anywhere other than North America. Indeed, many of these animals lived in only one or two rivers, a restriction that would unhappily contribute to their later demise.

The streams and rivers of eastern North America, especially the Southeast, were the freshwater equivalent of the tropical rainforests or coral reefs. To a degree matched only by a few ancient lakes like Baikal and Tanganyika, and a few rivers such as the Amazon and Mekong, our streams and rivers supported an enormous array of fish, turtles, shellfish, and other species that lived nowhere else on Earth. Every schoolchild knows that rainforests and coral reefs are filled with wonderful plants and animals that live nowhere else on Earth, that have fascinating habits and adaptations, and that are imperiled by human activities. But very few people, even those who grew up among the remnants of the great southeastern center of diversity, know about its remarkable diversity and peril.

III.

Not much now remains of the great southeastern "rainforest". All of its principal rivers – the Ohio, Tennessee, Alabama, and Cumberland – were dismembered and converted into pools and reservoirs by a series of hydroelectric and navigational dams. Pollution from factories, mines, cities, and careless land use practices killed countless animals outright, or made stream and river habitats unsuited to the needs of their former inhabitants. Dredging, channel straightening, and dike-building destroyed more habitat, and blocked animals from moving freely between rivers and their floodplains, which were vital nursery areas for many species. And poorly regulated harvests of fish and shellfish, or careless introductions of species like carps and zebra mussels from other parts of the world have imperiled native species.

As a result, many species have disappeared forever from our streams and rivers (and from the planet). Biologists have documented the extinction of at least 60 species of fish and shellfish from eastern streams and rivers (by way of comparison, no more than 7 species of birds and mammals from the continental United States have gone extinct), and hundreds of additional species are so critically imperiled that they may disappear during our lifetimes. And these are just the species that we know about – while biologists were watching fish and shellfish disappear, smaller creatures were slipping quietly into oblivion, destroyed by humans before we even discovered them.

IV.

It can be hard to see the rainforest as something special when you've lived there all your life. The St. Joe becomes just another muddy river, the same as every other river in Ohio, running behind gas stations and ball parks, and coming up to flood the corn fields every spring. We need to see Ohio as the early explorers did, running with clear streams that were filled with bright fishes. Then, we need to see the muddy old St. Joe as a little bit of this ancient Ohio, still improbably supporting the world's embattled last populations of catspaw and rabbitsfoot mussels and sand darters that once ranged across the state. And if we hope that the Brazilians and Filipinos will accept their responsibilities for protecting the rainforests and coral reefs that are part of our shared inheritance, we must also hope that we can understand and accept our responsibility for protecting the streams and rivers that are part of that same legacy.

V.

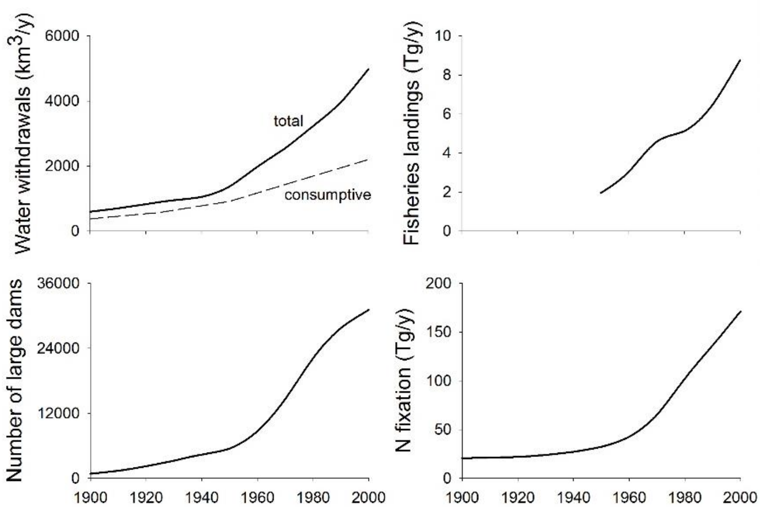
So when the reporter asked what it felt like to find that rare mussel, I should have said: it felt like I had glanced into the little patch of woods behind the Wal-Mart and seen the bright flash of a macaw's wing. It felt like I had peered into the murky waters of a harbor somewhere and seen through the oil sheen a school of angelfish swirling around a single coral head, somehow miraculously intact. But I've never been that quick with an answer.

Millbrook Matters, 2 June 2008 (reprinted in the Poughkeepsie Journal, 29 June 2008)

The Forces That Destroy Freshwater Ecosystems

If you ever saw "Star Wars," you'll remember the trash compactor scene: trying to escape from the Imperials, Luke and his friends duck into what turns out to be a trash compactor, where things go from bad to worse. First, some alien creature tries to eat Luke, and then the walls start closing in, threatening to smash them flat. Only R2D2's quick thinking saves the day.

I've been thinking about that scene a lot lately while working with a scientist from Hong Kong on an analysis of biodiversity in the world's fresh waters. As part of that analysis, we've put together a little summary of human demands on the world's fresh waters.



When I look at these four graphs, I see the four walls of the trash compactor closing in on our freshwater ecosystems. Human demands on freshwater are now so large that we capture half of available water flowing to the ocean, and several of the world's greatest rivers – the Nile, the Ganges, the Colorado, among them – no longer even flow to the ocean during dry periods. Tens of thousands of huge dams and almost a million small dams fragment our river systems, blocking fish migrations, and preventing ¼ of the sediment that they carried from reaching the sea. Consequently, river deltas on the Mississippi, the Ebro, the Nile, and other rivers are eroding because they are being starved of sediment, and coastal fisheries are suffering from an imbalance lack of key nutrients.

Pollution now extends into even the most remote corners of our planet, and has reached unprecedented levels, as shown by the enormous increase shown in nitrogen inputs to the world's ecosystems. We've overfished many lakes and rivers to the point that large-bodied fish species have vanished, leaving only small and less desirable species, to which we are now turning our hungry attention. And just like in the trash compactor, there is even a monster in the room. Careless introductions of invasive species such as water hyacinth, zebra mussels, and Nile perch have driven native species to the edge of extinction, and degraded our freshwater resources.

It is pretty clear from the shape of the lines on the graphs that human pressures on fresh waters will rise steeply as our populations and economies grow in the next few decades. Already, inadequate water causes great human suffering in many parts of the world. As human populations grow, water shortages will spread and intensify, probably leading to political instability and possibly war. In our struggle to obtain water for drinking, agriculture, industry, and hydroelectricity, it seems very likely that we will fail to leave enough water for freshwater ecosystems and their inhabitants, extinguishing many of the 10,000-20,000 freshwater species already endangered through human activities.

This is the part of the article where the writer is supposed to offer a solution, a way out of the trash compactor, but I'm afraid that I'm no R2D2. Somehow we must deal with pressing human needs for fresh water in an unfair and politically contentious world. Somehow we must keep in mind the needs of the irreplaceable and splendid natural world that we have been given, and remember to take into account the enormous benefits, both tangible and intangible, that it can give us if we manage it wisely. Somehow we must deal with these problems in a thoughtful way, before crisis and disaster force us into hasty, ill-considered actions that are poor choices for both humans and our world. And somehow we must do all of this in the next few years, before the walls of the trash compactor smash our fresh waters beyond recognition.

These are really difficult problems, and I can't offer an easy solution today, just a warning – look out, the walls are closing in. Let's hope The Force is with us.

Poughkeepsie Journal, 18 January 2009

The Mysterious World of Ground Water

Few ecosystems on our planet are as mysterious and misunderstood as ground water. Despite the fact that 60% of us in Dutchess County drink ground water every day, and all of us eat food that was irrigated by ground water, very few people know where it comes from, where it goes, or that ground water is full of life. Because we are so misinformed about ground water, we don't always manage this valuable resource wisely.

All ground water originates as rainwater or snowmelt that soaks into the ground. Although people might imagine rushing underground rivers, ground water typically trickles slowly between grains of sand or through cracks in the bedrock. Only in areas of limestone rock, where caves are common, does ground water often flow through underground stream channels. Where water in a river or creek might travel 5 or 10 miles in a day, daily groundwater flow is measured in inches to feet. This means that deep ground waters may have originated from snow that fell when mastodons roamed North America. It also means that if we overpump or pollute ground water, it may take many centuries for the pollution to be flushed away, or the aquifer to refill.

The fact that the ground water we drink has to run through our yards, fields, and roadways before reaching our wells ought to make us very careful about how we treat the landscape. Some pollutants are held tightly in the soil or destroyed by soil bacteria before they reach our wells, but other pollutants travel unchanged to our wells. The short lesson: don't put something on your lawn or field that you wouldn't want coming out of the tap that you or your grandchildren will drink from. Here in the Northeast, our ground waters are commonly contaminated by excessive salt (from road salt), gasoline from leaky storage tanks, nitrate (from sewage and fertilizers), or industrial chemicals (like the tetrachloroethene that has contaminated wells in southern Dutchess). Once contaminated, ground water is difficult to clean up, and it's usually expensive and awkward to find alternative sources of water to replace contaminated wells.

Just as water flows into the ground from the surface, ground water emerges back to the surface in the form of springs or seeps. This ground water supplies most of the water that flows in our streams during dry periods – this is why streams continue to flow for a long time after the last rain. Because deep ground water is around the average annual temperature, these inputs keep streams cool enough to support trout through the summer and warm enough to keep from freezing during the winter. If we pump too much ground water from our wells, the water table will drop, and springs and small streams will dry up and disappear. This has already happened over large areas of the Great Plains and arid West as a result of excessive pumping. So ground water and surface waters (streams, lakes) are not separate, but part of a single hydrologic system.

Perhaps most surprising, ground water isn't sterile, but is full of life. Ground waters near the Earth's surface or in limestone bedrock contain a rich variety of special animals that do not occur in surface waters, including tiny crustaceans, worms, and snails; there is even a tiny blind catfish named *Satan* in Texas aquifers. Deeper ground waters contain only bacteria, but these bacteria can live at extraordinary depths and survive under remarkably inhospitable conditions. Scientists have found specialized bacteria as deep as three miles below the Earth's surface, living happily at 140 °F without any oxygen, and we don't yet know how deep the groundwater ecosystem extends.

Ground water is both an extraordinarily valuable resource and a fascinating ecosystem, a familiar part of our everyday life and a dark place whose inhabitants are scarcely known to us. Better knowledge of this ecosystem and careful planning will preserve this valuable resource for future generations.

Poughkeepsie Journal, 1 March 2009

Don’t Ream the Stream

The Hudson Valley was hit hard by repeated flooding over the past few weeks. Homes, businesses, farms, roads, and bridges all were badly damaged by near-record flood waters. Now we’re hearing calls to take action to prevent damages from future floods, and in particular to dredge or hem in streams with walls and levees.

Although these projects seem like just common sense, centuries of similar responses have caused large and long-lasting ecological damage, wasted money, and ultimately failed to reduce flood risk (or even made it worse!). As taxpayers and owners of the natural resources in and around these streams, we should ask four questions about flood-control projects before any equipment is put into the stream.

What is the problem?

It may seem obvious that flood damage is just caused by a badly behaved stream. In fact, flood damage can result from many factors, including severe weather, building in floodplains, streams that are blocked or filled with sediments, too many impervious surfaces (parking lots, houses) in the watershed, and alterations to the stream channel itself (channel straightening or levees, for example). All of these probably contributed to recent flood damages.

Unless the causes of damage are correctly diagnosed, it is unlikely that effective treatments for reducing flood damages can be prescribed. For example, dredging a stream channel won’t prevent flood damages that arise from putting a building into harm’s way on a floodplain.

Will the treatment be effective?

Just as in medicine, different treatments are available to reduce flood damages, which differ in effectiveness, cost, and severity of side effects. A treatment should be pursued only after an analysis shows that it will actually reduce flood damage, is worth the money, and won’t cause unnecessary ecological or property damage.

For instance, if flood damages result from a channel that has filled up with sediment, treatment might consist of controlling erosion in the watershed, removing sediment from the stream channel, or both. If careless land use is filling streams with sediment, simply removing sediment from stream channels isn’t an effective long-term treatment any more than one-time liposuction is an effective treatment for chronic obesity.

Does the treatment have harmful side-effects?

Some of the treatments that have been proposed for local streams are worse than ineffective – they may actually increase flood damage. Treatments such as channel straightening and levee-building often make flooding worse downstream, and can accelerate bank erosion for miles both upstream and down.

Projects may cause severe ecological damage, too. Streams and rivers are complex and sensitive ecosystems, and inept flood-control projects can cause ecological damage that lasts for decades and extends miles beyond the project area. It is therefore essential to assess the likely ecological consequences of a project, and to choose a project design that minimizes damages.

For instance, I've heard people suggest that we need to remove boulders, logs and other "obstructions" from our streams. What these people call "obstructions" a trout would call "habitat".

Is it worth the money we'll pay?

Stream improvement projects can be expensive, and you and I are paying the bills, so it's important to know that we're getting our money's worth. How often will treatments like dredging have to be repeated? Is the proposed treatment really the cheapest way to reduce flood damage over the long term? Especially in this time of tight budgets, we should demand that any public money devoted to stream improvement be well spent.

It is surely a good idea to look for ways to reduce future flood damages in the Hudson Valley, and I know that some of the solutions that have been suggested seem to be just common sense. However, a long, sad history shows that well-intentioned "seat-of-the-pants" stream management in North America and Europe has wasted billions of dollars, badly damaged ecosystems, and actually worsened flood damage in many cases. We and our streams deserve a more careful approach.

Poughkeepsie Journal, 23 October 2011

The Rain in Spain Runs Mainly Through the Floodplain

Our homes are filled with things that we use only on rare occasions, but still really need. Thank about fire extinguishers, aspirins, automobile jacks, or plumber's helpers. We use these objects less than 1% of the time, but our lives would be unpleasant without them.

Likewise, streams use their floodplains just once in a while, but they (and we!) really need them. Why does a stream need a floodplain? As I write this, it has been sunny and dry for several days, and the small creek running behind my office is maybe 15 feet wide and calf-deep, fed by the ground water that has slowly percolated through the soil from past rain and snow. The water doesn't even begin to fill the channel, and the floodplain is dry.

But suppose tomorrow afternoon we get a real frog-drowner and it rains 2 inches. This amounts to more than 800 million gallons of water falling on the 24 square mile watershed. All of that water has to go somewhere, and where it goes is towards the creek.

This means that the channel that looks far too big for the stream today will be far too small for the rush of flood waters tomorrow. Flood flows often are 100 times to more than 1000 times greater than stream flows during low water. In response, the stream spills onto its floodplain to move all that water. During floods, water flows fast in the channel and slow in the floodplain – this spreads out the flood peak so that flood waters don't all arrive at the same time downstream.

Floods carry a lot of energy, too. If all of the water from that 2-inch rainstorm were to flow to the Hudson, it would expend more than 1 million kilowatt-hours of energy on its way (a typical American house uses about 1000 kilowatt-hours of electricity per month). As we know from last fall's floods, this energy can tear up stream banks and property. But as the flood waters spread over a flood plain, much of this energy can be harmlessly dissipated.

If I decide that I want to "reclaim" the floodplain by building dikes and levees to keep the stream in its channel so that I can build something on the floodplain, the water will rise higher and move downstream much more quickly. All of that water and energy will sweep down onto my downstream neighbors, and cause more severe flood damage to their properties.

So floodplains allow for the gentle dissipation of the huge amounts of water and energy that are generated by rainstorms (or snowmelt). Human activities that destroy floodplains reduce the protections that they provide, and can seriously increase flood damages downstream.

A second lesson that many people have learned the hard way is that an area marked as a floodplain will flood. It's not a question of if, but when it will flood. It is a loser's game to bet that something built on a floodplain will stay dry.

Third, as every birdwatcher, hunter, and amateur botanist knows, floodplains are valuable habitats. The combination of rich soils deposited by floodwaters, a nearby source of water in the stream, and (often) lower levels of human disturbance makes floodplains biological hotspots.

Here are a few suggestions about how best to manage floodplains. First, know where floodplains are – they can be surprisingly large even for small streams, and are easy to underestimate during periods of low water. Almost 8% of Dutchess County is in a 100-year floodplain. Consult FEMA maps (www.msc.fema.gov) to find your local floodplains. Second, make sure that any new land uses on the floodplain are not damaged by flooding and do not block the floodway. Parks, nature preserves, and agriculture that can tolerate flooding are good choices. Third, if incompatible land uses have already been put onto floodplains (and this is unfortunately very common in Dutchess County), evaluate the options (including abandonment) based on the long-term costs and benefits of all options, including impacts on downstream properties.

Healthy floodplains are valuable to both people and nature, and deserve to be managed thoughtfully.

Poughkeepsie Journal, 3 June 2012

Holy Toledo, or Water, Water Everywhere...

Perhaps this summer's most ironic story was the news that residents of Toledo, Ohio, a city on the shores of one of the largest and most magnificent lakes in the world, had no water to drink. For two days, half a million people in and around the city survived on bottled water because city water, drawn from Lake Erie, was too filled with toxins to be safe for drinking, cooking, or even bathing.

The toxins came from blue-green algae (also called cyanobacteria) that live in the lake. Among the many interesting things about blue-greens, and the most relevant here, is their ability to make a wide variety of strange and potent toxins.

Scientists are still debating what functions these toxins might perform for the algae (protection from being eaten?, nutrient storage? , protection from sunburn?), but they are undoubtedly poisonous to animals, including people. Some of these toxins, like the microcystin that fouled Toledo's water, target the liver and can cause nausea, diarrhea, liver damage, and perhaps even cancer. Microcystin is the toxin that is thought to have killed dozens of patients at a dialysis center in Brazil in 1996.

Other kinds of blue-greens produce poisons that target the kidney as well as the liver. These toxins are worrisome because one of the species that produces them, *Cylindrospermopsis raciborskii*, is an invasive species that is now spreading around the world.

Some blue-greens produce nerve poisons that are among the most potent known to science. It will perhaps suffice to say that one of these neurotoxins was known originally as Very Fast Death Factor when it was discovered in an investigation of livestock deaths in Canada, and that the military has had a strong interest in these chemicals.

Finally, if that isn't scary enough for you, blue-green algae produce BMAA, an amino acid that has been linked to neurodegenerative diseases like Parkinson's and ALS.

If blue-green algae are so common, and they make all of these poisons, could what happened to Toledo's water supply happen elsewhere? It's rare, but algal toxins have contaminated water supplies all around the world. Although blue-green algae are common, dense, toxin-producing growths of blue-green algae are far less common, and processes used in water treatment (flocculation of particles, chlorination, activated charcoal treatment) can remove most of these toxins. More frequent are deaths of livestock, waterfowl, and dogs from drinking raw water from scummy lakes and ponds, with its full load of algae and toxins.

The problems in Toledo almost certainly arose because of the way that people have managed (or failed to manage) the lake and its surrounding landscape. Blue-green algae thrive in warm water that is rich in nutrients. Much of the land around Toledo is used to grow row crops and livestock. Runoff of nutrients from these operations, along with sewage from Toledo and Detroit, encourages the growth of these noxious algae during warm weather.

It is likely that problems with blue-green algal toxins in water supplies will become more common in the future, and we will read more stories like the one from Toledo. Already, many lakes and rivers, including Lake Erie and the Hudson River, are rich in nutrients from farm fertilizer, sewage, and other sources, and we all know that the planet is warming. Studies done here at the Cary Institute show that the amount of blue-greens in the Hudson's water rises from essentially zero in cool summers to more than half of all algae in warm summers, so we are probably looking at a more blue-green future for the Hudson and other waters around the world.

The news from Toledo reminds us how much we depend on the natural world for essential services and materials that support our lives and societies, including the very water that we drink. If we do not manage this natural world wisely, then we can expect to pay higher costs, whether measured as dollars spent to make our water safe to drink, or as human health.

Poughkeepsie Journal, 17 August 2014

Cleaning Up the Clean Water Act

I spent a lot of time outdoors as a kid in southern Michigan in the 1960s and 70s. The river in my hometown was a sour-smelling mess the color and consistency of potato soup, the miles of enticing beaches along nearby Lake Erie were never once open for swimming, and I was familiar with the sight and smell of incompletely treated human waste. My mom used to worry that my brother and I would drown when we went down to the river to fish. She should have worried that we'd touch the water. Anyone who spent much time outdoors before 1980 can tell similar stories.

The Clean Water Act of 1972 (CWA) and related laws put an end to the worst of this by regulating releases of pollution and providing money for better sewage treatment. As local activist John Cronin has rightly pointed out, the CWA has failed to meet some of its lofty goals (to make all of our waters swimmable and fishable by the year 1983), but it has made important progress. At least kids today who want go fishing won't see and smell what my brother and I did.

One curiosity about the CWA is that, although it aspires to protect "the waters of the United States", it never actually defines what it means by that phrase. Congress clearly intended to protect navigable waters (like the Hudson) and rivers that cross state boundaries (like the Hudson or the Susquehanna), and had the authority to do so. And it seems clear that they intended to protect the tributaries of these waters. They understood that you can't protect the water quality of a river like the Hudson if somebody is filling its tributaries with pollution. But how far up into the landscape do the "waters of the United States" extend? A marsh along a small stream in Pine Plains? A stormwater detention pond at the Galleria Mall? A ditch in a farm field? A puddle on your sidewalk? Not surprisingly, these "gray" cases have ended up in the courts, resulting in a slow, expensive process that neither the EPA nor the supposed polluter likes.

The EPA has just released a proposed definition of the "waters of the United States" (a 370-page definition!) to reduce the number of these troublesome gray cases. The proposal identifies waters like the Hudson that are clearly included, and waters like farm ditches and that puddle on the sidewalk that are clearly excluded, while proposing criteria for helping to decide whether the inevitable remaining gray cases are in or out. I am an ecologist, not a lawyer, but the proposal looks sensible and well supported by science, and clarifies rather than expands the jurisdiction of the CWA.

Not surprisingly, big agriculture has mounted a splashy and misleading campaign against this proposal (google "Ditch the Rule" to see it). As much as we like farms, no industry in the US uses more of our water than agriculture, or causes more difficult and widespread water pollution. The toxic algal outbreaks in Lake Erie and the Dead Zone in the Gulf of Mexico are just two recent examples. So it is natural that big agriculture would like to roll back the CWA as far as they can. One leader in this campaign is the Farm Bureau, a powerful lobby that has demonstrated its sensitivity to environmental issues by opposing any attempt to regulate greenhouse gases.

So when you see some hype about how EPA's new definition is going to ruin farming and the American Way, remember that you're looking at the product of a well-organized and self-interested industry group with a less-than-stellar environmental record. I'm not going to suggest that you read EPA's full 370-page proposal to see the truth, but you can see a nice summary of the new proposal at http://www2.epa.gov/uswaters/ditch-myth . Decide for yourself, and if you have the time before October 20th, send a comment to the EPA.

Poughkeepsie Journal, 14 Sept 2014

Living Where the Sun Doesn't Shine

It's easy to feel light-deprived during these short, pale winter days, especially after a week of gray weather. Compared to many underwater habitats, though, a cloudy winter's day is a floodlit paradise.

Water, especially if it is impure, absorbs so much light that you don't have to descend very far into a lake or river to reach twilight and then darkness. The clearest local waters are lakes like Awosting in the Shawangunks, which contain few impurities. Even in these lakes, only about 1% of the sunlight reaches a depth of 40 feet.

But there are much darker places.

Most local lakes and rivers contain suspended mud or dissolved organic matter (a natural tea that is steeped from leaves and soils) that absorb light, and are far darker than Awosting. For perspective, an overcast, moonless night is about one-billionth as bright as a sunny day. However, the bottom of the Hudson at Poughkeepsie, under 60 feet of muddy water, gets about one-billionth of one-billionth of the sunlight that shines on the river's surface, engulfing that habitat in a profound and perpetual darkness.

The bottom of the Hudson is not the only dark underwater habitat. Although clear ice is about as transparent as water, ice that is filled with bubbles or covered with snow can block more than 99% of sunlight from reaching the water beneath, so it is very dark under thick, snow-covered ice. And caves and aquifers are completely dark.

As you can appreciate, living where the sun doesn't shine poses challenges for aquatic life. To begin with, how do you find anything? (Like the food that you want to eat, or the predator that wants to eat you?) Most humans are so visual that it's hard for us to imagine getting around where it's pitch black.

But there are senses other than sight, and they are well developed in many aquatic animals. Some have finely honed senses of smell that they use to find food and avoid danger. Fish have a lateral line, an exquisitely sensitive system for detecting vibrations in the water. Electric eels, elephant fish, and quite a few others use electric fields to sense prey and predators, or communicate with one another. So animals adapted to living in the dark manage just fine.

A more basic problem is where food comes from in the first place. Except in a few special habitats like deep-sea vents, photosynthesis fueled by sunlight provides all of the food that supports food webs. So these dark corners of the world can't grow their own food, but instead depend on food that is carried in from some well-lit habitat.

This journey may be surprisingly long. You could probably guess that some of the food that feeds the animals on the bottom of the Hudson comes from phytoplankton carried down from the upper, sunlit parts of the river. But even more of that food comes from bits of leaves and soil washed in from distant parts of the watershed, and some of that material is thousands of years old. This means that creatures in the Hudson are feeding today on sunlight that was captured by photosynthesis when Jesus was alive.

Ground waters offer an even more amazing example. Some of the food that feeds groundwater bacteria and animals is carried in with the water that seeps through overlying soils, and is only weeks to months old. But part of their food was made on some sunny day millions or even hundreds of millions of years ago, and then locked into the rocks that form the aquifer until it was consumed today. And you thought aged cheese was old!

But even though much underwater life manages without light, turning light habitats dark can kill. When soil erosion or algal blooms turn clear water turbid, there is too little light to support underwater plants, and they and all of the animals that depend on them disappear. And when snow-covered ice covers a lake and prevents photosynthesis for a long time, the animals in the lake can use up all of the oxygen and die, which is called "winterkill".

I doubt that anyone enjoys these gray winter days. But unless you've spent time at the bottom of the Hudson, you don't know what dark is.

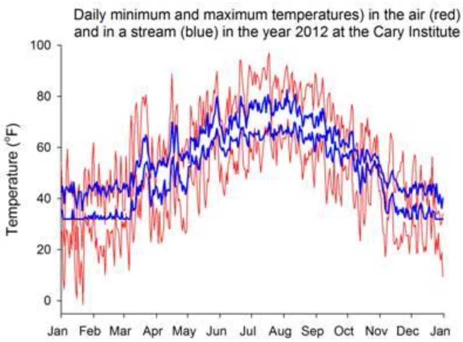
Poughkeepsie Journal, 3 Jan 2016

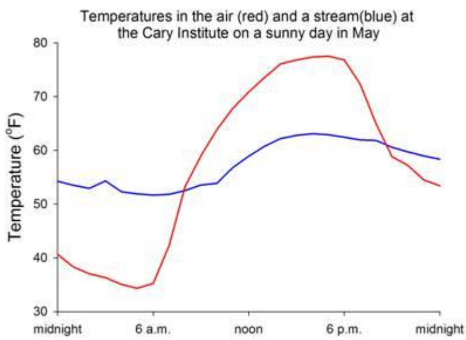
Living in the Temperate Zone

Whoever named the "temperate zone" must have had a sense of humor. I'm writing this during a week of humid, 90-degree days, and just a few months ago it was 13 below, a stiff north wind providing the icing on that frozen cake. Since then, we've had rain, snow, sleet, warm spells, cold snaps, and thunderstorms.

Wouldn't it be nice to live someplace without the broiling heat, bone-chilling cold, and erratic swings that have you reaching for a short-sleeved shirt one minute and a parka the next – in a word, where the climate was a little more … temperate?

There is a place like that, right here in Dutchess County. A place where the temperature never gets much above 80 or goes below freezing, and changes only gradually, in the most genteel fashion. And if you can't think of any place like that, it's because you're a habitual air-breather (go ahead, admit it), and are overlooking underwater habitats.





As the upper graph shows, water temperatures can be strikingly different from air temperatures right next door. Notice that the stream doesn't get nearly as hot in the summer or as cold in the winter as the nearby air. How can this be?

First, it takes a lot of heating or cooling to change the temperature of water. Very few known substances resist temperature change as stubbornly as liquid water does. As a result, air temperatures may change by 40 degrees or more on a clear, sunny day, while stream temperatures scarcely change 10 degrees between the pre-dawn chill and the mid-afternoon heat (see the lower graph).

Second, liquid water is very reluctant to change into a gas (water vapor) or a solid (ice). Huge amounts of energy that otherwise would make water very hot in the summer or very cold in the winter are instead consumed when water evaporates or freezes. When 1 pound of water evaporates on a summer day, it consumes the energy that would otherwise heat 1000 pounds of water by 1 degree. Likewise, when 1 pound of water freezes on a winter night, it prevents nearly 150 pounds of water from chilling by 1 degree. So evaporation and freezing protect underwater habitats from the extreme hot and cold that those of us who live above the waterline are all too familiar with.

Third, deep ground water in our area is 50-55 degrees year-round. Habitats like springs and small streams that are fed by ground water are kept near this temperature both summer and winter. This moderating effect can last for many miles downstream because it takes so much energy to change the temperature of water (as explained above).

(The early settlers understood this, and built "spring houses" over springs to keep things cool during the summer in the days before Frigidaires. You can still see the ruins of these spring houses all over the Hudson Valley.)

So life in the watery part of the temperate zone sounds pretty nice, without those uncomfortable extreme temperatures that we air-breathers suffer through.

Not quite.

Many aquatic animals are sensitive even to what we'd call moderate temperatures, probably because they evolved in habitats where temperatures were so stable. The trout that live in local streams will die if the water gets much above 80 for even short periods of time.

This means that cool-water refuges like springs, seeps, and deep shade can mean the difference between life and death for trout during hot summers. Trout will almost certainly be unable to survive the hotter summers that are coming to the Hudson Valley as the climate changes in the next few decades. One model suggests that trout will disappear from all streams in the eastern United States by the year 2100, although protecting cool-water refuges can keep them around for a little longer. Species less conspicuous than trout will disappear from local waters as well.

So we all suffer together, air-breathers sweltering in the upper 90s in the air and trout sweltering in the low 80s in the water, and summers will get harder for all of us as the climate warms. Temperate zone, my Aunt Fanny.

Poughkeepsie Journal, 28 August 2016

Who Owns the Waters of the United States?

When Scott Pruitt takes the reins of the Environmental Protection Agency, we can expect him to dismantle federal environmental protections. Among the protections that he would like to roll back is the recent rule defining the "waters of the United States" under the Clean Water Act. Repealing this rule would cut the heart out of the Clean Water Act, effectively hand our waters back to big polluters, and diminish public benefits arising from those waters. This should be resisted.

When I was growing up along the shores of Lake Erie in the 60s, the lake and surrounding rivers were polluted by industrial, agricultural, and municipal wastes of the most appalling variety – I saw oil slicks and old condoms and sour-smelling river water the color of cardboard. When this pollution killed fish and waterfowl, or made the beaches unsafe for swimming, the polluters at most received small fines – far less per fish than I would have been fined for taking a few fish out of season. By the time I was 12 years old, I understood what this meant – the lake and rivers belonged to the steel companies and the paper mills to use as they pleased.

Nor was Lake Erie an isolated case. Here in New York, sewage from millions of people was dumped essentially untreated into the Hudson, along with a rich brew of metals, oil, and other toxins from industry. Fish kills were common, and high concentrations of intestinal bacteria in much of the river made the water unsafe for even incidental contact (e.g., fishing).

The condition of our waters finally became so bad, with burning rivers and dying lakes, that the rightful owner of those waters, the people of the United States, reasserted our claims through the Clean Water Act in 1972. Although sometimes portrayed as a radical coup by the environmental left, the Clean Water Act had broad bipartisan and geographic support. The final bill passed the Senate 74-0 and the House 366-11, including overwhelming majorities of both parties and majorities in the congressional delegations of every state. And despite its flaws, the Clean Water Act has been essential in stopping or reversing further deterioration of water quality in many lakes and rivers (the Hudson, for example, is now safe for swimming much of the time and widely used for all kinds of recreation).

A central issue with the Clean Water Act is that it claims authority over the "waters of the United States" without explicitly defining that phrase. Congress had the authority under the Commerce Clause to protect bodies of water that were navigable or crossed state boundaries. But it is clear from the language of the Act that they also meant to protect the tributaries of these waters – they understood that you can't keep a river clean if the streams that feed into it are being polluted. But how far upstream does federal authority extend? A little up the tributary, all the way to the mountaintop, or somewhere in between?

Such ambiguity led to the courts, where the Supreme Court ruled in 2006 that only bodies of water with "a significant nexus" to protected waters were included as "waters of the United States". To clarify what waters would be covered under the Act, the EPA and Army Corps of Engineers issued a detailed rule last year that defined what would be included or excluded. This rule was carefully developed and exhaustively reviewed, is consistent with prior application of the Act and legal precedent (including the "significant nexus" test), and is supported by a large body of scientific knowledge.

Nevertheless, the rule was attacked by polluters, especially Big Agriculture, even though many agricultural activities are specifically exempted from the Act. Agriculture undoubtedly finds the Clean Water Act to be burdensome, because no sector of the US economy uses more water or pollutes more lakes and rivers than agriculture. Agricultural pollution has been blamed for the toxic algal blooms that shut down Toledo's water supply and the excessive nitrate that threatens Des Moines' drinking water, and damages populations of fish and wildlife all across the country.

Rolling back the protections of the Clean Water Act would allow agriculture to pollute more waters and roll out the red carpet for other polluters. And we all would be left paying the price as the quality of drinking water degrades, beaches close, lakes and rivers fill with algal scums, waterfront businesses and property values suffer, and fish, birds, and other wildlife disappear.

As the Trump Administration moves to turn campaign rhetoric into reality, it is time to remind them that the owners of the waters of the United States are the people of the United States, and that we do not want hand ownership over to the polluters.

Albany Times-Union, 11 February 2017

The Lost Snail of the Yangtze

Sometime around 1900, the Department of Mineralogy at the National Museum of Paris received a block of limestone from "Kouei-Tchéou, a town located on the Yang Tse River, more than 1200 km. from Chang-Hai". The rock sat around Mineralogy for a while until the mineralogists noticed that the rock was covered with shells, so they sent it over to the Department of Malacology (the people who study snails).

Rocks from the Yangtze River, containing the world's only known specimens of Helicostoa sinensis. Photo from Museum Nationale d'Histoire Naturelle http://mediaphoto.mnhn.fr/media/15109385882519F5DXnkXUeBB5J4Q.

When the museum's mollusk experts finally got around to looking at the rock in 1926, they were mystified by what they saw. The shells on the rock were so peculiar that the malacologists weren't even sure what kind of animal they were looking at (a mollusk?, an insect?, a worm?), but they finally decided that "this disconcerting form" must be a very odd snail. The shells were of two forms (male and female?), some were only loosely coiled, like a cinnamon roll that had come apart, and all were firmly cemented to the rock. Clearly unhappy with their inability to understand this snail, in a paper called "Sur une coquille énigmatique" ("coquille" means shell, and I bet you can guess what "énigmatique" means) they gave it a provisional name – *Helicostoa sinensis* – hoping that someone would be able to find more specimens of this animal and figure out what the heck is was.

Nearly a century later, malacologists still are arguing about what sort of animal *Helicostoa* is. No one has seen it again, and probably no one ever will. Judging from the bit of information on the collection site and the habit of the animal, *Helicostoa* probably lived in the rushing waters of the Three Gorges, a habitat that was destroyed by the massive Three Gorges Dam. So we may never know more about this snail than what we can discover from that piece of limestone in Paris. (How did *Helicostoa* find food and mates if it was cemented in place? What other snails was it related to, and how did it evolve? Were the juveniles able to move around before settling down? If so, how did they get around in the torrential waters of the Three Gorges? What kind of strong, waterproof cement did it make? Could it dissolve the cement when it needed to move?)

All around the world, the rapids and gorges of our largest rivers harbor mysterious animals like *Helicostoa*, whose ways of life and even existence are scarcely known to us. Indeed, many inhabitants of the rapids probably have not yet been discovered or disappeared before they were ever seen.

Why do we know so little about the denizens of the great rapids?

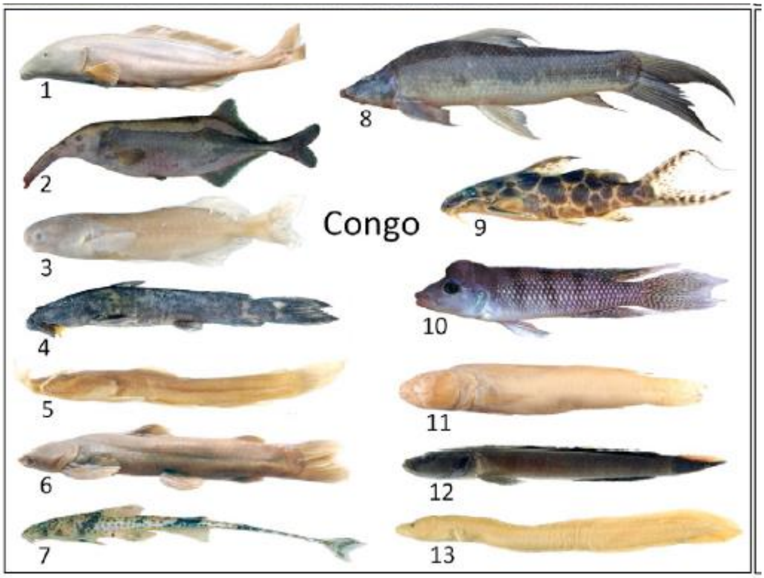
First, ecological conditions in these great rapids are so unusual that they offer stresses and opportunities that require special adaptations (such as cementing to the river's bed) for species to survive. Torrential currents impose enormous stresses on the rapids-dwellers. Even moving from place to place can be next to impossible. This means that evolution has produced species that are especially adapted to these strange environments, and may rarely be found anywhere else. Biologists must come to the rapids to find and study these species.

The enormous physical forces in the Inga Rapids of the lower Congo River. Credit: Red Bull.

Second, most of the Earth's great rapids are isolated nearly completely from similar rapids on other great rivers. *Heliostoa* had no more chance of reaching the Inga Rapids of the Congo River or the Grand Canyon of the Colorado than I have of eating lunch tomorrow on Mars, even though it might have found hospitable conditions in these other rivers. Evolution worked independently in each set of rapids, and produced different sets of species in each river.

Third, the great river rapids are devilishly hard for biologists to explore. It can be next to impossible to scale down cliff faces or float down over rapids and waterfalls to reach the places where the animals live (and then get back out again!). There are parts of the Congo River rapids that biologists still haven't been able to reach. And if you do get into place with your crew and gear all in one piece, how is a biologist supposed to observe or capture the river's inhabitants under such extreme conditions? Biologists from the American Museum of Natural History describe the difficulties of exploring the Congo River rapids at https://www.amnh.org/explore/videos/biodiversity/evolution-in-action-isolation-and-speciation-in-the-lower-congo-river). Few places on our planet are so difficult for people to explore.

Finally, humans destroyed many of the world's great rapids and gorges before biologists got more than a cursory look at them, and are in the process of destroying those that remain. The animals and plants that live in rapids are especially vulnerable to changes in their habitat – they require swift currents, plenty of dissolved oxygen, and clean river beds, all of which are lost when we destroy rapids.

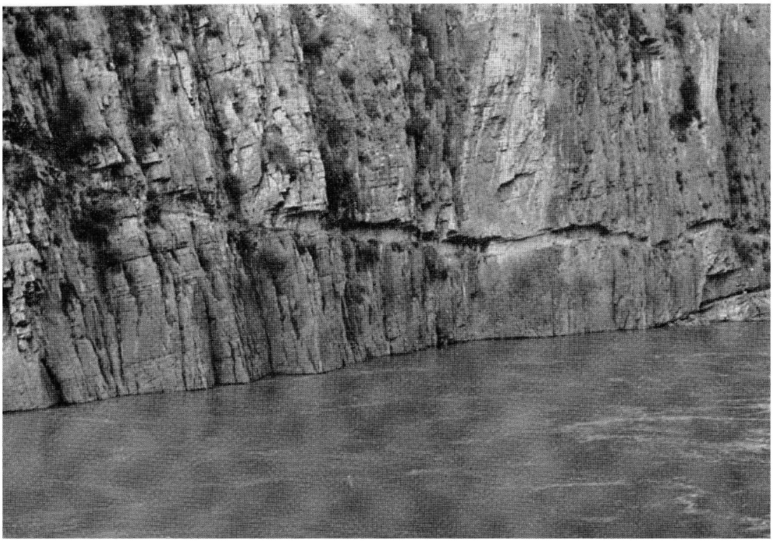


A few of the fishes found in the Congo River rapids (Winemiller et al. 2016, Science). 1 = Mormyrus cyaneus (CR), 2 = Campylomormyrus rhynchophorus (R), 3 = Stomatorhinus microps (CR), 4 = Euchilichthys guentheri (R), 5 = Bagrus caeruleus (C), 6 = Notoglanidium pallidum (CR), 7 = Trachyglanis sp. (CR), 8 = Labeo sorex (R), 9 = Synodontis soloni (C), 10 = Lamprologus tigripictilis (CR), 11 = Lamprologus lethops (CR), 12 = Teleogramma brichardi (CR). "C" means that the species lives only in the Congo River basin, and "R" means that it lives only in rapids.

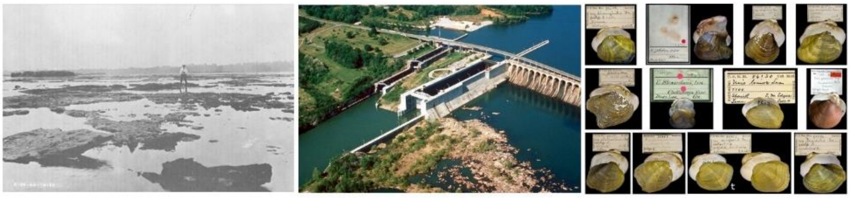
Why have we been so eager to destroy the rapids? Destroying great river rapids can bring huge benefits to people. For millennia, we have used rivers as highways to transport people and goods, and the great rapids are deadly obstacles on these highways. In "Science and Civilisation in China", Joseph Needham and his collaborators described the difficulties of navigating the Three Gorges and other rapids on Chinese rivers. To move cargo upriver, teams of men harnessed to bamboo cables towed ships through the rapids (see the photograph below). Where river banks were too steep to be passable, people hand-cut towpaths into the bedrock of the gorge wall.

Ships going downriver ran the risk of being dashed against submerged rocks or overturned by the turbulent water. Over the centuries, many men and cargoes were lost in the battle against these waters, and fervent prayers must have been offered for relief from the rapids. And the Yangtze is by no means the most challenging of the world's big rivers – the rapids of the lower Congo are completely impassible to ship traffic. It is no surprise that we destroyed many river rapids to improve navigation as soon as we had the ability to do so by explosives or (more often) by flooding them with locks and dams (see the photograph of Mussel Shoals below).

A boat being towed upstream by teams of men through a rapids in the Yangtze gorges near Chongqing, about 1938. From Needham et al. (1971).



A trackers' towpath cut into the rock-face of the Wind-Box gorge along the Yangtze River. Some similar rockcut towpaths along Chinese rivers are almost 2000 years old. From Needham et al. (1971).



(Left) Muscle Shoals, a shallow rapids on the Tennessee River before the construction of the Wilson Dam (center), which replaced the rapids with a reservoir and lock-and-dam system for navigation. (Right) Extinct species of the freshwater mussel genus Epioblasma, which lived chiefly in rapids like Muscle Shoals. The few surviving species of Epioblasma catch different species of fish to serve as hosts for their larvae, and we can only guess that these extinct species also were able to catch fish. Photographs from B.G. Isom. 1971. A biologist's look at the history of Muscle Shoals (Mussel Shoals).Malacological Review 4: 203-206, Wikipedia, and the MUSSEL project.

Water rushing through a rapids has power that can be harnessed to drive mills or generate electricity. For centuries, people built mechanical mills together with dams or diversions along streams and small rivers to grind grain, crush rock, and saw wood. But only recently have we have developed the ability and the need to harness the enormous power of the largest river rapids to generate hydroelectricity. The amount of electricity that can be generated is large, and can replace other problematic methods of electrical generation (e.g., coal-burning, nuclear), so it can be very attractive to build hydropower dams to flood the great river rapids. The Three Gorges Dam that probably wiped out *Helicostoa* and other creatures of the Yangtze River gorges has a capacity of 22,500 megawatts (equal to ~25 large coal-fired power plants), and generates ~$4 billion/year in electricity. The proposed Grand Inga project, which would destroy much of the rapids on the lower Congo, would have almost twice this much capacity (40,000 megawatts), and could supply something like 40% of Africa's electricity needs. These are perhaps irresistible inducements for destroying the remaining big-river rapids.

Conflicts between humans and wild rivers are many millennia old. Over this long history, we've exploited rivers and their inhabitants for short-term human benefits, often damaging both rivers and long-term human interests in the process. Nowhere has this conflict between human desires and wild rivers played out with such intensity as in the rapids of the big rivers. Destroying these special habitats had both especially large benefits to humans and especially large costs to biodiversity. This conflict has caused, and probably will continue to cause, large worldwide losses of biodiversity from the great river rapids.

There are a few glimmers of hope in this relentless story of destruction. Persistent biologists going through the scraps of rapids habitat remaining in our southeastern rivers have rediscovered remnant populations of several species thought to be extinct (see photo below). So perhaps some enterprising biologist will yet discover a living population of *Helicostoa* in some unexplored Chinese river. And with the increased appreciation for the value of riverine biodiversity, plans for exploiting rivers now sometimes make provisions for preserving some of the river's plants and animals, either by reserving parts of the habitat from destruction or sharing some of the river's flow with its ancient inhabitants. Perhaps we will find a way to share the remaining few great river rapids with their unique animals. Or maybe people around the world who want to preserve one of the grandest parts of our planet will raise the money to preserve the Inga Rapids and provide an alternative source of electricity to Africa.

But it's hard to be optimistic. The financial rewards for destroying rapids are so great, the appreciation for their biota so limited, and the challenges of protecting these sensitive species so daunting that it seems likely that many of these species of the rapids, including the enigmatic *Helicostoa sinensis*, will vanish in this present period of intensive human impacts.

The snail Tulotoma magnifica, rediscovered in 1988 after it had been thought extinct from destruction of rapids in the Alabama River system (photo from Wikipedia).

My editor always tells me to try to end these essays on a positive note, or at least provide a clear lesson to readers, and she is usually right about such things. But I think that the whole point of the story of *Helicostoa* and the rapids is that the problem of the big-river rapids offers no easy solutions or clear lessons. We have a marvelous, mysterious, vanishingly rare habitat that supports interesting species that live nowhere else. At the same time, destroying the remaining big-river rapids can bring huge benefits to people, especially in parts of the world where people lead very hard lives. It's hard to imagine any half-solutions that would preserve the grandeur of these habitats and save their inhabitants without substantially diminishing those benefits. Instead, this story reminds us of just how difficult it is to be responsible for a planet.

Cary website, 22 July 2021

The Clean Water Act: Fifty Years of Useful Imperfection

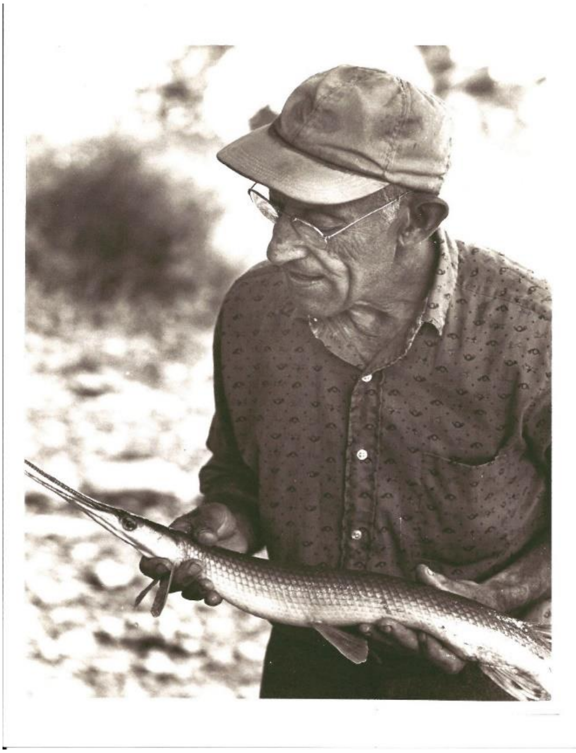
Devastating storms, dying coral reefs, frightening new pollutants, invasive species, widespread extinctions – we hear so many grim stories about the environment that it's easy to forget that we can solve large, complex environmental problems if we choose to do so. The 1972 Clean Water Act (CWA), now in place for 50 years, shows that even an imperfect policy can improve the environment, and offers useful lessons for solving pressing problems like climate change.

Water Pollution and the Clean Water Act

I will begin this story in Ohio, where a couple of famous events in the history of water pollution occurred, and where we have good descriptions of water quality before and after the CWA. Milton Trautman, an avid naturalist who studied fish from the time that he was a boy in the early 20th century until he was an old man in the 1970s, described conditions before the CWA. Trautman lived in an Ohio where sewage and other wastes stripped all oxygen from the water, suffocating fish and other aquatic life; erosion from farm fields smothered fish spawning sites, destroyed aquatic vegetation, and clogged fish gills; toxic metals, cyanide, oils, and other pollutants ran uncontrolled into streams and rivers; drainage from coal mines made streams so acid that no fish could survive; and excessive nutrient loads fueled runaway algal growth in Lake Erie. Over his long life, Trautman watched as pollution worsened and drove dozens of Ohio's fish species out of their native waters into shrinking refuges or out of Ohio entirely; a tiny catfish named for Trautman went extinct.

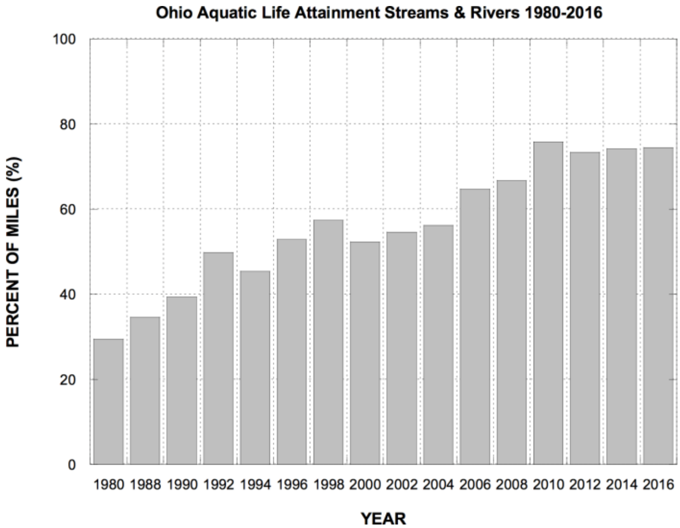
It was a long way down for Ohio from the earliest Europeans' descriptions of clear rivers filled with fishes and waterfowl to:

> "The surface [of the Cuyahoga River] is covered with the brown oily film observed upstream as far as the Southerly Plant effluent. In addition, large quantities of black heavy oil floating in slicks, sometimes several inches thick, are observed frequently. Debris and trash are commonly caught up in these slicks forming an unsightly floating mess. Anaerobic action is common as the dissolved oxygen is seldom above a fraction of a part per million. The discharge of cooling water increases the temperature by 10 to 15 °F. The velocity is negligible, and sludge accumulates on the bottom. Animal life does not exist."



Milton Trautman.

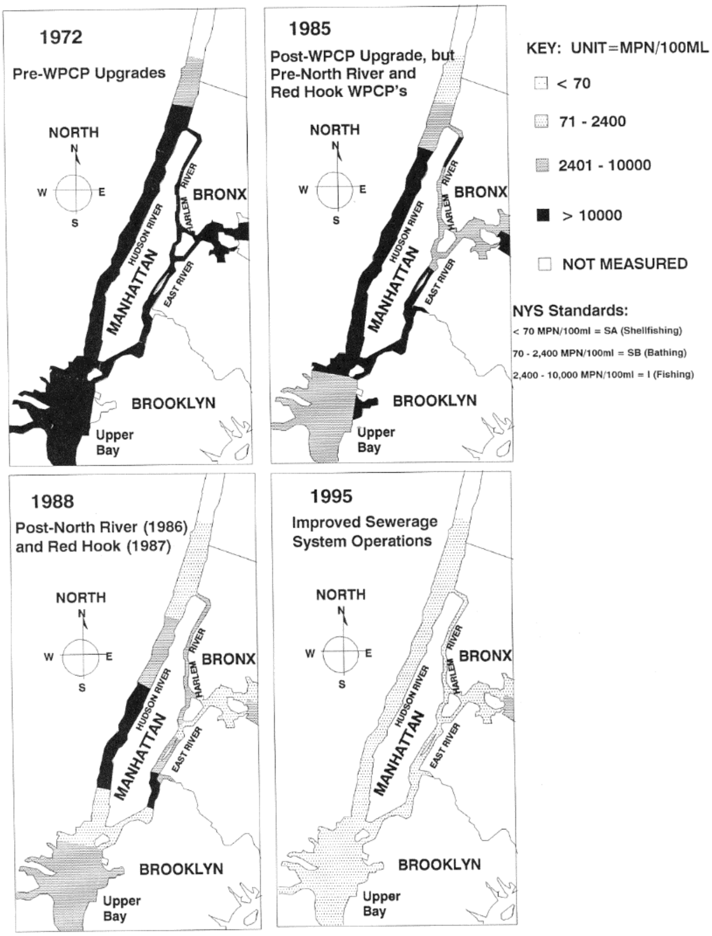
The Ohio EPA also documented poor conditions in Ohio's waters. In 1980, before the CWA had been much implemented, less than one-third of Ohio's streams and rivers had acceptable water quality, as judged by the kinds of fish and invertebrates that they contained.



The number of miles of Ohio's streams and rivers that meet water-quality standards has been increasing. Source: Midwest Biodiversity Institute.

You didn't need to be an expert to see that things were bad. I was born in 1955, and I spent a lot of time as a kid in the 60s and 70s on the polluted rivers and lakeshores around western Lake Erie. The magnificent beaches near my hometown were never once safe for swimming. I saw dead fish and all kinds of trash in the water (including plenty of old condoms, long before I knew what they were for), and knew the sour aroma of paper mill waste in bubbling, oxygen-free rivers.

You didn't have to go to Ohio to find dismal water quality. When my family took a vacation to New England in the late 60s, we smelled the familiar sauerkraut-odor of paper mill waste coming from milky-brown rivers running through the beautiful Maine woods. New York City dumped the nearly untreated waste of millions of people into the Hudson River, where concentrations of fecal bacteria were far too high for safe swimming or fishing. Water pollution was a nationwide problem, and it was bad.

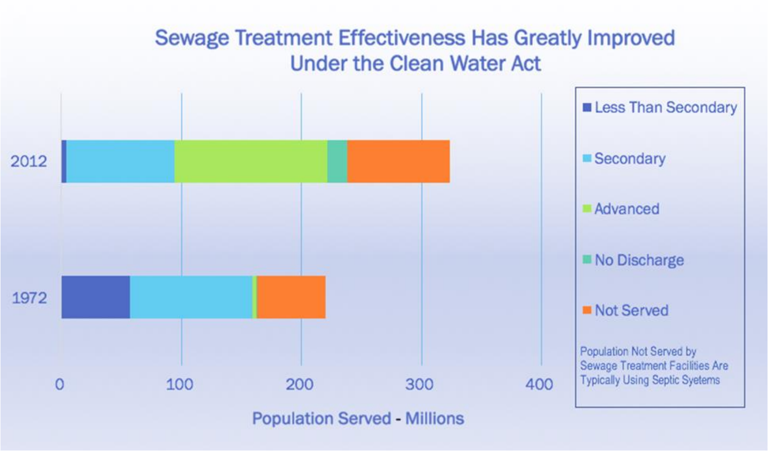


Water quality (concentrations of fecal coliform bacteria from human waste) around New York City improved following the Clean Water Act. Black areas were too polluted for swimming or fishing; light-stippled areas were safe for both swimming and fishing. Source: Brosnan and O'Shea. 1996. Estuaries 19: 890-900.

In the late 1960s, two events in Ohio pushed forward national resolve to eliminate water pollution. Lake Erie had become overly green as a result of nutrient pollution from detergents, fertilizer, and sewage, leading to algal scums and fish kills. In the late 1960s, national media declared that "Lake Erie is dead" – a compelling image, even if not true. More spectacularly, the Cuyahoga River in Cleveland caught fire on 22 June

1969. These and similar stories about water pollution inspired Americans to gather for public protests and push their legislators for a solution.

The result was the Clean Water Act of 1972, which passed the Senate 74-0 and the House 366-11, including overwhelming majorities of both parties and majorities in the congressional delegations of every state. President Nixon vetoed the bill (he thought it cost too much), but Congress overrode his veto the next day. The CWA required permits to release pollution into surface waters, or to dredge or fill these waters, compelled polluters to use the best available technology to reduce pollution, allowed the government to fine violators, and provided federal dollars to upgrade sewage treatment plants. The CWA greatly improved sewage treatment in the United States, preventing about 700 billion pounds of toxic pollutants from reaching our waters each year.



Improvements in sewage treatment in the United States following the Clean Water Act. Source: USEPA.

As the provisions of the CWA came into effect, conditions in Ohio's waters and around the country improved. The proportion of Ohio's streams and rivers with acceptable water quality rose from 30% to 75%, and the waters around Manhattan became acceptable for fishing and swimming (if not shellfishing) for the first time in generations. Fishes that Trautman had watched declining or disappearing rebounded or spread back into waters from which they had been eliminated. Sand darters reappeared in the Maumee, paddlefish moved back into the Scioto, mooneye populations grew throughout the Ohio River and its tributaries, greater redhorses spread from a tiny refuge into multiple rivers around western Lake Erie, and gilt darters were seen in Ohio for the first time since 1893.

The gilt darter, which reappeared in Ohio's waters in 2010 after an absence of 117 years. Source: Wikipedia.

These widespread improvements in water quality benefited people as well as aquatic life. Beaches along Lake Erie, the Hudson River, and many other waters re-opened for swimming after decades of closure. Waterfront property that had been undesirable and neglected because of the unappealing sight and odor of polluted water became hot sites for redevelopment of restaurants, marinas, and luxury homes. Formerly polluted rivers and lakes filled with kayakers, sunbathers, power-boaters, and anglers, and businesses popped up nearby to support them.

Despite all of this progress, the CWA fell far short of its goals. The central goals of making all U.S. waters fishable and swimmable and having no releases of pollutants into navigable waters were not met by the mid-1980s as stated in the CWA, and indeed have not been met today. Improvements in water quality stalled in many regions after an initial period of progress, leaving a substantial portion of US waters still polluted, as shown in the illustration for Ohio's streams. Because the drafters of the CWA thought of pollution as something that came out of a pipe, the CWA did a poor job handling non-point-source pollution, such as runoff of fertilizers from farm fields. In some respects, the CWA was a failure.

Lessons of the Clean Water Act

We could draw several lessons from the story of the Clean Water Act, some instructive, others misleading. Perhaps the most important is that we can make progress on large, complex environmental issues, even if the policy solution is not perfect. The CWA failed to meet its stated goals. Both environmentalists and the regulated community have complained for decades about its flaws, which need to be fixed. Yet data from Ohio and elsewhere show that the CWA greatly improved water quality, aquatic life, and recreational and economic opportunities. This obvious lesson is probably underappreciated because so few Americans are old enough to remember the widespread and gross water pollution before the CWA. Issues like climate change, plastics pollution, and invasive species also are large and complicated, and policies to address them will be imperfect, but we can still take action and improve our world.

Second, the history of the CWA could be misread to suggest that effective environmental policies appear automatically once problems become bad enough. The Cuyahoga River burned, Lake Erie died, and Congress solved the problem. In this worldview, once climate change or invasive species get bad enough, adults will step in and solve the problem. But the full history of the CWA shows that action didn't automatically follow catastrophe. According to John Hartig's book "Burning Rivers", the Cuyahoga River burned in 1868, 1883, 1887, 1912, 1922, 1936, 1941, 1948, and 1952 (a 5-alarm fire). Pollution caused massive losses of plants, fishes, and other aquatic life from western Lake Erie for decades before the media declared the lake dead. In 1948, angry duck hunters dumped hundreds of the more than 10,000 ducks and geese killed by oil spills on the Detroit River onto the sidewalk in front of the Michigan State Capitol. Both ordinary people and politicians understood that water pollution was a problem for many decades before the CWA finally appeared.

Clearly, public knowledge and outrage alone were insufficient to produce a political solution to water pollution, suggesting a third possible lesson. Perhaps the CWA appeared only when a long-standing environmental problem met a serendipitous combination of interest from the media, a galvanized general public, and a favorable political climate. If this interpretation is correct, we should advise environmental activists to document the problem, marshal their arguments, think about solutions, keep up the pressure, and wait for the stars to align. If the history of the CWA is any guide, they can expect to wait for many years or decades. So maybe the lesson from the CWA is that we should tell Greta Thunberg to be patient –

someday, the right combination of public interest, politics, and other secret ingredients will occur, and then action will be taken to solve climate change.

But the history of the CWA shows us the high costs of patience. Generation after generation of people across the United States were robbed of benefits that they could have enjoyed had we dealt sooner with water pollution – safe recreation, clean drinking water, wholesome food, and spiritual and cultural connections with our waters. Properties along polluted waters were left to decay, real estate values were depressed, businesses like waterside restaurants, marinas, and kayak dealers were denied the opportunity to develop and prosper, and entire waterside communities languished for decades while we waited patiently for politicians to act. What is more, the burdens of inaction on water pollution fell most heavily on people of color and others with little money or political power, contributing to America's persistent problems with social justice and inequality. If we had focused on the considerable flaws in the CWA back in 1972, and waited until we had the technical knowledge and political strength to put an ideal policy into place, we could still be waiting for relief.

So I take three key lessons from the history of the CWA. First, we *can* face down large, knotty environmental challenges, and improve ecosystems and our lives. Second, policy solutions are likely to be imperfect, and will need to be refined over time to increase their effectiveness and reduce unfair burdens on the regulated community. These imperfections did not keep the CWA from substantially reducing water pollution across the United States, and they should not prevent us from acting on climate change, invasive species, and other complicated problems. Third, it may seem prudent to delay acting on big problems until we have full scientific understanding, perfect technical solutions, and broad political consensus, but delay costs livelihood and lives, damages ecosystems, and prolongs social injustice. Delays in dealing with water pollution robbed generations of Americans of the benefits of clean water, and decades of delay in dealing with climate have already damaged ecosystems and led to enormous damages from storms, rising seas, and other problems. So perhaps the central lesson of the CWA should be *impatience* – impatience to confront known and growing problems whose costs mount every day while we chase after a perfect solution.

Great Lakes Echo, 29 June 2022

The Hudson River

400 Years of Change in the Hudson River: A Series in Four Parts

Part One: Revisiting the River

"Would Henry Hudson even recognize the Hudson River if he sailed up it today?" My friend Lori asked me this intriguing question the other day as we were talking about the upcoming 400th anniversary of the European discovery of the river, and all of the ecological changes that have taken place since then.

Even though the river has been thoroughly transformed by human action, I think that Hudson and his crew would know the river as they sailed through the New York harbor and past Manhattan. With a sailor's fine sense of currents, soundings, and the shape of the shore, they would hardly fail to recognize the fine deepwater harbor, the strong, swirling currents of the East River and Spuyten Duyvil, and the imposing Palisades on the New Jersey shore. Further upriver, they would remember the broad waters of the Tappan Zee and Haverstraw Bay, and the imposing Hudson Highlands. Of course, they would notice how much the shoreline had been improved, by the little wetlands and beaches replaced with tidy seawalls and useful piers. Surely they would marvel at Manhattan and wonder what great race had built this glittering city, but they would know the river. Apart from the obvious signs of an advanced civilization (soaring bridges, strange iron tracks along both banks), the straight, deep channel of the river and its wooded banks would be familiar, as least as far as the city of Hudson.

Hudson is where Henry's troubles really began in 1609. What had been a navigator's dream south of Hudson – a beautiful deep channel – turned into a bewildering nightmare of islands and side channels north of the city. The crew must have spent all their time trying to find the water and sounding for shoals, their dream of a Northwest Passage fading fast.

Hudson and his crew would be well pleased with what they would find in the river north of the city of Hudson today – the maze of islands and shoals replaced by a clear, deep channel as far as Albany, courtesy of two centuries of dredging, filling, and channel-training. And that wretched mud bank at Castleton – the nemesis that grounded his ship in 1609! – gone without trace.

Neither Hudson nor his crew had much interest in ecology, so it's not likely that they would have noticed most of the profound ecological changes that have occurred in the river since 1609. But what if there had been an ecologist on board in 1609, say Henry's cousin Peter ("Doc") Hudson, a lad who had grown up as a seafarer like Henry, but who had always been more interested in the animals that grew on the hull of the ship than in the ship itself (how odd), and who thought of trees as something more than potential masts.

He would notice a lot that escaped Henry's eye. The forests, for instance. Henry would have said that the land outside the cities was still largely covered with forests and left it at that, but Peter would have seen at once that the forests of 2009 were quite different from what they had seen in 1609. These new forests were young, for one thing, with few of the giant pines, oaks, or chestnuts that Peter had remembered. Although Peter would have known he was looking at a different forest, it seems unlikely that he would have the insight that he was looking as a landscape that had been almost entirely cleared and domesticated in the 18th and 19th centuries, then gradually abandoned back to the forest after the Civil War.

And where were the chestnut trees, so common in their earlier voyage, and so valuable to humans and wildlife alike? Had loggers come through and cut down all of the chestnuts? (And the elms – weren't there more elms along Hudson's river?) What was troubling the hemlocks that lined the glens of the Highlands and Catskills, now just grey skeletons? Peter would have no way of knowing that it was not logging, but diseases carelessly brought into North America, that led to the demise of the chestnuts, the elms, and now the hemlocks.

Next week – The River of Islands

Part Two: The River of Islands

This is the second of four pieces in which we're charting the ecological changes that have occurred in the Hudson River since it was "discovered" by Henry Hudson in 1609. What changes would Hudson (and his imaginary cousin, Peter ("Doc" Hudson, the ecologist) notice if they sailed up the river in 2009?

The transformation of the upper part of the Hudson from a tangle of islands and useless side channels in 1609 into a decent channel today that his ship could use without sounding for shoals every three minutes would have put Henry into a rare good humor. Peter would have been confused and disappointed, though. Where were the stands of wild rice and tall grasses that had rippled so beguilingly in the breeze? Where were the flocks of speckled teal and comical peeps that used the shallows and mudflats of the Hudson as a welcome stopover in their long migration south? Where were the blind channels that opened so promisingly to entice ships, then narrowed to an impassable slot, which Cousin Henry had cursed with such vigor and eloquence? And, most of all, where were the innumerable islands that he remembered from the earlier voyage, lined with tall cottonwoods and so endlessly fascinating and individual?

Peter had to agree with Huck Finn, who although himself the creation of a riverboat pilot, thought that islands gave rivers much of their charm and mystery. With no disrespect to his cousin Henry, who was surely a great explorer, Peter would have named this river "The River of Islands". If Peter had been a really careful observer, he would have recorded that the new, improved version of the Hudson River in 2009 lacked 44 of the 68 islands that he had seen in 1609 (each of which he had given fanciful names – The Sleeping Cat, Shad Island, Circe's Isle, and so on), and was missing 3800 acres of rich shallow-water habitats (see illustration).

And it was not just charm that these islands, shallows, and side-channels gave to the Hudson. The upper river in 1609 must have been alive with birds, fishes, and all kinds of plants and animals that found their food and homes in the complex array of habitats. Peter would have filled his sketchbooks with drawings of plants and shells and waterfowl and quick little fishes that abounded in the vegetated shallows. I'm sure that Peter would have tried to capture the amazing colors of the drake wood duck, the ephemeral iridescence of young shads, and the ferocious appearance of the huge snapping turtles that he found in the riverside marshes.

Some of the species that Peter would have seen among the islands are now scarce in the Hudson, or have vanished altogether from the river as their preferred habitats disappeared. Even species that are still common in the river, like shad and river herring, must have been more abundant in 1609 as they benefited from the rich nursery and feeding grounds that the vanished river-shallows offered. Of all the parts of the Hudson and its surrounding watershed, this is the place I would most like to see in its original state.

I don't mean to suggest that these habitats are gone entirely from the Hudson. There are still 24 islands in the river, enticing anglers, campers and modern-day Huck

Finns, and some marshes and side-channels still exist, especially between Kingston and Castleton. We are fortunate that the Hudson still contains 4450 acres of submerged plant beds, chiefly water-celery, a valuable species for invertebrates, fish, and waterfowl. And these remaining patches of shallow-water habitat still fill up in season with migrating birds and baby fishes, and are wonderful places for us to visit. But we will never see the tangle of islands, side-channels, and marshes of the upper Hudson that Henry saw (and undoubtedly cursed!) in 1609.

Next week: Comings and Goings

Part Three: Comings and Goings

This is the third of four pieces in which we're charting the ecological changes that have occurred in the Hudson River since Henry Hudson first saw it 400 years ago. Today, we'll consider the species that have appeared or disappeared from the Hudson as a result of human activities. What changes would Henry (and his imaginary cousin Peter ("Doc" Hudson, the ecologist) see if they sailed up the Hudson in 2009?

Doc was a careful observer of biology, and spent much of his time in 1609 examining and sketching the new plants and animals that he found in the river. What a shock it was in 2009 to find what was clearly the same river occupied by different plants and animals! Several times he consulted his old notes in bewilderment, thinking that his memory had failed him.

For instance, where were the oysters? One of his indelible memories of the harbor, apart from its beauty and Cousin Henry's delight at its depth and breadth, was the abundance of oysters that it held. Miles and miles of oysters, plump and succulent. This time it had taken three days of dredging before they saw their first oyster, and that one was puny. Instead, the dredge kept coming up full of small, wedge-shaped clams (wedge rangia, an invader that first appeared in the 1980s) that he had never seen before, tasty enough it was true, but hardly a substitute for the oysters that had sustained the crew in their earlier voyage.

He also had fond memories of the Hudson's sturgeons. Although they had captured only one or two, they often saw these enormous fish splashing and jumping. This voyage they had trawled up just one sturgeon (one of the small kind), and hadn't seen any of them leaping. And had he misremembered the abundance of shad?

They were seeing shad to be sure, but in small schools, not in the endless shoals that he recalled.

There were subtle and disturbing changes as well, ones that he wouldn't have been sure of if he hadn't had his old journals at hand. For instance, he remembered trawling up lots of catfish off of the muddy bottoms, but they were small and square-tailed (the native white catfish), not the big sleek fishes with forked tails (the introduced channel catfish) that filled the nets now. How could the catfish have changed so much?

Then there were the species that he hadn't recorded at all in 1609, too numerous and distinctive (Peter kept assuring himself) to have been overlooked in that earlier voyage. The remarkable, bright-green beds of some tropical-looking plant everywhere in the shallows (water-chestnut). Going in to get a close look, Peter had gotten the jolly-boat completely entangled in the strange plants, to the delight of the catcalling crew. The tiny zebra-striped mussels that covered the rocks. The plump (and delicious) big green perch (black bass, imported from the Midwest) that lurked among rock piles and weed beds. Where had these new plants and animals come from? The crew always called him a dreamer, but it was hard to believe that he had been so inattentive in 1609 that he had somehow missed these dozens of species. Or had he...?

Poor Peter had no way of knowing that the changes that so puzzled him were the product of four centuries of over-harvest and species introductions. Over-harvest has nearly eliminated the big sturgeons and fat oysters from the river, and brought stocks of shad and other species to a tiny percentage of their former abundance (see graphic of shad landings and maybe sturgeon landings). At the same time, canals, deliberate stocking, careless release of pets and plants, and hitch-hiking species riding in the hulls and holds of boats have brought more than 100 foreign species into our local waters. Some of these species are desirable (the tasty largemouth and smallmouth bass that Peter noticed), but many (like the entangling water-chestnut and the zebra mussel) cause ecological and economic problems. Taken together, though, these changes have made the Hudson a very different ecosystem than the one that Henry saw in 1609.

Next week: Poisoning the Hudson

Part Four: Poisoning the Hudson

This is the last of four pieces in which we're charting the ecological changes that have occurred in the Hudson River since Henry Hudson sailed up the river in 1609. What changes would Henry (and his imaginary cousin Peter ("Doc" Hudson, the ecologist) notice if they sailed up the river in 2009? Today we will consider some important changes that have occurred that even careful observers might miss.

Of all the human impacts on the Hudson River since 1609, probably the best known is toxic pollution. After all, because of PCB contamination, the Hudson River is the country's largest Superfund site, and has been the subject of protracted legal and public relations battles between General Electric and environmental organizations and the EPA to decide whether and how these toxins should be removed from the river. The Hudson has also been badly polluted by sewage, toxic metals, paper mill wastes, pesticides, and other residues of our industrialized society. So in this series of essays about ecological changes in the Hudson over the past 400 years, why have I waited until the end to mention toxic pollution?

These essays are based on the reactions of Henry Hudson and his imaginary cousin Peter (an ecologist) to the changes they saw upon their revisit to the Hudson after 400 years. Without sophisticated instruments like gas chromatographs and modern spectrometers, Peter and Henry would have no way of seeing the full extent of the toxic contamination of the river, although Peter would surely have noticed unmistakable signs that we've been using the Hudson as our wastebasket and our toilet.

The first signs would come as soon as they arrived in the harbor. Bushels and bushels of plastic and other trash floating on the water, and piled up in windrows along the water line. Peter would have been baffled by many of the objects that he found – what could <u>these</u> be used for? – but there would be no doubt in his mind that they had been made, and discarded, by humans.

Peter would have noticed the smell, too. Wherever he dredged up the river mud looking for shellfish, he would have wrinkled his nose against the oily smell, a smell that would stick tenaciously to his hands or anything else touched by the mud. He also would become familiar with the thin rainbow sheen of oil, which he would perhaps admire without understanding its origin.

He would be more upset by what he found when he cleaned the tomcod for their meals. He remembered these small, delicious fish from their earlier voyage, but he certainly didn't remember the grotesque growths on their livers. More than half of the adult tomcod in today's Hudson suffer from liver cancer, a disturbing product of industrial contamination.

The other signs of toxic contamination of the Hudson, so pervasive and obvious to a modern environmental scientist, would probably be too subtle for our 17th-century visitor to notice. However subtle, the contamination of the Hudson has made a lasting impression on Henry's river and devalued its utility to us as a source of food and recreation.

There hasn't been the space in this little series of essays to describe all of the important ecological changes that have occurred between 1609 and 2009. I haven't even mentioned the effect of the railroads in creating wetlands like Tivoli North Bay, or the innumerable dams that block fish migrations everywhere in the Hudson's tributaries, or the countless changes to the river arising from wholesale transformation of its watershed, and so on.

It isn't necessary to go through the entire catalog of ecological changes to answer the question that inspired these essays: "Would Henry Hudson even recognize the Hudson River if he sailed up it today?" Yes, Henry Hudson probably would recognize the river that bears his name. However, we've changed the river is so many ways that it really isn't the same river anymore. In this sense, Henry would recognize his river, but he would be wrong.

Here's a question to ponder for the next 400 years: If we were to sail up the Hudson in 2409, would we recognize it? Or will our careless stewardship of the river and its planet bring us yet another Hudson River, more degraded than the last?

Poughkeepsie Journal, August 2009

Invasive Species

Two Cheers for Invasive Species Policy

A new invader is about to carve out a home in the Hudson River. Chinese mitten crabs, native to Eastern Asia, have been spotted in the Hudson and along our East Coast several times since last June. This burrowing crab is of concern because it breeds prolifically and migrates far inland. It could destabilize river banks and damage native blue crab fisheries.

One of the most important federal policies to control invasive species is the Lacey Act, which prohibits importation and interstate commerce in wildlife species that are deemed to be “injurious”. Although this sounds like a good policy, it is in fact of little value.

Consider the most recent addition to the Lacey Act’s list of injurious species, the black carp. While black carp have been used to control disease-carrying snails in fish farms, they have voracious appetites for all shellfish. When they escape into the wild, they can damage native shellfish populations, many of which are already endangered. Experts have concluded that the risks of importing this fish far exceed its benefits, so it’s now illegal to import this dangerous fish into the U.S. or take it across state lines. So far, so good.

Now for the bad news. It took almost eight years to get the black carp listed under the Lacey Act. The listing process didn’t even begin until 27 years after the fish was brought to the U.S., and 6 years after it was accidentally released into the wild. This lag in response probably allowed the fish to establish itself in our rivers. Biology is faster than bureaucracy.

The Lacey Act deals only with interstate commerce. This means that it is still legal to breed and stock black carp in fish farms, as long as you don’t take them across a state line. Unfortunately, when animals escape into the wild they don’t stop at the state line. Leaving jurisdiction for harmful species to individual states doesn’t make sense when the ecological and economic costs of invaders are borne by all of us.

In the 107-year history of the Lacey Act, the black carp is only the 18th species to be listed as an injurious. This is a small fraction of the hundreds of harmful invaders that have established themselves in the U.S. and continue to arrive each year. The damages these species cause reach more than $100 billion dollars a year.

The Lacey Act's injurious species list is small because it is limited to wildlife (not plants or fungi, for example), and listing is an arduous process that requires proving that a species is harmful. Countries that are serious about preventing damage from invaders use the reverse approach: species aren't allowed into the country until the importer shows that they are harmless.

The ineffectiveness of the Lacey Act is highlighted by the fact that the Chinese mitten crab itself was listed as an injurious species nearly two decades ago. This did not prevent mitten crabs from being sold in New York City live markets (perhaps the source of the East Coast population) or establishing itself in the Hudson. Having missed our chance to keep mitten crabs from moving into our waters, there is probably little we can do to control their spread along the East Coast.

Clearly, we need effective federal policies to deal with invasive species, not a slow, deeply flawed process that addresses just a few of the invasive species that cause ecological havoc and cost us money. Tools like the Lacey Act just aren't getting the job done. The fate of our natural areas depends on it.

Poughkeepsie Journal, 3 February 2008

Chinese Mitten Crab: A New Invader in the Hudson

Look for a new animal in the Hudson this summer. The Chinese mitten crab is at our doorstep. Although just a handful of crabs have been caught in the Hudson and other nearby rivers since 2004, it seems likely that they are now established and spreading through the Northeast.

Mitten crabs are easily recognized by the large, hairy claws that give the species its name. Adults are 2-3 inches across the back, and 8-12 inches from tip to tip of their long legs. The species is native to Chinese rivers, but humans have spread them widely, first to Europe in 1912, then to our West Coast in 1994, and now to the Northeast. Mitten crabs probably traveled to Europe and San Francisco Bay in the ballast water of ocean-going ships, and may have been deliberately released from live markets in the Northeast.

Adult mitten crabs breed in the salty waters of the ocean, but young crabs soon move into freshwater rivers to grow and mature. Mitten crabs are highly migratory, and can move more than 500 miles inland. If they encounter a barrier during their travels, they can crawl out of the water and just walk around the barrier. As a result, they have turned up in some odd places, including human homes and swimming pools. Like other crabs and crayfishes, mitten crabs have a broad diet, and feed on plants, shellfish, worms, and carrion. Young crabs spend 1-5 years in fresh water before moving back to sea in late autumn.

So is the arrival of the mitten crab good news or bad news for us? In China, mitten crabs are so prized as food that wild populations have nearly been fished out, and 400,000 tons were raised in aquaculture ponds in 2004. Unfortunately, mitten crabs from the Hudson probably will be too contaminated with PCBs to be safe to eat. If mitten crabs become abundant in our area, they may crowd out native species, including the blue crab, which is eagerly sought in the Hudson and all along the East Coast. Mitten crabs live in burrows along the water's edge, so they can damage dikes and levees, and increase shoreline erosion. They also can become so abundant that they clog water-intake screens at power plants. In total, they have caused more than $100 million in damages in Germany since they appeared in 1912.

Mitten crabs also can be a nuisance to fisheries. They eat fish that are caught in fishing nets, and damage the nets themselves. They are such accomplished bait-stealers that they have shut down recreational angling in areas where they are abundant.

It's a fair guess that the mitten crab will bring us more problems than benefits. So how did it happen that we're getting stuck with another nuisance species in the Hudson? First, we don't have adequate laws to prevent harmful foreign species from making their homes here. It is still legal to release untreated ballast water into US waters under many conditions, even though we know that mitten crabs and many other species move freely around the world in ballast holds. Second, the laws that we do have are insufficiently applied and enforced. Both federal and state laws prohibit shipping or sale of mitten crabs, yet they are often intercepted in carry-on luggage and live markets. This highlights a third weakness – that people don't understand the problems caused by invasive species and the dangers of carelessly moving species around. Releasing a species into a new habitat is as reckless as tossing a lighted match into a dry forest. Until we fix these weaknesses, we will continue to find new species in our rivers, forests, and back yards.

Welcome to the Hudson River, mitten crabs.

Poughkeepsie Journal, 30 March 2008

Shutting Down the Ballast Water Express

New York State is taking an essential step to deal with invasive species, one of the most damaging and difficult environmental problems of our time, by proposing to limit the importation of ballast water into the state. This action represents real progress towards solving a problem that has been allowed to continue for too long. It deserves our support.

Modern ships use large ballast-water tanks to control their stability and safety. Typically, ships take on ballast water in one port, and release the water and its inhabitants at the ship's destination, hundreds or thousands of miles away.

Unfortunately, large volumes of untreated water in ballast tanks are huge floating aquariums that are very efficient at moving aquatic species around the world. Many of the world's most troublesome invaders have hitched a free ride in ballast water and are now causing economic and ecological problems far from their native homes.

Here in the Hudson Valley, the zebra mussel is the best known of the ballast-water invaders. Zebra mussels appeared in the Hudson River in 1991, and now largely dominate the river's freshwater regions. The weight of all of the zebra mussels in the river is greater than the combined weight of all other animals in the river. Their filter-feeding has reduced plankton populations by 80 percent, killed hundreds of millions of native mussels and contributed to the catastrophic decline of the American shad in the river.

Zebra mussels also damage infrastructure. By fouling water intakes, boats, docks and beaches throughout North America, zebra mussels have caused hundreds of millions of dollars in economic damage. But zebra mussels are hardly the only ballast-water invader causing problems in local waters.

This year, Chinese mitten crabs, quagga mussels and spiny waterfleas all appeared in the Hudson basin. Each of these species is capable of causing substantial ecological and economic damage.

Nor are ballast-water invaders confined to the Hudson Valley. The Great Lakes, Chesapeake Bay, San Francisco Bay and lakes, rivers, and coastal waters around the world are filling up with crabs, fishes, algae, mussels and other species that used ballast water to expand their ranges, causing problems for native species and human economies. And hundreds more potentially damaging species are waiting in ports around the world for their ticket to North America on the Ballast-Water Express.

It usually is difficult or impossible to control invasive species once they are well established. If we want to prevent invasive species from causing problems, it is especially important to keep them from moving around the world in the first place. Although biologists have identified the most important ways by which invasive species arrive in new habitats - ballast water, raw timber and wood packing, the pet and horticulture trades, aquaculture and so on - governmental actions to control these known pathways have been sluggish.

Federal actions in the past few decades have provided some control over some of these pathways, but much remains to be done. For instance, the U.S. Coast Guard now restricts release of ballast water, but almost 1/4 of ballast water still enters our country untreated. Other important loopholes remain as well, so marine and freshwater species are still able to ride the Ballast-Water Express into the United States.

The controls New York State is proposing would close these loopholes by requiring ships to exchange or treat their ballast water before coming into New York's waters and set high standards for allowable populations of animals, plants and microbes in ballast water entering the state. Together with actions by California, Michigan and other states that have been hard-hit by ballast-water invaders, the proposed controls offer the first real prospect of finally closing down the Ballast-Water Express into North America. Certainly, the ballast-water controls New York State proposes won't solve the large and complicated economic and ecological problems that invasive species cause, but they are a welcome step in the right direction.

Poughkeepsie Journal, 7 December 2008

Trouble in Chicago: The Silver Carp Invasion

Last month's news that the invasive silver carp had crossed the electric barrier in the canal at Chicago and were just a short day's swim from invading Lake Michigan caused outcries from the outdoor community and tourist industry across the Great Lakes region. Scientists should find some way to kill this fish! The canals around Chicago should be poisoned to kill <u>all</u> their fish! Unfortunately, neither of these solutions is likely to work, and neither addresses the real problems that led to the headlines about silver carp.

Silver carp were brought into fish farms in Arkansas in the 1970's to control excessive algal growth. Like so many other farmed fish, they soon escaped from the farms and made themselves at home in our rivers. These voracious plankton-feeders now constitute more than 90% of the weight of fish populations in parts of the Mississippi, Missouri, and Illinois Rivers, diverting resources from native fish and wildlife.

The silver carp is also famous as the jumping carp. For some reason, the sound of an outboard motor or Jet-Ski causes these fish to leap several feet into the air (http://everydayexplorers.nationalgeographic.com/individual-video.php?mediaid=459235). These large (up to 60 pounds), wet missiles have already injured boaters in the Midwest and made water-skiing risky.

Scientific studies suggest that silver carp will do well in all of the Great Lakes except Superior. They may seriously damage the lakes' multibillion dollar recreational and commercial fisheries, already harmed by other invasive species, habitat destruction, pollution, and overfishing.

There is every reason to believe that silver carp will move through the Great Lakes into the Hudson River. The Hudson's plankton-feeding fish are already doing so poorly as a result of the zebra mussel invasion, offshore fisheries, and habitat loss that the DEC is about to close the shad fishery for the first time in history, and river herring populations are at 1% of historic levels. Adding silver carp to the mix will only further imperil these populations.

Asking biologists now to keep silver carp out of the Great Lakes, when they are well established across the Midwest and at Lake Michigan's doorstep, is like asking your doctor to give you a pill to let you run a marathon after you've been smoking for

30 years and are 100 pounds overweight. What you're asking for is not so much a cure as a miracle. Biologists don't have tools to kill silver carp and leave the rest of the ecosystem unharmed, or keep them from swimming those last few miles into Lake Michigan, any more than doctors have pills to undo the damage caused by decades of smoking and a hundred pounds of excess weight.

So what can we do? Just as in medicine, prevention is more effective than trying to cure a well-established problem. The path to the Hudson that is open to the silver carp has been used by many other invaders including the zebra mussel. This path, from Lakes Erie and Ontario through the Erie Canal, could be closed by installing an effective barrier on the Erie Canal. A barrier could be designed and built now, before six silver carp turn up in Albany, thereby avoiding a repeat of the hasty, expensive, and ultimately ineffective events at Chicago.

More importantly, we could do a much better job keeping invasive species out of North America in the first place. Despite some recent progress in restricting movement of invasive species in ballast water and wooden packing, our borders are still open to the arrival of new invaders through the pet, aquaculture, and horticulture industries, ballast water, and other pathways.

Solving the invasive species problem will require political action at the federal level, from a government that does not yet give high priority to invasive species. So if you are concerned about invasive species, the next time you read about problems caused by silver carp, or Burmese pythons, or mile-a-minute weed, or Asian long-horned beetles, clip the article and send it to your legislator with a note asking what they're doing to prevent the next disaster. Let's see if we can fix this problem at the source instead of hoping for a miracle cure that doesn't exist.

Poughkeepsie Journal, 6 December 2009

Invasive Species in the Hudson Valley: Yesterday, Today, and Tomorrow

Willie Nelson once sang that he only missed his ex-lover on three days: yesterday, today, and tomorrow. This simple division of time works as well for invasive species as it does for heartbreak.

Yesterday's invaders include hundreds of species and pathogens that are now well established throughout our region. Examples include many popular sport fish (brown and rainbow trout, smallmouth and largemouth bass) and devastating diseases and pests (Dutch elm disease, chestnut blight, Japanese beetles, most of the garden slugs), as well as species that are hard to classify simply as beneficial or harmful (yellow iris, purple loosestrife).

What should we do about yesterday's invaders? Probably we should begin by determining their actual effects, and not fall into the trap of believing that they are entirely bad just because they are not native. Clearly, many are desirable. But others cause serious harm, so we don't want to welcome them with open arms. For demonstrably harmful species, we might determine what management options are actually feasible. Usually, region-wide control is not possible, and even local control may be expensive, ineffective, or have nasty side effects. As a result, management of yesterday's invaders may best be targeted at local programs to achieve specific goals. So while there is little hope of eliminating bush honeysuckle from North America, we might be able to control it on a nature preserve to benefit particular native animals and plants that it might be crowding out.

Today's invaders are just arriving in the Valley, either directly from overseas, or after first landing elsewhere in North America. These are the invaders most likely to make the headlines: Asian long-horned beetles (which threaten to cause tens of billions to *trillions* of dollars of damage to our trees), the infamous silver carp now making its way into the Great Lakes through the Chicago canal, and the Chinese mitten crab, which recently appeared in the Hudson River.

Although ecologists usually can roughly estimate the effects of today's invaders, it's difficult to predict precisely the extent and cost of the damage they will cause (note the wide range in damage estimates for the Asian long-horned beetle). So to avoid making costly and irreversible mistakes, we should control these species wherever possible, unless they are demonstrably beneficial.

Luckily, we have more options for controlling today's invaders than yesterday's. We can mount intensive campaigns to eradicate the most harmful of these species at the beachhead, as soon as they are detected. For instance, the New York Department of Environmental Conservation has been trying to eradicate the northern snakehead, a voracious predatory fish, from a lake in Orange County before it spreads out of control, and the U.S. Department of Agriculture has been engaged in a decades-long, multistate campaign, costing hundreds of millions of dollars, to eradicate the Asian long-horned beetle. We do not know if such programs will succeed, but they are much, much more likely to succeed in eradicating an invader than if we wait for it to become well established.

Even if we cannot eradicate today's invaders altogether, we often can slow their spread. Outreach targeted at boaters has probably significantly slowed the spread of zebra mussels (which even today have reached fewer than 10% of suitable lakes in the Great Lakes states), and erecting a barrier on the Erie Canal might keep the silver carp and other invaders from spreading from the Great Lakes to the Hudson.

Even though thousands of invaders have already come into North America, thousands more are waiting for their chance, lurking in ballast tanks of ships, pet shops, and plant nurseries. These pathways that will bring *tomorrow's* invaders to the Valley usually won't discriminate between desirable and harmful species. Because we know that some of tomorrow's invaders are capable of causing great harm to native species and our economy, it makes sense to control these pathways as much as possible. Fortunately, we have many options – technical, legislative, and educational – to improve control of tomorrow's invaders.

Somehow I doubt that Willie's lover ever came back, but his song does give us some insight into how we might deal with one of our most difficult environmental problems—and avoid heartbreak.

Poughkeepsie Journal, 31 January 2010

Alien Invasions

I watched a lot of scary movies as a kid. When I was little, I was most frightened by the big monsters – like the enormous ants that even the US Army couldn't destroy. As I got older, though, the insidious creatures bothered me more. Space aliens who came to town not in a huge spaceship, but on the Greyhound bus, and who looked and acted like real humans. These aliens would quietly take over, and by the time anybody realized what was going on, <u>it was too late</u>. You've seen the movie – aliens appear who look just like your neighbors, except that they can't stand the sunlight and have slightly webbed fingers. Our central character, a quiet, bookish fellow, is leaving the library when he notices the pretty young librarian's fingers. He rushes out into the street, eager to share his horrifying discovery, and everyone – from toddlers in strollers to the geezers on the park bench – is wearing sunglasses. Reeling with shock (the aliens are everywhere!), he flags down a passing sheriff's car. Once in the car, he spills out his story to the sheriff, who smiles, locks the doors (revealing webbed fingers), and drives off. The closing shot shows our hero pounding on the windows of the departing police car.

That's pretty much what it's like being a biologist these days. Alien species are traveling around the world by the most mundane means – cargo ships, pet stores, boat trailers, garden centers – quietly establishing themselves in streams and forests, and by the time we see what's going on, <u>it's too late</u>. They're causing billions of dollars in economic damages, permanently transforming our ecosystems, and spreading human disease. And unless we begin to take more effective action to curb these invaders, things could get a lot worse.

Biologists use the term 'aliens" for species that were carried beyond their native homes by humans, and then established themselves in the wild. Aliens include species that we've moved deliberately – carp, pheasants, and gypsy moths – as well as those that we've moved inadvertently – zebra mussels, West Nile virus, and many weeds. No one knows exactly how many alien species there are, but they are legion – more than 4000 species are known from the United States alone, and dozens more arrive every year.

Many of these aliens are harmless or even beneficial, but many cause harm. The basic problem is not that all alien species are bad, but that we don't adequately distinguish between good and bad species when we move them around the globe.

And the bad ones can be very bad. The emerald ash borer, a small insect that probably traveled from Asia to Detroit in untreated wooden packing material, has already killed tens of millions of ash trees across the Great Lakes region. It probably will spread across North America, killing almost all of the ash trees as it goes, and ultimately causing $7 billion in losses to street trees alone. A hitchhiker from southeastern Europe, the zebra mussel, has killed billions of native mussels in the Great Lakes and rivers, and may drive dozens of species of these imperiled animals into extinction. And the West Nile virus has caused about 30,000 reported illnesses and 1100 deaths in humans, and killed countless birds since it appeared in the United States in 1999. A very approximate estimate puts the economic costs of alien species at more than $100 billion per year in the United States, about the same as the wars in Iraq and Afghanistan, and experts believe that alien species endanger more of our native plants and animals than any factor other than habitat destruction.

So what is to be done? Some invaders can be controlled after we realize that they're causing problems, but like the body-snatchers of my childhood movies, most are difficult or impossible to control once they're well established. Instead, we need to do a much better job of keeping potentially harmful invaders from establishing themselves in the first place.

Here are a few places to start. First, we need to close the highways that alien species are using. This means better controls on ballast water of ocean-going ships, on packing materials used in shipping, and on plants, animals, and diseases brought in as part of the pet, aquaculture, and horticulture industries, as well as adequate money and people to enforce the regulations that we have. These controls need to be applied at the federal or even international level. Actions that have national-level consequences should be regulated at the national level, not by the patchwork of local regulations that now covers many aspects of alien introductions.

Second, we need better education to help people understand the potentially disastrous consequences of moving species around. After all, regular people create alien species problems by planting aggressive alien plants, releasing fish into new bodies of water, sneaking fruit across the border in their luggage, moving contaminated boats between lakes, and a hundred other everyday activities. People should realize that releasing alien plants and animals into the environment is an act of environmental recklessness comparable to tossing a lighted match into a forest.

Better public understanding of the enormous costs incurred by the careless movement of alien species is also essential for the third element of the solution – building the political pressure needed to deal seriously with alien species. Right now, dealing with alien species is far down on most politicians' "to do" list. So the next time you read about some plant or insect that is marching across the country, costing you money and endangering our native species, clip out the article, send it to your representative, and ask them "how could you let this happen?"

Speaking on behalf of the guys in the back of the sheriff's car, we biologists need your help, and we need it now.

written 19 May 2010 but not published

Requiem for a Tree (with Gary Lovett)

As you drive around Dutchess County this fall, try to get a look at the dusky yellows and purples of the ash trees, because they won't be around much longer. Ashes are among the first trees to change color; their subtle tones set off the deep red creepers in their branches. Ash trees also are valuable as timber (most famously for baseball bats, but also for flooring and many other uses) and are commonly planted as shade trees.

Ash trees are likely to disappear from Dutchess County and across all of North America as a result of the careless introduction of the emerald ash borer. This Asian insect probably traveled to Detroit in untreated wooden packing materials. Because it went undetected for several years, it was able to establish and spread beyond our control. Millions of dollars have been spent removing infested trees, treating trees with insecticides, quarantining infested areas, educating people about the dangers of moving firewood, and researching biological controls, but it now appears that the emerald ash borer will spread across North America and kill nearly all of our ash trees. The nuisance insect has already been seen in seven counties in New York (including Ulster and Greene). Unless a miracle occurs, it will soon appear in Dutchess County.

The ash die-off will affect all of us. Nearly 7% of all the trees in New York State are ashes, so there will be a lot of dead trees. The loss of this many trees will affect the character of our forests for years to come, and cost us dearly. For instance, the cost removing and replacing all of the ash trees planted along streets and in yards has been estimated at $8 billion, money that we will all pay in the form of increased taxes or checks to tree service companies.

And what is our government doing about this catastrophe? Federal and state agencies have been working hard to eradicate the ash borer or slow its spread. Last month, Senator Schumer was in the Hudson Valley to announce $1.5 million in federal funds to help "eradicate" the insect.

These well-intentioned but ultimately inadequate measures do not address the real problem: the careless movement of plants and animals around the world. Trying to stop the spread of established pests like the emerald ash borer is like trying to clean up the Gulf oil spill without capping the leaking well.

Careless human activities have already moved thousands of non-native species into the United States, and dozens more establish themselves each year. Many of these species cause ecological and economic harm. As long as we keep waiting until an invader has gotten out of control and causes huge damage, then defining the issue as "the ash borer problem," "the silver carp problem," or "the mile-a-minute vine problem," we are always going to be playing catch-up and will have few good options for solving these "problems". We need to start thinking about the next pest, not the last one.

And the emerald ash borer is just the latest in a long list of invasive forest pests and diseases that have wreaked havoc with our trees (chestnut blight, Dutch elm disease, hemlock woolly adelgid, and Asian longhorned beetle, among others) and caused tens of billions of dollars in damage. Many of these forest pests reach us on live plants imported for the horticultural trade or as unintentional stow-aways in untreated wood packing material (such as crates and pallets).

Both of these routes of entry should be shut off. First, we should ban the importation of live plants altogether. The horticultural trade will howl about this suggestion, but they reap all the profit from this trade while U.S. citizens pay the steep price of economic and ecological damage. Second, we need effective enforcement of existing laws that require wood packing material to be treated at its point of origin to kill insects such as the emerald ash borer. This would involve greatly beefed-up inspections at our ports and serious penalties for infractions. Third, we need to develop better networks for the early detection and rapid eradication of invaders. All of these steps could have prevented the ongoing ash disaster, and can prevent future disasters.

Think about this when you're taking a last look at the ashes this fall, or writing a check to replace the beautiful dying shade tree in your yard. And if you're sad or angry, or disappointed with our inability to wisely manage the beautiful world that we've been given, share your feelings with your elected officials.

Poughkeepsie Journal, 10 October 2010

The Ecosystem Strikes Back, or Return of the Natives

One of the best-known bits of folk-wisdom about invasive species is that they settle down after a while to become part of a rebalanced ecosystem, and stop being a problem. This is an appealing idea, but how often is it true?

It turns out that scientists don't have very good answers to questions like "do the impacts of invasive species diminish after a while?", "how long does this take?", "how much do impacts diminish – a lot or a little?", or "what causes the impacts of an invader to diminish?" We haven't been able to watch many invasions continuously for a long time (funders prefer short studies to long ones, alas), so questions like these are among the biggest unanswered questions in invasion ecology.

Our group at the Cary Institute is watching an interesting example right now. The impacts of the zebra mussel invasion on the Hudson River ecosystem seem to be diminishing, just 20 years after this invader appeared in the river.

The zebra mussel is a European species that came to North America in the mid-1980s in the ballast water of ocean-going ships. It was first seen in the Hudson in 1991. By the end of 1992, zebra mussels outweighed all other animals in the river, and their population filtered a volume of water equal to all the water in the river every 1-2 days.

As a result, plankton populations fell by 50-90%, which caused large changes to the food web, water chemistry, and water clarity. In fact, nearly everything that we measure about the ecosystem changed when zebra mussels appeared.

But now it looks like these changes might not be permanent. Since 2000, some parts of the Hudson's ecosystem have begun to recover. Populations of native mussels, which were falling by 20-60% each year, stabilized and even began to increase. Numbers of crustaceans, worms, and other small invertebrates fell by about 50%, then came back nearly to pre-invasion levels. This is especially welcome news, because these animals are the chief food of most of the Hudson's fishes.

So have zebra mussels disappeared from the Hudson? Hardly. Billions of these animals still live in the river. But they're not having an easy time of it – their survival rates are now less than 1% of what they were in the early 1990s. As a result, most of the remaining zebra mussels are young and small, which must soften their impacts on the ecosystem.

We are still trying to understand what is causing these dramatic changes to the Hudson's ecosystem. Blue crabs are part of the story. They are eating many more zebra mussels than they used to, and are responsible for part (but not all) of the increased mortality on zebra mussels. There is certainly more to the story than blue crabs, though, and our group is now trying uncover the rest of that story.

So can we conclude from this study that the impacts of zebra mussels and other invaders last for just a few years, and aren't worth worrying about? As intriguing as our results may be, I am not ready to reach this conclusion, for three reasons.

First, we don't know whether the Hudson's recovery is permanent, or whether the ecosystem will slide back into a zebra-mussel dominated state. Second, even if the Hudson recovers fully and permanently in the next few years, zebra mussels did cause large ecological changes and economic damages in the Hudson for 20 years. These impacts seem too large simply to dismiss (think how we would react if some industrial polluter caused such changes for 20 years!).

Finally, regardless of what happens with zebra mussels in the Hudson, we know that many invaders don't settle down so quickly. Our yards and gardens are still full of dandelions, Japanese beetles, and European slugs; chestnut blight and Dutch elm disease still ravage our forests; and carp and water-chestnut still thrive in our waterways, even though these invaders have been here for decades to centuries.

So what we can actually conclude is that some invasions may settle down fairly quickly, while others may have severe effects for centuries or longer. It also seems likely that this problem will keep invasion ecologists busy for a while.

Poughkeepsie Journal, 24 April 2011

Welcome, Freddy, or Letting the Pig Out of the Poke

We've all been to movies where the characters do something stupid and dangerous – something no reasonable person would do ("let's split up and search the old barn!"). Sometimes this is just the result of a cheesy script, but sometimes the characters don't recognize their situation as dangerous – they think it's just an ordinary tendril, or an old rust stain, or that nice neighbor boy dressed up in a hockey mask.

We're acting like those foolish movie characters right now by failing to recognize growing populations of non-native wild boars in New York as a menace. Private hunting preserves in New York release wild boars for "trophy hunters" to shoot. This benefits just a tiny population of hunters and the game preserves themselves, while presenting serious risks to the public.

The boars easily escape from these preserves and have now established breeding populations in New York. These wild pigs tear up the forest like Roto-Tillers, causing soils and stream banks to erode and killing ground-nesting birds, wild flowers, and other native plants and animals. They damage crops, and carry diseases like brucellosis and pseudorabies that can spread to domestic livestock. Wild pigs may even harm human health – there is good evidence that wild pigs may have been involved in the contaminated spinach from California farms that sickened so many people across the US in 2006 (and of course they may chase you down and gore you!)

The solution to this potentially large problem is to prohibit hunting preserves from releasing wild boars and aggressively eradicate the population that has established itself outside of the preserves. If we fail to do so, we may be looking at large damages to agriculture, forest ecosystems, and water resources, and millions of dollars in losses and control costs in the future.

Why did we allow this situation to develop, and why aren't we fixing it? When new industrial development (like drilling in the Marcellus shale) is proposed, we rightly are concerned with its possible impacts, and try to ensure that its long-term costs to the public don't outweigh its short-term benefits to the few.

For some reason, we don't often subject plans to move species around to the same scrutiny, even though the careless movement of species probably has cost more human lives, environmental damage, and lost dollars than industrial developments. If this claim seems extravagant, consider the human deaths and suffering caused by the movement of European diseases into the New World, or the arrival of the potato blight into Ireland in 1845. Or consider the ecological havoc that resulted when escaped European rabbits ate their way across the Australian landscape, or when blight removed chestnuts from our eastern forests. And if you think these are just isolated catastrophes too rare to worry about, then let me remind you of the multibillion dollar damages now piling up from the ongoing invasion of the emerald ash borer, the ecological and economic damage from zebra mussels, the deaths of millions of hemlock trees in the East and oak trees in the West, the spread of disease-carrying mosquitoes around the world, or a thousand other examples.

Shouldn't a human activity with such large risks for the public be given our most careful scrutiny?

I don't know why we don't recognize that moving species around is dangerous – perhaps our long association with agriculture has led us to regard species as benign, despite so much evidence to the contrary. I don't know how we can get over this misleading way of thinking, and start treating species introductions with the caution that they deserve.

Come to think of it, I don't even know how we can deal with the wild boar problem in New York before they spread out of control, damage our natural resources, and cost us millions of dollars. I suspect that some sharp letters to the elected officials who are supposed to be safeguarding our natural resources and tax dollars might be a good start. Tell them Freddy Krueger is knocking at the door.

Poughkeepsie Journal, 4 June 2011

More Action is Needed to Stop Invasive Species

Humans have carelessly moved thousands of species outside their native ranges through activities such as transfer of ballast water, release of pets and bait, movement of untreated wood, escapes from agriculture and aquaculture, and deliberate release of species that we thought to be beneficial. Many of these species have had large, unwanted impacts on ecosystems, economies, and human health. We don't have a good comprehensive accounting of the total effects of invasive species in New York, the United States, or the world. However, we do know that invasive species are one of the most important ways that humans are changing ecosystems all around the world, that they cause enormous economic damages (estimated to be more than $100 billion per year in the United States alone), and that they harm and kill Americans every year. We also know that New York is one of the most heavily invaded parts of the world, and suffers disproportionately from the impacts of invasive species.

Invasive species can cause large changes to our ecosystems

Even a single invasive species can turn an ecosystem upside-down. Let me illustrate this point by describing how the zebra mussel changed the Hudson River. Our research group has been studying the Hudson continuously since before zebra mussels arrived, so we have good measurements of zebra mussel impacts. Zebra mussels are small mollusks native to Europe that came into North America in the mid-1980s, probably in untreated ballast water. They first appeared in the Hudson in 1991, and by the end of 1992 had reached a population of 550 billion animals. This population weighed more than the combined weight of all other animals (fish, zooplankton, insects, native shellfish, etc.) in the river. Zebra mussels have remained abundant since then. Zebra mussels are filter-feeders, and the huge population in the river filtered a volume of water equal to all of the water in the Hudson every 1-4 days. As a result, the amount of plankton in the river dropped by 80%. Because plankton is one of the important foundations of the food web, many other species were affected. For example, 1000 tons of fish food disappeared (this amounts to half of all the fish food in the river). One result of this was that the number and growth rate of Atlantic shad dropped substantially. This fish is doing so poorly that the historically important commercial and recreational fisheries for this species were closed for the first time ever in 2010, and the zebra mussel has just added to its problems. Zebra mussels changed nearly everything that our group measures about the Hudson – water chemistry, water clarity, and the populations of many other plants and animals in the river. Humans have done many things to the Hudson over the years, but it is hard to argue that any had a greater impact on the ecosystem than the introduction of this one invader.

New York is filled with invasive species and receives more every year

The zebra mussel is not the only species that humans have brought into the Hudson. A study led by Professor Edward Mills of Cornell University found that the fresh waters of the Hudson River basin contain more than 120 non-native species. Six or seven new species arrive each decade. Just in the past few years, we've seen snakehead fish, hydrilla plants, Chinese mitten crabs, and Asian clams appear in the Hudson basin, all species capable of ecological and economic harm.

And it's not just the Hudson that's being invaded – every assembly district in the state now suffers economic and ecological damage from established invaders, and is endangered by new invaders waiting at the doorstep. New Yorkers living in cities and suburbs probably will pay billions of dollars to remove and replace ash trees killed by the emerald ash borer, communities along the Great Lakes and Finger Lakes are seeing valuable fish killed by viral hemorrhagic septicemia, the autumn tourist and maple sugaring industries are imperiled by the spread of the Asian long-horned beetle, our farmers have to deal with stink bugs, and plum pox, and now wild boars, hundreds of New Yorkers have been sickened and dozens killed by the West Nile virus, and so on and so on.

There are many good opportunities to reduce the spread and impacts of invasive species

There is no good reason why we should continue to endanger our ecosystems, our economy, and our health by continuing to allow invasive species to move freely around the globe. It is often said that species invasions are an inevitable consequence of globalization. I suppose that is true, in the same sense that pollution is an inevitable consequence of industrialization. But just as we know that we can have careless industrialization with a lot of pollution or careful industrialization with little pollution, we can have globalization with many damaging species invasions, or globalization with a few damaging species invasions. And just as we have learned for pollution, it is usually much cheaper to prevent problems with invaders than to clean them up after they occur.

We have many good tools to reduce the movement and impacts of invasive species, but we need to use them. We can treat ballast water, keep potentially harmful species out of the pet, horticulture, and aquaculture trades, stop moving untreated wood, better inspect our ports of entry, and educate the public. Here in New York, we have made a good start with the Invasive Species Council, the Office of Invasive Species Coordination, and the programs they oversee, but these programs have too few people and too little money to take advantage of all of the good opportunities we have today to better manage invasive species.

I worry that our children and grandchildren will some day look out onto a world filled with undesirable and unmanageable invasive species, as they pay bills for problems that we created, and wonder why we did so little when we understood very well that invasive species were a problem and had the tools to stop them. Why are we doing so little?

Poughkeepsie Journal, 19 November 2011 (based on testimony presented to the Environmental Conservation Committee of the New York State Assembly)

Pets Gone Wild

I write today about the science and politics of snakes. You may have heard that non-native Burmese pythons (probably released by a pet owner) are now established in Florida's Everglades, where they have developed a taste for the local cuisine. A just-published study shows that local wildlife populations plummeted following the spread of these 18-foot-long predators. Roadkill surveys (now there's an attractive job) show that raccoons and opossums are down by 99%, deer are down by 88% (probably not entirely a result of the pythons, although they do eat deer as large as 76 pounds), bobcats are down by 88%, and rabbits have disappeared entirely. Biologists have captured and killed 1500 pythons in the Everglades, but this hasn't stopped their spread, and they probably are here to stay.

Another recent scientific study emphasizes that the escape of these pythons is not an isolated occurrence, but part of a larger pattern. An amazing 137 species of foreign reptiles and amphibians have been introduced into Florida, of which 56 species are now established in the wild. Many of these species were first found right outside poorly secured animal importation and breeding facilities, from which they crawled, hopped, or slithered to freedom and into our wetlands and back yards. The pet trade and its customers are leaking species across Florida and across the country.

Of course, most of the animals released from the pet trade die in nature, or do not cause problems even if they do establish. But as the pythons remind us, some species do cause big problems and are hard to control.

A more local example of "pets gone wild" reinforces this point. Northern snakeheads, Asian fish widely sold by pet stores, apparently were released into Ridgebury Lake in Orange County, where they began to reproduce and spread. Snakeheads are large predators that could spread through the Hudson Valley and beyond and cause large impacts to our ecosystems. Consequently, DEC decided to try to eradicate this population. The eradication effort in 2008-2009 killed 250 snakeheads and eight tons of other fish and cost at least hundreds of thousands of tax dollars. Now we're all hoping that it worked, so that we're not facing larger damages in the future.

So what ought we to do about all of this?

In response to the situation in the Everglades, the federal government last month finally prohibited the importation and interstate transfer of Burmese pythons. This action is years too late, and will probably be just slightly more effective at stopping the invasion than standing at a window and singing "rain, rain, go away" to stop a summer rainstorm.

Here are some options. First, we could continue with business as usual. This is easy, maximizes profits for the pet trade (an important and valuable industry), and allows pet owners to buy whatever they like. When harmful ex-pets do cause problems, we all pay to clean them up, and just accept the ecological and economic problems that result when we can't clean them up.

Second, it might sound appealing to make pet breeders and pet owners pay when their pets escape and cause problems. However, once a problem arises, it rarely is possible to track down the person who released the problematic pets years earlier. Also, few pet owners have deep enough pockets to pay for the huge damages that result when things really go bad.

Third, I suppose we could impose a small tax on the pet industry to set up a standing fund to pay for programs to educate pet owners about the dangers of releasing unwanted pets, campaigns to control or eradicate unwanted escapes, and compensation for damages suffered as a result of escaped pets.

Finally, we could develop a rational national approach that would allow the pet industry to import and sell only species that can be shown to be unlikely to survive in the wild or be benign if they do escape.

Whatever we decide to do, it would be nice to have some policy that is fair and effective at minimizing problems from escaped pets, instead of just wringing our hands each time a problem arises.

Poughkeepsie Journal, 25 March 2012

How Do You Solve a Problem Like Invasives? (with Gary Lovett)

Nearly every day, we read about problems caused by invaders like the emerald ash borer killing trees across New York, West Nile virus killing people across the US (1499 so far), zebra mussels clogging water intakes and changing the Great Lakes and Hudson River ecosystems, and Burmese pythons eating everything in the Everglades. If you're like us, you probably are upset by the billions of dollars in economic costs, thousands of human deaths, and deep and irreversible ecological damage that these species cause. But what can any of us do to solve the problems caused by invasive species? Here are a few suggestions for how you personally can help solve this problem.

Don't add to the problem by releasing potentially harmful new invaders into the wild. Don't buy exotic new plants for your garden, unless they are already widely planted in your region or have been positively shown to be harmless. Many of our most problematic invaders started out as "desirable" garden plants, or as insects or diseases hitchhiking on those plants.

Likewise, don't release pets into the wild or dump your aquarium or bait bucket. Every year, thousands of unwanted pets are dumped into the wild. Besides being cruel to the pets, some of them (like the Burmese pythons in the Everglades and the snakeheads that turned up in Orange County) end up creating big problems.

And don't try to smuggle fresh produce, live plants, or cute pets past the customs officials into the US. We know you're thinking "what harm could one little plant cause?", but some of these smuggled items, or the diseases that they carry, get out into the wild and cost us big bucks.

Don't move dirty stuff into clean environments. For example, moving insect-infested firewood (and yes, most firewood is insect-infested) or boat trailers festooned with aquatic plants into regions not infested with pests are good ways to speed the spread of problematic invaders across the country. Don't move firewood, and always clean your boat and trailer before launching them into a new lake or river. And use some common sense about other practices that may move items contaminated with invaders from place to place.

Here are a few things that you needn't worry about. You don't need to go out and kill all of the non-native species in your yard, if they are harmless or already widely distributed in the region. It's OK to plant non-native species that are already well-established in the region. Even though invaders like oriental bittersweet and Japanese barberry certainly cause problems, they are so widely spread through the Hudson Valley that one or two more or less in your yard won't make any difference in the bigger picture. You don't need to bother with weed pulls intended to rid the world of well-established species, because it is very unlikely that they will succeed. However, you could help with campaigns that have specific, attainable goals, like removing an aggressive plant from a sensitive nature preserve, or pulling water-chestnuts from a bay to allow boat access.

But we are not going to solve the invasive species problem with just these individual actions. Too many harmful species are coming into the country through pathways like ballast water and the pet and horticulture trades, which are not easily controlled by our individual actions. We need collective action to adopt and enforce laws and regulations to prevent the import and spread of harmful invaders.

You can help to spur these collective actions by writing to your elected representatives or to advocacy groups that are concerned with protecting the environment. Tell them that you're concerned about our inadequate responses to the challenges of invasive species, or express your opinions about specific proposals for new laws or regulations. (If you don't know what laws or regulations are being discussed, visit the web site of the National Environmental Coalition on Invasive Species at http://www.necis.net/, which keeps track of important news about invasive species).

Your letters can serve as an important counterweight to powerful industry forces that are looking out for their own narrow interests at our expense. Even if you don't know about specific legislation, your expressions of concern can at least get your elected official to start thinking about (or maybe even fixing) this problem. You can help solve this important environmental problem.

Poughkeepsie Journal, 16 December 2012

Are Invasive Species Killing Us?

Are invasive species killing us? This question must sound a little over the top if you think that invasive species are just garden pests, but history is filled with examples where they've killed humans. West Nile virus has killed more than 1500 people since it arrived in the US in 1999, the potato blight (an invasive fungus) led to the starvation of more than a million people in Ireland, and newly introduced diseases like smallpox may have killed as many as 80-90% of the indigenous peoples of the Americas. So yes, invasive species kill people, and lots of them.

Today, I want to look at a more subtle way that invasive species may be killing us. The emerald ash borer is a small insect accidentally brought to the US from Asia about 20 years ago. It has killed millions of our ash trees and will kill millions more all over North America. Now a new report in the American Journal of Preventative Medicine suggests that it may also have killed more than 20,000 Americans.

This study was based on a careful analysis of death records in counties with and without ash borers, before and after the borer invasion. The study found that invaded counties had more than 20,000 extra deaths after the borers invaded (but not before), even after accounting for factors like income, age, and ethnicity. The authors are quick to caution that this association does not prove that the ash borers *caused* people to die. It is just the most obvious explanation.

How can this be possible? The borers don't attack people, and the dead people weren't killed by falling branches. Instead, the authors of the study suggest that extensive losses of ash trees caused beauty and environmental quality to decline in affected areas, which led to 20,000 extra human deaths from cardiovascular and respiratory problems.

Many scientific studies have shown that people benefit from trees and other contact with nature. Contact with nature can reduce stress, reduce pain and speed healing in surgical patients, and produce healthier babies. People exercise more if their neighborhood has lots of trees. Street trees improve air quality in cities. Studies like these suggest plausible links between the invasive insect, the dying ash trees, a decline in environmental quality, and more human deaths.

I can think of two reasons why this sort of thing is so poorly appreciated. First, the links between nature and human well-being are complex and indirect. It doesn't take a fancy study to see the causal link between a knife and the death of someone found with that knife between his shoulder blades. However, such deaths from a single, obvious cause are less common than deaths from multiple indirect causes. It's much harder to ascribe a cause of death to someone who succumbs to cardiovascular disease that was a result of many factors – age, genetics, diet, lifestyle, and now the loss of street trees. But these 20,000 people are dead just as surely as if they had turned up with knives in their backs.

Second, nature is owned by everyone and by no one. No individual or company makes money if trees and parks keep people a little healthier, so there is no immediate reward for anyone to conduct or highlight studies show how nature benefits human health.

In contrast, if Merck owned nature, so that you had to come up with a co-pay each time you went for a walk or sat by the bank of a brook, you can bet that there would be plenty of research studies on the benefits of contact with nature. And we'd hear about the health benefits of nature all the time. "Do you suffer from depression, stress, or cardiovascular problems? Ask your doctor if a walk in the park could be right for you. Side-effects may include sprained ankles, mild sunburn, and mosquito bites."

So this new study reminds us of two truths that we should not overlook. First, we need to be careful about invasive species because they really can kill us. Even more important, it is worth jealously guarding the quality of the environment around us, even in cities (or maybe, especially in cities) because it affects us in the most profound and personal way – through our own health.

Poughkeepsie Journal, 31 March 2013

Beware Marauding Carp (with John Waldman)

Earlier this month, researchers demonstrated that a Eurasian species of fish, the grass carp, had begun reproducing in Lake Erie. This may not sound like alarming news, but unless we take steps to prevent its spread, this animal is poised to disrupt the ecology of the Hudson River and New York's other inland waters.

Grass carp are like underwater lawn mowers. They reach nearly five feet in length and 100 pounds in weight and are so efficient at consuming vegetation that they have been stocked all over the world as "biocontrols" for problematic weeds. But as with so many misguided introductions, the grass carp will spread out of control. Now that they are in Lake Erie, it is just a matter of time before they swim east to the Hudson River along the Erie Canal.

In the Hudson River, aquatic vegetation helps underpin the food chain and provides essential habitat to fish and wildlife. About half of the river's original aquatic vegetation was destroyed during the 19th and early 20th centuries by dredging and filling to improve the shipping channel, and the vegetation that remains faces serious threats from storms and the rising sea level. The establishment of a large population of grass carp, a fish that flourishes in large, turbid rivers like the Hudson, could further endanger this habitat and decimate the river's already embattled native fishes.

More than just the Hudson is threatened. Similar problems could occur in other waters along the course of the Erie Canal, including the Finger Lakes and Oneida Lake, which also contain valuable beds of aquatic plants.

This has happened before. In 1986, Eurasian zebra mussels first appeared in the United States, in Lake Erie, having been transported inadvertently in the ballast water of commercial vessels. The zebra mussels spread quickly, and in 1991, they were discovered in the Hudson. Just one year later it was estimated that 550 *billion* zebra mussels inhabited the river. This eruption of zebra mussels disrupted the workings of the river's ecosystem, depleting the phytoplankton at the base of the food chain by more than 75 percent and cutting populations of its fish by as much as 60 percent.

The grass carp is not the only new invader waiting to use the Erie Canal. Two other Asian carp species now swimming into the Great Lakes through the Chicago Canal are likely to use the Erie Canal as they move east to the Hudson, where their appetite for plankton will threaten the food supply of what remains of the once huge shad population in the river. In coming decades, many other potentially harmful species that have arrived through purposeful or accidental introduction are positioned to use the Erie Canal and cause problems for New York's lakes and rivers.

Fortunately, there still is time to stop the grass carp from invading the inland waters of New York. One solution would be to recreate the natural barrier between Lake Erie and the Hudson River by building a barricade along the Erie Canal that would allow essential canal operations like recreational boat passage while impeding the movement of invaders.

Various types of such barriers have been proposed or installed on canals around the world. This has involved replacing traditional canal locks with hoist or rail systems, chemical or electric barriers, or bubble screens (which deploy a thick wall of air bubbles that impede the movement of mobile creatures). The barrier best suited to the Erie Canal should be determined by a study of alternatives that considers their costs, compatibility with canal operations and effectiveness against invasive species.

Now is the time to perform such a study. Too often, people consider canal barriers only in a crisis, when an invader is already in the process of moving through the canal. Such delayed crisis planning often leads to hurried and flawed designs, wasteful spending and ineffective control of invaders.

Led by groups like the New York State Department of Environmental Conservation and the United States Army Corps of Engineers, and with the assistance of other conservation organizations and scientists, we need to develop and implement a plan that maximizes the benefits that the Erie Canal can provide to New York, while minimizing the risks from the spread of the grass carp and other harmful invaders. The zebra mussel has demonstrated how much ecological damage one species can cause, and the growing international record shows that invasive species are rarely eradicated once established.

We must do this now, before the carp take this decision out of our hands.

New York Times, 19 November 2013

World of Species Right Here on the Hudson

If you want to see plants and animals from around the world, you don't have to go to the zoo or botanical garden – just visit the Hudson River. When you get out of your car, you see common reed (phragmites), false-indigo, and purple loosestrife growing along the edges of the parking lot. A mute swan glides by a big bed of water-chestnut along the shore, and anglers are catching largemouth bass and channel catfish. Carp splash in the shallows, and if you pick up a rock at the water's edge, you'll see zebra mussels and faucet snails. And these are just a few of the dozens of species from other parts of the world that now make their homes in the Hudson.

How did all these species get here? Many, such as the water-chestnut, carp, and mute swan, were brought here deliberately by people who thought that these species would improve our lives. It turns out that we aren't very good at telling which of these "beneficial" species are going to turn out to be trouble. For instance, one of the men who brought us the water-chestnut wrote "but that so fine a plant as this, with its handsome leafy rosettes, and edible nuts, which would, if common, be as attractive to boys as hickory nuts now are, can ever become a nuisance, I can scarcely believe". (I know about a thousand boaters and ecologists who would like to travel back to the 19th century to talk some sense into this guy.)

Other species weren't intentionally released into the wild, but got into the Hudson through careless human activities. Zebra mussels came to North America in untreated ballast water, rudd (a big minnow) and rusty crayfish probably were spread by releases from bait buckets, and oriental weatherfish and Chinese mystery snails came in when people got tired of their aquariums and dumped them into local ponds and streams. Plants like purple loosestrife and common reed escaped from gardens, or came as contaminants of agricultural seeds or solid ballast.

An activity of special relevance to the Hudson was the linking of the Hudson with Lakes Erie and Champlain through canals. These canals have no provisions to block the movement of species, so animals like the freshwater drum came through canals into the Hudson.

What all of these activities had in common is that the people engaged in them gave little or no thought to the ecological and economic consequences of moving species into the Hudson. They thought that they were just bringing us a valuable plant or animal, or being kind to an animal in a bait bucket or aquarium, or allowing wheat to be shipped from the Genesee Valley to New York City. Instead, they permanently added species to our landscape, with ecological or economic effects that may last for centuries.

And what effects <u>have</u> these species had on the Hudson? People often emphasize the negative effects of nonnative species, and indeed many of the Hudson's invaders caused serious problems. Zebra mussels foul pipes and boat hulls, and divert food from species like shad. Water-chestnut crowds out the native wild-celery, and prevents boaters, anglers, and swimmers from using coves and bays along the Hudson.

On the other hand, some of the invaders are beneficial, or at least have some beneficial effects. Nonnative largemouth and smallmouth bass are among the fish most sought out by anglers in the Hudson, and invasive plants like common reed and water-chestnut help to prevent nutrient pollution.

Finally, many or most of the nonnative species in the Hudson are so rare that they probably have little or no ecological or economic effects, either positive or negative. In aggregate, though, nonnative species have caused large, long-lasting changes to the river. Many of these changes are negative, and none of them were carefully considered when the species were brought in.

This cavalier attitude towards species invasions was perhaps excusable in the 19th century, when people didn't appreciate the value of the Hudson River ecosystem or the long-term consequences of species invasions. It seems unworthy of us today. We know what careless activities are bringing new species into the Hudson, and we know how to reduce the number of species that these activities bring in. It would be nice if our grandchildren had to go to the zoo, not down to the river, to see the next generation of damaging invasive species.

Poughkeepsie Journal, 6 July 2014

Will Any Eft Be Left?

It's a tough time to be an amphibian. Countless millions of frogs, toads, and salamanders around the world are dying from two emerging diseases. The first plague appeared in the 1990s, and is so deadly to amphibians (especially frogs) that it is causing "the most spectacular loss of vertebrate biodiversity due to disease in recorded history".

Now, a second fungal disease has turned up in Europe. This disease kills many kinds of salamanders, including the red-spotted newt and eft that is so common here in the Northeast. This new salamander disease probably will move to North America, too, if we continue business as usual.

It's ironic that these terrible diseases are being spread by some of the people who most love amphibians. Although the export of frogs for food and medical purposes was important in the origin and spread of these diseases, both of them appear to be moving in the inadequately regulated pet trade.

People who like frogs, toads, and salamanders don't just keep tadpoles from their local pond any more, but animals from all around the world. And the number of imported animals is staggering: it was recently estimated that importers brought 200 million live animals a year into the US for pets, 4 million of them amphibians. Not surprisingly, few of these animals are adequately inspected, many are misidentified, and some carry disease.

Why do we care if amphibians die? Well, first, amphibians are an interesting part of life on earth, so we may simply miss them when they disappear. I know that I would miss seeing efts trundling over the forest floor. Second, at least some people think that we have a responsibility to be a good steward for the Earth and its life, which would not include killing off its amphibians. Third, it is likely that amphibians play important roles in ecosystems globally, even if those roles are not yet well understood. Here in northeastern forests, there can be as many salamanders (by weight) as birds or mammals, so they must have a prominent role in the food web.

So these losses make the world a poorer place, and change the world's ecosystems in ways we don't understand. And what benefits did we receive in exchange for these losses and risks? A cure for cancer? World peace? No, it just costs a little less to buy exotic pets. Really? I don't know about you, but I want a better price if I'm going to sell the natural heritage of my planet.

These amphibian diseases are only part of the cost of a carelessly run pet trade. The pet trade brought us Burmese pythons for the Everglades, snakehead fish for the Potomac, and a thousand other problems, and diseases of humans as well as wildlife (who remembers monkeypox?).

And at the core of all of these cases, there is what seems to me to be a fundamental unfairness. The pet industry engages in risky or careless practices so that it can increase profits and offer cheaper pets to the few people who want exotic pets, In contrast, when problems inevitably arise, all of us pay, either through our tax dollars or the loss of our shared natural resources.

Here are some things we could do to fix the problems caused by the pet trade. (1) Make it illegal to import any species until independent scientific studies show that it is unlikely to cause ecological, economic, or health problems if released into the wild. (2) Insist that shipments of live animals from outside the US be inspected by an independent agency, paid for by the industry, to verify that animals being shipped are correctly identified and free of disease. Violators should receive stiff fines and sanctions. (3) Provide better education for pet owners of all types so that they understand that releasing unwanted pets into the wild is a reckless and irresponsible act akin to tossing a lighted match into a dry forest. (4) Offer shelters for all unwanted pets, not just cats and dogs, where they can be re-adopted or humanely destroyed, so that pet owners have a good alternative to releasing unwanted pets into the wild.

In the meantime, you may want to ask your congressperson where they stand on H.R. 996, a stalled attempt to address these problems.

Poughkeepsie Journal, 23 November 2014

Successes and Failures in Invasive Species Management

A story circulating this month about the eradication of a population of the Chinese pond mussel (*Sinanodonta woodiana*) has been offered as an example of a success story in invasive species management. But when I read this story, I was left feeling that I had learned more about the failures of contemporary non-native species management than its successes.

Here's the basic story. In 2007, the New Jersey Conservation Foundation bought some property that included several ponds. Three years later, they found that the ponds contained Chinese pond mussels (*Sinanodonta woodiana*), a species that has been spreading around the world via aquaculture, escaping from captivity, and causing ecological problems. In the fall of 2019, the mussels were killed by lowering the water level in the ponds and poisoning them with copper.

I was happy to hear that this mussel population was removed, apparently before it spread. In that sense, this *is* a success story. But the larger story here is about the multiple management failures that led to the need for the eradication of 2019.

Let's catalog these failures. First, according to the news story, the mussels were found in 2010, but not removed until 2019. A nine-year lag may count as a rapid response in the bureaucratic world, but not in the biological world, where nine years can easily allow a non-native species to reproduce and spread beyond the point of feasible control. It is a triumph of good luck rather than good management that the ponds weren't breached in a large storm or mussels weren't carried out of the ponds and planted in a nearby lake by a curious nature-lover during those nine long years. Unfortunately, delays like this are common in jurisdictions across the US, which lack both the legal authority and logistical means to carry out rapid responses on a time-scale that matters to biology rather than bureaucracy.

Second, the "early detection" of this mussel was a result of a random sighting rather than any organized surveillance. We don't actually know how long the mussels were living in the ponds before someone noticed them because no one was looking. It is widely appreciated that early detection and rapid response is more effective than trying to control a non-native species only after it has spread widely and caused problems. However, we still have few organized programs to detect non-native species before they spread widely. "Hoping that somebody notices" is not an early detection system to be proud of, but it is still the system that we largely rely on.

Third, the mussels came to the US as parasitic larvae attached to their host fish, the bighead carp (*Hypophthalmichys nobilis*). Yes, this is the same Asian carp that has spread through the Mississippi River basin, displaced native fishes and inspired those jumping carp videos. We're now spending hundreds of millions of dollars to keep this fish out of the Great Lakes. How is it possible that someone in New Jersey was able to import such a harmful species? The answer is that we still don't have either the legal controls, inspection, or enforcement in the US to keep damaging non-native species from being imported through pathways like the pet, aquaculture, and horticulture trades.

Fourth, as icing on this SNAFU cake, the existence of the mussels tells us that the carp brought to New Jersey were not clean, but infested by parasites when they were transported to the US. In fact, this story makes me wonder whether those carp were carrying any other fish diseases or parasites that might even now be working their way across New Jersey. Despite the long, sad list of non-native pathogens, from chestnut blight to the fungus that causes sudden oak death, that have arrived and caused problems in the US, we still don't have adequate inspections to verify the hygiene of plants and animals imported into the US.

So, yes, we should applaud the NJCF, USFWS, and their partners for eradicating the Chinese pond mussel from New Jersey, and we should learn from this example. But the lesson we need to learn is not how to successfully manage non-native species, but rather how unsuccessfully we are managing them, and how we must do better.

Cary website, 9 January 2020

It's Time to Reimagine Spread of Harmful Aquatic Invaders

Last month's discovery of round gobies in the Hudson should remind us of our failures in invasive species management and spur us to do better. Today, New York has a rare opportunity to use the "Reimagine the Canals" initiative to slow the spread of harmful aquatic invaders.

Round gobies are small European fish that hitchhiked into the Great Lakes in the untreated ballast water of oceangoing ships. Since their appearance in 1990, they have spread throughout the Great Lakes, using canals to invade the Illinois River and now the Hudson.

Gobies have thrived in the Great Lakes, exceeding 1 per square foot in favored habitats. *Billions* of the fish now live in Lake Erie. Their impacts are many and varied. Gobies feed heavily on invasive zebra and quagga mussels, although rarely enough to suppress mussel populations. They displace small native fishes like darters and sculpins, but are also a favored food for many predators.

The effects of gobies on their predators are complex, however. Growth rates of goby-eating smallmouth bass have increased, but so has egg predation on smallmouth bass nests. If an angler catches a bass that is nest guarding, even if the fish is quickly released, gobies can swoop in and eat as many as 4000 eggs in 15 minutes. This has led to closures of the popular recreational bass fishery during nesting season in May and June.

Gobies accumulate toxins from their prey and pass them up the food chain to predators (and people who eat them). Thousands of loons and other waterbirds in the Great Lakes have died following the goby invasion, the victims of botulism toxin passed from mussels to gobies to waterbirds.

We do not know how gobies will affect the Hudson ecosystem, but large, harmful effects are possible. The Hudson's imperiled sturgeons, the fishes of rocky shores, and fish-eating waterbirds are especially at risk. If gobies reduce zebra mussels in the Hudson, harmful algal blooms may increase.

Shortcomings in ballast water and canal management allowed gobies and many other invaders to reach the Hudson. National and international action is needed to correct weaknesses in ballast water management. This includes reducing releases of untreated ballast water from overseas and between Great Lakes ports.

In contrast, New York is able to block invasive species movement through the Erie Canal. We have long known that canals are highways for invasive species, but have been slow to install barriers. Press reports that the "Reimagine" initiative had been considering invasive species barriers have led to concerns that that the canal would be closed. It is not necessary to close the canal to install barriers to slow invasive species. Depending on the design and purposes of a canal, a wide range of options for barriers are available (e.g., replacing a lock with a hoist or rail system, behavioral deterrents such as electric fields or bubble curtains to discourage fish movement) and have been used in working canals around the world.

The "Reimagine the Canals" initiative is a perfect chance to evaluate which of these approaches best fits the Erie Canal. We missed the chance to keep gobies bottled up in the Great Lakes, but barriers on the Erie Canal could stop or slow the arrival of even more damaging invaders (e.g., grass carp, bighead carp, silver carp) now on their way towards the Hudson.

The establishment of every new harmful invader in our region, from ash borers to zebra mussels, diminishes the benefits we receive from our natural resources. But it also represents an opportunity to change our practices to stop the next harmful invader. Let's seize that opportunity.

Albany Times-Union, 25 August 2021

Invasive Gobies in the Hudson River

The news that round gobies were just found in the Hudson River raises questions about how these invaders will change the Hudson ecosystem. It also reminds us that weak policies on invasive species needlessly risk the future of our natural resources.

The round goby is a small fish from southeastern Europe that was carried into the Great Lakes in untreated ballast water of an ocean-going ship. Since its first appearance in 1990, it has spread through the Great Lakes basin and into the Illinois River. It can be abundant, especially in the rocky shallows, where populations may exceed 1 per square foot.

Adult round goby (Wikipedia)

Round gobies have wide-ranging ecological impacts in the Great Lakes. They force out small native fishes like sculpins and darters, and eat eggs and young of many fish species. In turn, many predators eat gobies. In some cases, this benefits the predators, resulting in faster growth rates for smallmouth bass, and more and bigger water snakes (something I know you're looking forward to!). Gobies also are expert bait-stealers, and are the bane of anglers along Great Lakes shorelines.

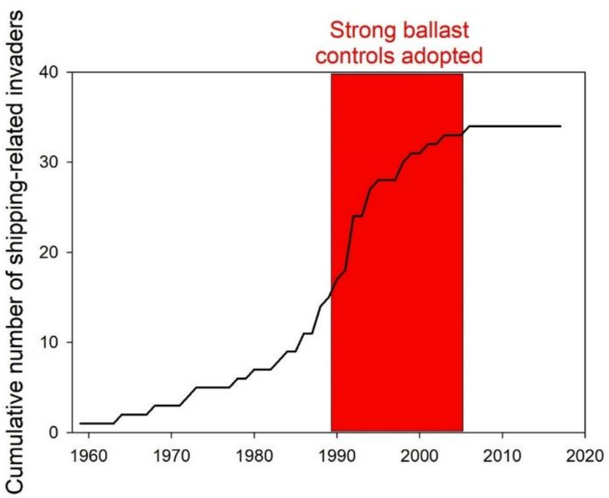
Round gobies eat a lot of zebra and quagga mussels, but they reduce populations of these mussels only in a few places. However, by eating mussels, round gobies move pollutants and poisons up the food chain. This has led to the death of thousands of loons and other waterbirds that wash up on beaches in the Great Lakes, the victims of botulism toxin moved up from mussels to gobies to waterbirds.

Loon killed by avian botulism in the Great Lakes (source is National Park Service, via https://www.interlochenpublicradio.org/news/2019-10-21/despite-dozens-of-dead-loons-its-a-mild-year-for-avian-botulism).

Despite what we know about gobies from the Great Lakes and elsewhere, we can't predict precisely how they will change the Hudson's ecosystem. The effects of invasive species can vary enormously from one ecosystem to the next. To begin with, we don't know how many gobies will eventually live in the Hudson. Will there be a large population because the Hudson has so many rocky shores (prime goby habitat), or a small population because those rocky shores are filled with predators like eels, smallmouth bass, and cormorants (all of which will happily eat gobies)?

If there is a large goby population, will it reduce the massive zebra mussel population in the Hudson? If it does, this will change almost every part of the Hudson's ecosystem. Will gobies benefit the Hudson's sturgeons (Great Lakes sturgeons treat gobies as choice prey)? Or will they eat so many sturgeon eggs that they reverse the recent recovery of these endangered fish in the Hudson? Scientists can make educated guesses about these effects, but we will have to wait and see for a definitive answer.

The careless practices that allowed gobies and other invaders to reach the Hudson are well known, but have not been adequately controlled. Round gobies came to the Great Lakes in untreated ballast water. Imports of ballast water from overseas into the Great Lakes have now been effectively controlled, leading to a dramatic decline in the number of invasive species being brought into the Great Lakes (see figure). **Species invasions can be controlled by good policy**. However, large volumes of untreated ballast water are still arriving in American ports outside of the Great Lakes (more than 3 billion gallons from overseas in 2019, and more than 100 times that much from other American ports, according to the National Ballast Information Clearinghouse). And ships traveling within the Great Lakes are still allowed to release untreated ballast water, which almost certainly accelerated the movement of gobies (and other invaders) through the Great Lakes.



Strict ballast water regulations shut down new shipping-related invasions into the Great Lakes basin. From data of Bailey et al., Environ. Sci. Technol., 2011; Sturtevant et al., J. Great Lakes Res., 2019.

Gobies then moved from the Great Lakes into the Hudson through the Erie Canal (and into the Illinois River through the Chicago Sanitary and Ship Canal). We have known for a long time that canals are highways for invasive species, but have been slow to install barriers or deterrents along canals to slow invasive species. The "Reimagine the Canals" initiative here in New York is a great opportunity to redesign the Erie Canal to block invasive species while retaining and enhancing core canal functions. We missed the chance to keep gobies bottled up in the Great Lakes, but barriers on the canal could stop or slow the arrival of even more damaging invaders (e.g., grass carp, bighead carp, silver carp) into the Hudson.

Although they probably weren't part of the goby story, other pathways known to bring us harmful invasive species (e.g., the pet trade, the live plant trade, inadequately treated wooden packing materials) remain poorly controlled at best.

The DEC press release on gobies tells us to brace for possible changes in the Hudson, and reminds us of policy gaps that allowed these fish into the Hudson. Unless we want to keep seeing disheartening press releases about new invaders, we need to close these gaps. The Great Lakes ballast water example shows that targeted policies can be effective, if we have the political will to apply them. Let's find that will.

Cary website, 31 August 2021

Think Locally and Act Globally on Invasive Species

The advice to "think globally, act locally" has inspired grass-roots action on difficult political and societal problems. But it is time for local conservation groups to turn this advice around and act globally to solve thorny local problems with invasive species.

Local groups dedicated to the enjoyment and protection of nature, including watershed and lake protection associations, hunting and angling groups, garden clubs, bird-watching societies, and boating clubs are key points of contact between people, nature, and natural resource management. These groups have often been successful in organizing their members and channeling energy and money to preserve lands and waters, protect species, and control pollution.

Increasingly, however, their missions are being threatened by invasive species. Plants like buckthorn, garlic mustard, and honeysuckle overrun nature preserves. Efforts to conserve biodiversity and manage game species are undercut by whirling disease of trout, white-nose syndrome of bats, chytridiomycosis of amphibians, and other virulent diseases spreading around the world. Invasive aquatic plants choke lakes, impairing their value for recreation and reducing lakeside property values. City parks and wilderness forests alike have lost chestnuts, elms, hemlocks, and ash trees following wave after wave of exotic pests. Murder hornets, spotted-wing drosophila, and spotted lanternflies threaten gardens and crops.

In response, many local conservation groups have stepped up to confront invasive species. They have largely chosen to "act locally" through activities such as pulling weeds, cutting brush, inspecting boats, and educating their members to behave responsibly (buy native plants, clean your waders). Such local actions can slow the spread of invaders and reduce their impacts, but they are not enough to protect the natural resources that these groups care about. Indeed, focusing on local actions misses the best opportunities for solving invasive species problems.

Expert studies consistently identify large-scale, coordinated actions as the best and most cost-effective way to reduce damages from biological invasions over the long term. The US has been slow to adopt such actions, which has led to high and rising invasion rates and billions of dollars in damages each year. We need national actions to lessen these problems. We need better controls over the routes that bring in harmful new invaders, including massive imports of live plants and animals, insect-infested wooden crates and pallets, and incompletely treated ballast water that teems with animals and microbes. We need larger budgets for agencies such as USDA-APHIS, U.S. Customs, and the Coast Guard that protect us by inspecting imports and monitoring invaders. We need more research on detection and control of established invaders, new and old.

If these opportunities are so great, why haven't we pursued them? Industries that would bear the cost and inconvenience of new regulations and technologies have applied political pressure to maintain the status quo. In contrast, there has been little organized counterpressure from the larger community that pays the high costs of invasions and would benefit from better controls. When I was talking with a lawmaker a few years ago about the need for better control of invasive species, he said – "Hey, I get it, but why don't I hear from my constituents about this?" Until lawmakers start hearing from their constituents, we can expect little relief from invasive species and the problems they cause.

No one is better poised to serve as a counterweight to industry lobbies than local conservation organizations, with their longstanding commitment to protecting natural resources and the experience and energy to organize their millions of members. Here are a few suggestions for engaging. Groups can educate their members (and others in their communities) about the high costs of invasions and the need for national actions to reduce invasions and their impacts. Both groups and their members can contact elected representatives and demand action, especially at the federal level. (A good time to write that letter would be when you've just returned from a weed pull and are sweaty and frustrated.) If your local group is part of a national organization, you can push that national organization and its government affairs office to weigh in on invasives.

I know that it is easier for local groups to energize members to come out for local actions. But even the most dedicated local action can address only yesterday's invaders, whereas national action can help with yesterday's invasions and prevent tomorrow's. Without effective national action, local conservation organizations that are facing five troublesome invaders today will face ten tomorrow, with an increasing probability that one of these invaders will be a game-changer that irreversibly damages the resources that they are trying to protect. So when your group is planning its activities and priorities for the coming year, please consider acting globally to protect your local resources by engaging with invasive species at the national level.

Natural Areas Journal, April 2022

Freshwater Mussels and Other Shellfish

Pearly Mussels are Interesting (Really!)

Most people who have run into freshwater pearly mussels don't think they are very interesting. You may have seen these animals along a river or lake shore, where they seem to be nothing more than living rocks. Or worse yet, you may have encountered pearly mussels in a biology classroom through a diagram of their complicated plumbing, or dissected a watery, gray animal whose actual plumbing didn't look at all like the picture in the book. If so, you just didn't get off on the right foot with these animals, which are actually pretty interesting.

Pearly mussels are pretty

Pearly mussel shells are beautiful, and are made out of the same material as real pearls (that's why we call them "pearly mussels", right?). People have collected mussel shells for centuries for ornaments like knife handles and pearl buttons. In fact, about a hundred years ago, pearl buttons were big business in the Midwest, with button factories along all of the major rivers. People caught whole bargeloads of mussels from these rivers – mussellers took 25,000 tons of shells from just a single mussel bed in the Mississippi River, and more than 14,000 tons of mussel shells from Illinois in just one year. Of course, harvests like this couldn't go on forever, and the pearl button industry faded away about 1925 from a combination of falling catches and competition from plastic buttons.

Pearly mussels also make beautiful lustrous pearls that people have treasured for more than a thousand years. One of the reasons Julius Caesar invaded Britain was to get its pearls, and pearls from freshwater mussels decorate many Russian religious icons. Here in the United States, pearl fisheries were a key source of cash in the rural subsistence economies of the 19^{th} century. (If you're thinking about going out right now and collecting a bunch of pearly mussels to make your fortune from their pearls, don't bother. You'd have to kill and sort through a lot of smelly mussels to find a few crummy pearls, and besides, it's illegal to collect pearly mussels in New York).

These living rocks have strange, secret lives

Really they do. To begin with, instead of making respectable baby mussels, or even swimming larvae that turn into baby mussels (like clams and mussels in the ocean do), pearly mussels make tiny larvae that are parasites of fish. This seems like a bad idea, because these larvae need to contact and attach to just the right kind of fish, but the larvae can't swim and they only live for a few days. But mussels aren't as dumb as they seem. Instead of just releasing their hapless larvae into the water to die at the bottom of some God-forsaken creek, pearly mussels trick fish to come to the larvae. Some mussels release their larvae in packets that look just like delicious morsels of fish food, while others display lures that entice fish to attack the mother mussel, who then infects the attacker with larvae. Some mussels even angle for fish by dangling their larvae on the end of a 3-foot-long clear fishing line.

Pearly mussels are disappearing

Many American rivers used to be full of pearly mussels – one bed in the Mississippi River probably held more than 100 million animals. The Hudson River estuary held 1.1 billion pearly mussels before zebra mussels arrived in the early 1990s, of which about 30% remain. In fact, North America had 300 kinds of pearly mussels – more than anywhere else in the world. One rapids at Mussel Shoals, Alabama, held 63 species of pearly mussels. Many of our pearly mussels are going the way of the passenger pigeon – scientists estimate that 37 American species are extinct, and 2/3 of the remaining species are in danger of going extinct in the coming decades. The disappearance rates can be breathtaking – over half of pearly mussel populations in Iowa streams vanished between 1984 and 1998. Pearly mussels are disappearing because people have been really rough on the rivers that mussels prefer – we've blocked rivers with thousands of dams (the "shoals" at Mussel Shoals are now drowned deep behind a hydroelectric dam); polluted the water with poisons, sewage, and agricultural runoff; brought in exotic species from around the world; and of course, harvested tons of mussels for pearls and buttons – and mussels can't swim away to a clean river. No other group of animal in North America is worse shape than the pearly mussels, and prospects for the future don't look that bright.

Despite these sharp declines, many lakes, streams, and rivers in our area still contain pearly mussels – about 15 species can be found locally, including three species that are protected by the federal government or New York State as threatened or endangered.

So the next time you see a pearly mussel shell washed up on the beach, don't forget that these are fascinating, beautiful, and endangered animals, with an illustrious history that reaches back to the great Caesar. And for those of you dissecting a mussel in a stuffy classroom, try to remember – these animals are more interesting than they seem to you right now!

Poughkeepsie Journal, 11 July 2004

A Mollusk of Mystery

Because people know that I work on freshwater shellfish, they send me shells. I get blurry jpegs attached to emails with subject lines like "What are these?", and little cardboard boxes full of dirty shells and cotton the way that the Antiques Road Show guys get Queen Anne chairs and silver creamers. Lately, most of these of these emails and boxes have contained Chinese mystery snails.

Chinese mystery snails have thin, olive shells as big as golf balls (if you see such a big freshwater snail around here, it's a mystery snail – you don't need to send it to me), and have become abundant in our ponds, lakes, and marshes. They are native to East Asia, but were brought into the US in the late 19^{th} century as a possible food source (ick), and appeared in New York a few decades later. Their rapid spread through the Hudson Valley and the US suggests that many people are releasing them from their aquariums and water gardens.

When you hear a name like "Mystery Snail", you have to ask "so what's the mystery?" Unlike most freshwater snails, these snails are live-bearers – instead of laying eggs, the mother carries the developing eggs inside her body, then gives birth to cute baby snails. The mystery is simply where the new baby snails in your aquarium came from – you didn't even know that your snail Bertram was expecting, and suddenly your aquarium is full of little snails.

But there are two other interesting mysteries about these snails. The first is: what role do they play in our ecosystems? In addition to being big, Chinese mystery snails often are abundant. We recorded a population density of 20 adults per square foot in one local wetland. This means that you literally couldn't put your hand on the bottom without touching a mystery snail.

Although ecologists usually are pretty good at sniffing out unanswered questions to study, there has been very little scientific work on mystery snails, and some feel that this is an invading species without much of an impact. But when you see 20 of these big snails per square foot, it's hard to believe that they don't have an impact.

For example, they've got to be eating something, and a lot of it. Mystery snails can either browse algae off the bottom or filter edible particles from the water. A large population of mystery snails must greatly change the amount and type of such food that is available to native animals.

Other impacts seem likely as well. Freshwater snails carry a lot of parasites, so invading snails can increase diseases in an ecosystem.

For instance, when the European faucet snail appeared in the upper Mississippi River in 2002, it caused an explosion of a parasitic disease that kills thousands of ducks each year. No one knows what parasites the Chinese mystery snail might carry, but I know that I come down with a bad case of swimmer's itch (a snail-borne disease) every time I work in the wetland that is so full of mystery snails.

The second interesting mystery is why people like to buy mystery snails, keep them in their aquaria, and move them around from lake to lake. Do they think that mystery snails are pretty, or beneficial, or just cool? I suspect that few of the people who like mystery snails harbor any similar fondness for their close cousins the orange slugs that slither through our gardens. Clearly not all mollusks are created equal.

An even broader mystery is why we so often move species around from place to place. The last few centuries should have taught us that moving species around is a risky business that can lead to ecological and economic disaster. We should have learned from zebra mussels, carp, kudzu, rabbits in Australia, lampreys in the Great Lakes, West Nile virus, hemlock woolly adelgids, and hundreds more.

However, as the mystery snail shows, these bitter experiences have failed to kill our optimism that moving a species like the mystery snail will make the world a better place. This is the central mystery of the mystery snail.

Poughkeepsie Journal, 20 October 2013

What Good are Clams, Anyway?

What good are clams? I work with a lot of obscure animals, like bivalve mollusks (clams and their relatives), and one of the most common questions I get is "what good are they?" This is an odd question, because it suggests that the purpose of billions of years of evolution was to produce species to be useful to humans. You might just as well turn the question around and ask what good humans are to sycamore trees, or woodpeckers, or herring. In fact, the utility of a species to humans probably tells us more about human ingenuity than about that species.

So to rephrase the question about what good bivalves are, we should ask what human inventiveness has been able to do with them. Well, to begin with, we eat them. Whether oysters, scallops, mussels, clams, quahogs, or coquinas, marine bivalves are prized menu items all around the world.

What about freshwater bivalves? Native Americans ate a lot of freshwater mussels, as do a few country folk today. Personally, although I find freshwater mussels to be alluring to study, I think they're revolting as food. My aversion is well founded. Biochemists have found that freshwater mussels are rich in "putrescine" (no, I didn't make that up), a chemical that gives rotting corpses their characteristic aroma. (If freshwater mussels still sound tasty to any of you zombie readers, and you want to try eating one, remember that raw freshwater fish and shellfish can carry nasty parasites, so collect them from clean water and cook them well.)

Many bivalve shells are made of a lustrous material called aragonite or mother-of-pearl, so we've valued bivalves for their beauty for nearly as long as we've eaten them. Indeed, the oldest known piece of art is a freshwater mussel shell that was inscribed with geometric figures by *Homo erectus* in Indonesia more than half a million years ago. In more recent times, we've used mother-of-pearl to make utensils, shirt buttons, and decorative objects. And of course bivalves give us one of the most sublimely beautiful and precious objects in the natural world – pearls.

Intriguingly, bivalve shells are used to decorate graves in cultures around the world, including Kentucky, Texas, the Balkans, and other places. I don't know the origin, significance, or symbolism of this practice.

Bivalve shells are also used for more prosaic purposes. In the South, where natural deposits of gravel are rare, huge numbers of the "Louisiana road clam" are fished from estuaries to build road beds (21.2 million tons in a single year!). And bivalve shells are commonly included as a supplement in poultry feed to provide calcium for egg production.

Finally, a surprising use for bivalves that I just learned about, and which inspired this column. Many bivalves such as the blue mussels that live on rocky seashores attach themselves to the bottom with a bundle of tough threads called a byssus. The byssal threads of the pen shell, a marine bivalve, are so long that they can be collected and woven into cloth. The golden "sea silk" made from these painstakingly collected and processed fibers is extremely light and strong, and among the most expensive of all fabrics. More recently, materials scientists have been investigating byssal threads as an inspiration for next-generation adhesives.

So we might give two answers to what good bivalves (or any other species) are. We could say that the good that people find in a species depends chiefly on our resourcefulness and experience with the species. So far, we've managed to use bivalves for food, art, jewels, shirt buttons, fine silk, grave decorations, road beds, and chicken feed, and this doesn't even count the good they do in natural ecosystems by clearing up the water, providing food and habitat to other animals, and so on.

But as the ongoing research of materials scientists shows us, we're not done yet. So because our resourcefulness and experience always are growing, we could just as easily say that we don't yet know what good any species, no matter how humble, will turn out to be.

Poughkeepsie Journal, 12 July 2015

An Interview with the Three Hundred Old Clam

I just read that some of the clams (freshwater mussels, technically) in Scandinavian creeks are thought to live for 280 years. This means that animals alive today were around when Johann Sebastian Bach was still playing the organ in Leipzig, mature adults when shots were fired at Lexington, old enough retire (if clams retired like people) when Napoleon's armies marched across Europe, and more than 125 years old when Lincoln freed the slaves.

Your first reaction on hearing this startling news might be – if only clams could talk, what tales they could tell! Get a grip – these are clams we're talking about. Listening to a clam reminisce about its 280-year life would be like getting stuck for hours at a family gathering with your dullest uncle, but much, much worse.

Even Doctor Dolittle didn't talk to the clams.

So let's consider what we might be able to learn from these venerable animals without having to talk with them. Clams, like trees, lay down annual rings in their shells. Very careful chemists guide a tiny laser across these rings, vaporize minute bits of shell that were laid down during each year of the clam's life, and collect and analyze the vapors. By measuring traces of different chemical elements and even the isotopes of each element in those vapors, these chemists can learn about conditions in that Scandinavian brook over past centuries.

For instance, the amount of a rare isotope of oxygen (oxygen-18, which makes up just 0.2% of atmospheric oxygen) in the shell tells us the temperature at which the shell was made throughout the clam's long life. To me, a poor chemist, this seems only slightly less magical than John Dolittle having a conversation with the pushmi-pullyu.

Environmental chemists do this kind of thing all the time to peer back into the Earth's history, not just for centuries, but for millions and even billions of years. And they can interrogate not just animals, but plants, and rocks, and even ancient air bubbles. If they know the age of an object, clever environmental chemists can almost always figure out some way to use it to tell them about past environmental conditions.

This approach has been especially important in understanding recent climate change. When someone shows a chart of the Earth's temperature over the last 10 million years, or the carbon dioxide content of the atmosphere since the year 1500, did you ever wonder where that information came from? It's not like we had weather stations 10 million years ago.

To figure out past temperatures, chemists use the same methods as for the clam shells. Corals, algae, and many other organisms have been making shells and other body parts out of the same carbonate material as clam shells for many millions of years. So chemists can use the oxygen-18 content of these abundant fossils to estimate ocean temperatures far into the past.

But how do we know about the carbon dioxide content of the atmosphere? One way is to analyze tiny air bubbles trapped in ice sheets. Ice sheets too have annual layers. Scientists collect cores from ice sheets, count back through the layers, and carefully sip the air from bubbles trapped in the ice. Then, they measure the carbon dioxide in this thousand-year-old air.

But scientists can learn even more from these environmental archives, by looking at the type as well as the amount of carbon dioxide in these samples. The isotopic content of the carbon gives us a clue to what has caused carbon dioxide in the atmosphere to increase.

As carbon dioxide has been increasing, its proportion of carbon-14 has been dropping. You may remember that carbon-14 is radioactive, produced fresh every day by cosmic-ray bombardment of nitrogen in the atmosphere. It gradually decays away over time, so that only half of the carbon-14 produced today will still be around 5730 years from now. The drop in carbon-14 content of the atmosphere tells us that the carbon dioxide filling up today's atmosphere comes from something too old to contain much carbon-14.

The amount of carbon-13 in the air also has been dropping. This non-radioactive isotope of carbon makes up about 1% of the carbon in the air. Plants prefer not to use carbon-13, so the decline in carbon-13 tells us that the increasing carbon probably ultimately came from plants.

In other words, the declines in carbon-13 and carbon-14 tell us the recent rise in atmospheric carbon dioxide was caused by the burning of fossil fuels, once contained in plants and now too old to contain any carbon-14.

As this example shows, environmental chemists can learn many secrets from animals (and rocks, and air bubbles, too), without ever having to talk them. Now if only we had some way to deal with your uncle...

Poughkeepsie Journal, 8 May 2016

Taking the Shell on the Road

Last month, 3214 freshwater mussel shells from the Hudson River made the trip from Cary's labs in Millbrook, NY to the University of Michigan Museum of Zoology (UMMZ). Why did we collect these shells, and why did they wind up at UMMZ?

We collected the shells as a part of scientific studies to see how many native mussels were living in the Hudson estuary (1.1 billion), what kind they were (mostly just 3 species), how big they were (all sizes from little fingernail-sized babies to big bruisers almost 5 inches long), estimate the roles they played in the ecosystem (pretty modest, most important up near Albany), and how fast they were growing (we didn't find out because for some reason the Hudson shells don't have annual rings like they should).

Then we got interested in knowing how the native mussels would respond to the zebra mussel invasion (they all got skinnier, two of the species disappeared, and the third became scarce and is probably on its way out, because zebra mussels ate all of the food). A few years later, it occurred to us that the shells of the mussels might be getting thicker in response to increased predation from crabs and other predators that were attracted to the bountiful banquet provided by the billions of zebra mussels in the Hudson (the shells are about 25% thicker than they were in 1991, but we're not sure it's from the predators).

So we've used these shells for everything that we could think of, and they've been an important part of Cary's uniquely detailed study of the effects of the zebra mussel invasion on the Hudson River ecosystem. But although we Cary scientists think of ourselves as pretty smart, we know that we're not smart enough to think of everything that these shells might tell us (see some examples in https://www.caryinstitute.org/news-insights/feature/interview-300-year-old-clam). Some day, a scientist who is smarter than us, has access to technology that we can't even dream of, or wants to test a theory that won't be articulated until the year 2082, will want to analyze those shells.

My favorite example of this sort of thing is how soil samples that were collected in the Rothamsted experiment in the UK in the mid-19th century, before radioactivity was discovered or even remotely imagined, were used a century later to measure radioactive fallout from the bomb tests of the 1950s. Other unanticipated uses for archived samples include analyses of DNA from species that went extinct before DNA was discovered, reconstructions of the timelines of environmental contamination, and so on.

The Cary Institute isn't well suited to preserve mussel shells for decades or centuries, but we know someone who is. When you go to a museum like the American Museum of Natural History in New York City or the Smithsonian down in Washington DC, you see magnificent public displays of dinosaurs, jewels, and dioramas. What you don't see is a less magnificent but equally important part of the museum – the research collections.

These research collections contain literally millions of specimens of all kinds of things in drawers, cabinets, boxes, and jars, meticulously organized and protected for centuries for the benefit of science and society. The UMMZ holds one of the world's greatest mollusk collections (more than 300,000 lots, to be precise), and their specialty is freshwater species. They're exactly the place that a scientist would go if they were looking for shells to study, and UMMZ is very good at keeping specimens safe and organized for the long haul, publicizing their existence, and making them available for scientific study.

So the shells that we collected in 1991-2018 may be used yet again sometime in the future, perhaps answering a question that I can state but couldn't answer myself (how are animals from the Hudson related to mussels in other Eastern rivers?, what was the history of environmental contamination in the Hudson through the mid- to late 20th century?). Or maybe some scientist with a futuristic haircut will use a tricorder or something to measure the tachyon content of our mussel shells in 2082, to answer a question that I wouldn't even understand. May these shells last long and prosper.

Cary website, 26 October 2020

What's Wrong with Having a Pet Snail?

Last Saturday, NPR's *Weekend Edition* ran a story about keeping snails as pets (www.npr.org/2020/11/28/939629411/in-defense-of-the-pet-snail) , and I wish they hadn't. Apparently snails are the trendy new pet (really!), and the story quoted happy snail owners extolling the virtues of their pets. Most of what NPR said in the piece was true. Snails are interesting animals that are fun to watch and easy to keep. But I'm afraid that the Weekend Edition story will encourage more people to get pet snails, and that could be a bad thing.

What in the world could be wrong with more people having pet snails?

Snails are among the world's most damaging invasive species (three kinds of snails are on the list of "100 of the World's Worst Invasive Alien Species" - www.iucngisd.org/gisd/100_worst.php) For instance, in the Midwest, the invasive faucet snail carries a parasitic flatworm that kills thousands of ducks and other waterfowl each year. The golden apple snail was spread from South America to Asia, where it damages wetlands and rice fields to the point that farmers now use dangerous pesticides to control the snails, leading to several human fatalities. The Giant African Snail, a popular pet, attacks many crops, may spread plant (and human) diseases, and damages stucco buildings by eating them. So invasive snails cause widespread ecological and economic damages, and can even harm human health.

But that adorable little snail in your terrarium isn't going to hurt anything, is it? Well, not unless it gets out. And when people keep pets, they always get out. Your cousin Dizzy decides that it would be cool to let their snails loose into the garden (won't they be <u>cute</u> on the petunias?), or their hyperactive dog knocks over the terrarium they've been keeping on the patio, or they just get tired of having a terrarium, and toss it, snails and all, into the compost pile. Almost all of the pet owners that I know are super responsible, and would never do any of these things. But it only takes 1 Dizzy in 100 pet owners to ensure that lots of pets are let loose into the wild. Then we have Burmese pythons in the Everglades, snakeheads in the Potomac, and feral cats eating the world's last Stephen's Island wren.

You might think that you wouldn't be able to buy any harmful snails (or any other harmful pets) in the first place because government regulations or voluntary screening by the pet industry would ensure that all species in the trade would be benign. In fact, here in the United States, there is little screening of animal imports as to whether the species is harmful, free of diseases, or even identified correctly. Nor do we generally have plans for detection or control of released pets when they start causing problems in the wild. Until then, we are counting on Dizzy's discretion and care to protect our natural resources from their escaped pets. That's reassuring, isn't it?

What we really need is better federal (or industry) control of the non-native species moving into the United States through the pet trade and other pathways. But that's not likely to happen anytime soon, in part because of opposition from the lucrative pet industry ("Big Pet"), which doesn't want anything to eat into their bottom line, no matter what it might cost the rest of us. In the meantime, let me say what I wish NPR and other responsible news outlets would say when they run a story about the latest fad in trendy pets: be really careful that you don't let those pets loose.

Cary website, 4 Dec 2020

A Year in the Kingdom of Ice

January: The Kingdom of Ice

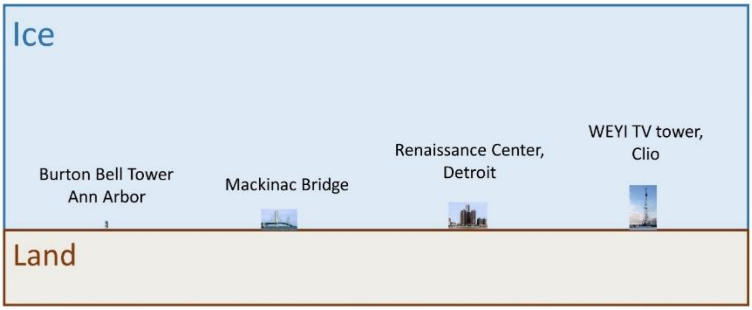
In January, Michigan is a province deep in the Kingdom of Ice. Looking through silvery feathers of frost on the window glass, I see big flakes of snow swirling against a gray sky. The air is filled with the sounds of snow shovels, ice-scrapers on car windows, and crunching footsteps on packed snow. Roads and driveways are covered in crusty, rutted ice. Out in the countryside, flocks of gray and brown winter birds rise and fall over snow-covered fields. And if there isn't any snow, the earth itself is frozen solid, as hard as iron. The solitary figures of ice-fishermen dot frozen lakes, and ice rattles in the surf of the big lakes.

You might deny being part of the Kingdom of Ice – Michigan is more about summer sunshine than it is about ice, you say – but our language betrays us. If we are not people of the ice-country, then why do we have so many words for what is just a single substance: frozen water? Ice, snow, slush, powder, drifts, flurries, blizzards, sleet, hail, freezing rain, frazil, frost, black ice, white ice, candle ice, skim ice, anchor ice, rime, and hoarfrost. And these are just the words I could think of off the top of my head, without going to the dictionary.

Now, how many words can you think of for sunshine?

But even more fundamental than the ice we see every day during our long winters, we live in a landscape that was shaped by ice. For the last 2 million years, immense ice sheets repeatedly grew and spread across Michigan, and then receded, as the climate cooled and warmed. As recently as 20,000 years ago, the whole state of Michigan was submerged in an ocean of flowing ice more than a mile deep (see the diagram).

As these ice sheets advanced and then melted away, they built the place that we know today as Michigan. Glacial ice gouged away at river valleys and soft spots in the rock to produce the Great Lakes and steep-sided beauties like Torch Lake. Then, they deposited this excavated material elsewhere to build new landforms. The hills of Ann Arbor are end moraines – piles of debris accumulated when the front edge of a glacier paused in place for a while. The charming hills and countless lakes and ponds of the Irish Hills were left by a dying glacier. Its lakes lie in the basins left when huge ice cubes submerged in a plain of sand and gravel melted away, and its gravelly hills are the remnants of deposits accumulated between walls of ice, long since gone.



This scale drawing shows how the ice sheets that covered Michigan would have dwarfed any human-made structures now in the state.

The scale of excavation and construction by the ice sheets is almost beyond comprehension. Suppose that some billionaire, instead of shooting himself into outer space, decides to build us another Lake Superior. He hires a big crew that is able to excavate a volume as large as the inside of the University of Michigan football stadium each day, and they work 7 days a week, 52 weeks a year, until 52,000 years later – voila! – they're done.

All of this material excavated from Lake Superior and other places had to go somewhere, and a lot of it was used to remodel Michigan. Most of the Upper Peninsula is covered only by a thin layer of glacial debris, but almost all of the Lower Peninsula is covered by more than 50 feet of glacial deposits. Most of the region between Grand Rapids and Traverse City is covered more than 300 feet deep by sand and gravel left by the glacier (in some places these deposits are more than 800 feet thick). It's hard even to imagine what the land looks like under all that debris, or what it must have looked like before the glaciers remodeled the state. I doubt we'd even recognize it as Michigan.

So in the same way that you might say that you live in a Frank Lloyd Wright house (lucky you!), we can say that we live in a landscape built by ice (lucky us!). And just as you can recognize a Frank Lloyd Wright house by its telltale design elements (strong horizontal lines, lots of glass, repeated use of simple geometric designs), you can recognize a glacial landscape by the abundance of lakes, large and small, rolling hills, plenty of sand and gravel, and not so much exposed bedrock – all of the things that you think of as Michigan. All over the world, we can recognize the work of that same great builder in the steep-sided lakes of the English Lake District, the sandy, lake-filled plains around Berlin, and the landscapes of Scandinavia.

You might wish that you lived in the Kingdom of Sunshine and Warmth. But if you live in Michigan, you may as well admit that you are a citizen of the Kingdom of Ice and enjoy the beauty of our country.

Great Lakes Echo, 10 January 2022

February: The Dead of Winter

February is the dead of winter. It's been cold for weeks, it's still cold, and it's going to be cold for many more days before spring arrives.

Inside our homes, things are warm and lively – soup is simmering in the kitchen, the houseplant on the windowsill is blooming, and your favorite jazz is playing. When you look out through the window, the only things that you see moving are cars, little bubbles of warmth in the wintry landscape. It's easy to think of the February landscape as lifeless. Even the language we use – the dead of winter – supports this idea.

(You might object that the "dead" in "dead of winter" doesn't mean lifeless, but simply means "absolutely", like "the shot hit dead center", or "he was dead right". Sure, that's possible, but then why don't we ever talk about a dewy May morning as "the dead of springtime", or a baking August afternoon as "the dead of summer"? No, I think you have to concede that we say "dead winter" to mean both absolutely winter, and the part of the year with no life.)

Plum and apricot blossoms forced to life in the dead of winter. Credit: Judy Bondus.

But a closer look shows that nature is very much alive, even in February's coldest days. To begin with, a lot of what seems to be dead is just sleeping. Many plants and animals go dormant in the fall, only to awaken when temperatures rise or days lengthen with the arrival of spring. You can see for yourself just how lightly they're sleeping by cutting some branches of a flowering tree or shrub and bringing them indoors into the warmth. Placed in a vase of water, these cuttings will awaken and bloom in a week or two. Forcing some cuttings is a pleasant late-winter activity, and a cheery reminder that spring is coming, even when it is still gray and sleeting outdoors. Forsythia, apricots (my favorite), plums, cherries, and quinces all are good subjects.

Other plants and animals don't need any forcing, because they're already awake in February to the prospect of spring. If you pay attention, you'll hear tufted titmice and other eager winter resident birds singing, setting up their territories for the upcoming spring. Great horned owls may even be incubating eggs by the end of February.

And it's not just the birds. Though most of our plants are still asleep, skunk cabbage may already be blooming by the end of February. This plant lives in marshy spots kept a little warm by seeps and springs. It is one of few plants that heat their flowers, which can be 20-60 degrees above the air temperature, and can melt their way right through the snow (see the picture). The plant's little furnace keeps its flowers from freezing. Along with the plant's pungent odor, the warmth of the flowers probably helps to attract its pollinators, insects that also woke up early to get a start on spring.

A skunk cabbage flower melting its way through the snow. Credit: Seon7376@Naver, from Wikipedia.

Then there are animals that have been active all through the winter, which you can see if you venture outside. The woods and fields seem empty compared to summer, but once you get out and look, you'll see plenty of birds, including some northern birds that come south to Michigan for the winter. If you want to see these birds, including such treats as snowy owls, siskins, and Lapland longspurs, it's best to get out in the dead of winter.

Although you may not see many mammals, tracks in the snow show that they are busy when you're not watching. One of the pleasures of winter walks is seeing tracks of animals that you rarely see in person. I've seen only two foxes in my neighborhood in five years, but I often see their tracks – foxes are always around, but are stealthier than I am.

If you look closely, you may even see some of the invertebrates that are active in February. Snow fleas (see the photo) sprinkle the February snow like ground pepper, and pile up in footprints. These tiny creatures are not fleas, and do not bite, but got their name because they hop like fleas. Seen under a microscope, they are endearingly cute (they'd make a great stuffed animal or Disney character). Snow fleas are able to stay active right through our winters because they make their own antifreeze.

Snow fleas (collembolans). Credit: mwms1916 via flickr. (https://www.flickr.com/photos/mmwm/16274301934)

And as crazy as it sounds, February is the hottest time of the year for winter stoneflies. These insects have been feeding on fallen leaves in our streams since last fall, and February is the time for them to emerge and mate on the snow-covered stream banks. It's too cold for them to fly, so the males and females trundle around on the snow, exchanging sweet nothings ("Did anyone ever tell you that you have beautiful tarsi?") by drumming on the ground with the tips of their abdomens.

It's true that February isn't as riotously alive as May, with flowers everywhere and singing birds in every tree, but it's far from dead. We just need to get out of the tropical cocoon of our house to appreciate its subtle vitality.

Great Lakes Echo, 7 February 2022

March: Stormy Weather

We all know that March comes in like a lion, which means snowstorms, rainstorms, windstorms, and even a few tornados. We're used to seeing branches sway and break in the March winds, and feeling the house shake and rattle. If the storm is really bad, we may even see trees snap or tip over. But the storms that we see up here are nothing compared to the storms that roar through beneath the surface of our streams.

March is the big time for these underwater storms. The combination of melting snow, saturated soils, and rain falling on frozen ground means that the most frequent and most severe floods typically occur in March here in Michigan. These floods may carry 100 or even 1000 times as much water as the stream carries on a dry summer day.

We think we know what floods can do, because most of us have seen March's floods in the local creek or river. What we see are muddy waters that rise up to engulf cornfields, woodlots, and sometimes our houses, and floating debris that piles up on bridge abutments and floodplains.

But what we don't see is more impressive. Out of sight beneath the muddy waters, the rushing, turbulent stream is tearing up its bed and banks, sometimes excavating the streambed to a depth of several feet.

We underestimate the strength of these underwater storms for a couple of seasons. First, the water is so muddy that we can't see what's going on beneath the surface. We know from repeated personal experience what an aerial storm looks and feels like, but can't have such personal experience with an underwater storm. Instead, it's like we're looking down on the surface of a hurricane from an airplane – we can't see the destruction that lies below.

Second, as surprising as this may sound, the stream refills its scoured bed as the storm passes, so that streambed often looks about the same before and after the flood – the same pattern of riffles, pools, and gravel bars. It's just that these structures are built of different stones and different grains of sand before and after the storm. We know this because the geologists who study streams have painted the rocks on the stream bottom and seen that the painted rocks were swept away and replaced by unpainted ones. These clever geologists have also invented devices to measure the depth of scour and fill during floods, which show that floods often scour streambeds down to a depth of several feet, then refill those scour-holes.

Another way to gauge the power of these destructive forces is by observing their effects on bridges and other infrastructure. Streambed scouring that undermines bridge supports is the most common reason that highway bridges in the United States collapse. In 1987, scour from a large flood dug a hole ten feet deep that undermined the piers of the Interstate-90 bridge over Schoharie Creek, New York, causing the bridge to collapse (see the picture) and killing ten people. When flood-borne debris piles up on bridges and blocks culverts, flood waters can push bridges off of their supports and wash out roads. In the famous Eden train wreck, a flash flood pushed a train off a trestle in Colorado, destroyed the trestle, killed about 100 people, and carried two of the railroad cars more than four miles downstream. So underwater storms can be very strong indeed.

The remains of the I-90 (New York State Thruway) bridge over Schoharie Creek, New York, after a flood undercut the bridge supports and destroyed the bridge. Credit: USGS - http://water.usgs.gov/wid/images/NY.figure.id.3.gif, Public Domain, https://commons.wikimedia.org/w/index.php?curid=56907491

How do the plants and animals that live in streams survive such immense forces? Some animals, especially fish and some of the strong-swimming invertebrates, move to quiet waters near the stream's edge and up on the floodplain. Other plants and animals live on parts of the streambed that stay in place even during floods. Freshwater mussels, sedentary animals that can live for decades in their storm-prone habitat, seem to live on these few stable parts of the streambed. Some plants even stabilize the streambed. Water-willow (see photo) uses its tough rhizomes to lace together the cobbles and gravel of the riverbed into a durable mat that resists scouring. Some of the streamside plants are damaged by floods but manage to survive. It's common to see vicious scars, high above the ground, on the upstream side of riverside trees, where floodwaters pounded ice, logs and other floating debris into the tree. And one of the advantages to being lithe and slender ("willowy") is that streamside willows can bend but not break when battered by floods.

A bed of water-willow, a plant that can stabilize stream beds. Credit: Mike Cline, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=2304022

In the end, though, many plants and animals are simply killed by floods. When you visit a river after a big flood, you see uprooted trees, dead fish in drying floodplain pools, and mussels and other aquatic creatures piled up on sun-bleached gravel bars. These and the many other plants and animals that died unseen in the flood must be replaced through recolonization.

In fact, some species depend on this cycle of destruction and renewal for their survival. Perhaps the premier example is the cottonwood. This streamside tree can produce millions of seeds each year, blanketing new sandbars that emerge after a flood. Cottonwoods live fast and die young – under ideal conditions they can grow to be 100 feet tall in a decade or two, but rarely live to see their 100^{th} birthday – good traits for a species living in a habitat that is frequently bulldozed by floods. Cottonwoods are so well suited to living along rivers that flood that they may disappear when flows are stabilized by flood-control dams.

Some dams can reduce flood severity downstream, but many human activities make floods worse. Climate change is causing bigger storms and more torrential rains, so most streams will see more severe floods in the future. In addition, we've changed the landscape so that water runs off into streams more quickly, feeding larger floods. Covering soils with roads, parking lots, and houses, adding subsurface tiles and ditches to farm fields, and draining wetlands all have made for bigger and more frequent floods in our streams and rivers.

As our activities increase the intensity of flooding, both stream-dwelling plants and animals and human infrastructure will be challenged, and may be damaged or destroyed. Reducing these damages will require us to better appreciate and manage the power of our underwater storms.

Great Lakes Echo, 4 March 2022

April: Hidden Migrations

Animal migrations are among nature's most stirring spectacles. Who hasn't felt a little thrill seeing V's of geese passing overhead and hearing their wild cries? Shots of the endless herds of wildlife migrating across the Serengeti are a staple of television nature specials, and many of us now plant milkweeds in a corner of our garden for that most improbable of migrants, the monarch butterfly. So why do so few of us know about spectacular migrations that happen every spring, right in our own back yards? Because these are migrations of fish, out of sight beneath the surfaces of our rivers and streams.

I know about these migrations because I'm an avid angler, and I'm out in the water with the fish. One of my fishing spots is the Maumee River, a big river that runs into western Lake Erie. Wave after wave of spawning fish fill the Maumee from March until June. Pike and walleyes appear in March, followed by redhorses and suckers, then white bass, and finally garfish, sheepshead, and catfish. In the old days, there were sturgeon, too, migrating far up into the small creeks that feed the Maumee during corn-planting season in late spring. My grandfather told me that farmers carried pitchforks into their fields, so that they could spear these huge fish when they heard them splashing in the ditches.

In clear streams, I've seen migrations of fish so thick that you couldn't see the bottom of the creek through the fish. The Maumee is too muddy to see many fish, but signs are everywhere that you're in the midst of an immense migration. You see fish jumping and swirling at the surface, and sometimes feel them bumping into your boots. On a good day, everyone is catching fish. Anglers take home tens of thousands of walleyes each year out of a run that is perhaps ten times that large, and the white bass run is even larger. Millions of fish migrate up the Maumee each spring, and the Maumee is just one of many fish-filled streams in our area. Suckers and steelhead run up out of the Great Lakes, pike move up out of our inland lakes, and smallmouth and rock bass migrate upstream within our rivers. Spring is a time of great fish migrations in the Great Lakes region.

You're missing one of nature's wonders by not being able to see these fish migrations. More importantly, because we don't see or appreciate these migrations, we've been mismanaging our rivers and fishes.

Migrations that occur above the water's surface are obvious, so we tend not to build obstacles that would block them. When we do erect obstacles, the results are readily apparent – migrating wildlife pile up along fences or are killed along highways; dead birds appear at the bases of wind turbines and tall buildings. But we don't so readily see the consequences when we obstruct underwater migrations, so we build barriers against fish migrations all the time. Many of the more than 7000 dams on Great Lakes tributaries completely stop fish from migrating upstream, and even small dams and poorly designed culverts can block migrating fish.

White suckers migrating up Silver Creek, Wisconsin. Credit: Titus Seilheimer (https://www.seagrant.wisc.edu/blog/quiet-time-with-the-fish-spring-is-the-time-for-fish-watching/)

When I was a kid, I thought that dams must be good for fish, because fishing was often so good below dams. Fishing is good below dams for the same reason that wildebeest hunting would be fantastic along a tall fence that blocked the Serengeti – the animals have nowhere else to go.

Instead, dams have harmed fish populations all over the world by preventing these migratory animals from reaching their spawning and nursery grounds. Highly migratory species like salmons, eels, sturgeons, and shads have been hurt most badly, but every kind of migratory fish, and there are many, is affected. In our region, dams have eliminated populations of dozens of fish species, including all of the species that I mentioned earlier in this piece.

But can't we build dams that give fish a way to get over them? Nearly everyone has seen a picture of a fish ladder, usually showing a salmon making its way up a watery staircase. The poor performance of fish ladders in the real world belies this happy image. Many fish ladders are poorly designed, so that fish can't find them, or even athletic species like salmon can't make their way up. Most migratory fish are not as athletic as salmon, and can't or won't use ladders. And even if adults can use a fish ladder to get up over a dam, when their young move back downstream, they may get lost or eaten wandering through the upstream reservoir, killed plunging over the dam, or chopped to pieces in hydroelectric turbines. Occasionally it has been possible to retrofit low dams to provide effective fish passage (see the photo), but overall, fish passages have largely been a dangerous illusion, allowing us to pretend that blocking fish migrations with dams is a problem with an easy solution.

A rock ramp installed just downstream of a small dam on the River Raisin that allows fish to pass. Unfortunately, fish that make it past these modified dams in the city of Monroe are blocked by a still-impassible dam less than 5 miles up from Lake Erie. Credit: Dave Strayer.

The only consistently effective way to restore runs of migratory fishes is to remove the dams that block them. Hundreds of dams in our region are deteriorating or have outlived their original purposes. Many of these old dams are in such poor shape that they are safety hazards, so removing them can serve the twin purposes of improving public safety and restoring fish migrations. But removing antiquated dams is expensive, and can be technically, legally, and politically complicated, so only a few have so far been removed. According to American Rivers and the DNR, only about 100 Michigan dams have been removed, while about 2400 remain.

If you live near a clear stream, you may be lucky enough to see the spring fish migrations, especially if you go out at dusk or after dark. But otherwise, the best way for you to see spring fish migrations may be with your eyes closed, imagining the unseen world beneath the surface of our rivers, either filled with schools of jostling fish, or as strangely empty as a spring sky devoid of birds.

Great Lakes Echo, 1 April 2022

May: Good Fish, Fun Fish, Bad Fish, Sunfish

May is a good time to look for sunfish nests. Sunfish build saucer-shaped nests (see the photo) a foot or two across in the shallows of lakes, ponds, and rivers. Anxious males hover above the nests, guarding the eggs and hatchlings, chasing away intruders. Because the nests often are in very shallow water (sometimes almost on the shore), they're easy to see and watch.

Three pumpkinseed sunfish (marked by yellow arrows) guarding their nests. Photo modified from Fernando Alonso Vendrell, via Wikipedia.

The sunfish family includes some of Michigan's most popular sport fish: largemouth and smallmouth bass, bluegills, pumpkinseeds, crappies, rock bass, and others. They are easy and fun to catch, attractive (see the photo), good to eat, and very common – almost every warm lake and river in the state contains sunfish. In Michigan and all throughout the eastern United States, sunfishes are among the most highly valued freshwater fishes.

They are also among the world’s worst invasive fish species.

Because sunfishes are so highly valued in eastern North America, they have been widely and indiscriminately stocked all over the world for recreational fishing, and released from aquaria into the wild. Anyone familiar with sunfishes knows that they are intelligent, inquisitive, aggressive, adaptable fish, and would predict that they might have strong impacts on ecosystems into which they are introduced. Indeed they have.

Largemouth bass introduced to Lake Atitlan, Guatemala, drove a species of flightless grebe to extinction by eating its food and its chicks. In California, “native fishes have paid dearly” for the introduction of largemouth bass, green sunfish, and other sunfishes, which helped to drive several of California’s native fish species to extinction or endangerment. In Europe, introduced pumpkinseeds displaced native fishes and reduced populations of native invertebrates. Certainly, some introduced sunfish populations are valued for angling or food, but “nearly all” sunfishes introduced into Europe are regarded as pests, and the largemouth bass is on the list of the world’s “100 worst invasive species”.

Sunfishes are among the very long list of invasive species that are valued in their native ranges but cause problems and are reviled where they were introduced. European rabbits are valued as food, pets, and objects of affection (think Peter Rabbit) in Europe, but caused immense damage to native wildlife and rangeland in Australia. Black cherry is valued for timber and wildlife food in North America, but ranked as one of the worst invasive species in Europe. Asian carp are valued as food fish in China, but regarded as an existential threat to fisheries in the Great Lakes and elsewhere in North America.

We spend a lot of time and energy arguing about whether such species are good or bad. People who want to control species in invaded regions often describe them as evil, sometimes in lurid terms (e.g., “frankenfish”, “plant from Hell”, “plant vampires”, “murder hornets”). Opponents of control often counter by describing the species as good, pointing out their value in their native land. The intent of such portrayals is to justify management actions: evil species must be destroyed, whereas good species must be protected or even spread.

But as the example of sunfish shows, it’s not simple to categorize species as good or bad. Sunfish are highly valued in the eastern United States and cause serious harm elsewhere. With a few exceptions (e.g., mosquitoes that carry serious human diseases), it is hard to simply sort species into the good and the bad from a human point of view. Attempts at such a simple classification are more likely to lead to heated, dead-end debates than to provide a helpful guide to management.

In addition, focusing on whether a species is good or bad diverts our attention away from the central problem of invasive species management, which is the careless movement of species around the world by people. The responsibility for problems with invasive species rests on the people who moved a species around, not with "bad" species. It's not that sunfish are intrinsically good or bad fish, but that people moved sunfish all over the place with scarcely a thought to consequences.

It turns out to be hard to predict the consequences of moving a species into a new ecosystem, which can be large and long-lasting. In fact, invasion biologists don't yet know whether accurate predictions can be made. At least, they will require careful analysis by smart people.

A pumpkinseed sunfish. Credit: Bernard Dupont, from Wikimedia (https://commons.wikimedia.org/wiki/File:Pumpkinseed_(Lepomis_gibbosus)_(13533753654).jpg) .

But we do know that the guy who stocked largemouth bass in Lake Atitlan wasn't smart enough, nor was the aquarist who released pumpkinseeds into France. Thomas Austin, the man who brought rabbits to Australia, and wrote "The introduction of a few rabbits could do little harm and might provide a touch of home", wasn't smart enough. Étienne Léopold Trouvelot, who brought what used to be called "gypsy moths" to North America, wasn't smart enough. I'm not smart enough, and you probably aren't either. And the people who want to introduce genetically engineered analogs of extinct animals like woolly mammoths and passenger pigeons haven't shown us that they are smart enough to predict the outcomes of these introductions, either.

So by all means go out and watch our beautiful and interesting sunfishes on their nests this month. If you are so inclined, go fishing for sunfish, and enjoy these delicious fish on your plate. But please, please, don't move them or any other of Michigan's beautiful and interesting plants and animals into a new ecosystem. You're not smart enough.

Great Lakes Echo, 6 May 2022

June: The Cruelest Month?

T.S. Eliot knew what he was doing when he wrote that:

> "April is the cruellest month, breeding
>
> Lilacs out of the dead land, mixing
>
> Memory and desire, stirring
>
> Dull roots with spring rain."

But you could also make the case that June, not April, is the cruelest of months. All through the spring, baby fish hatch and laze in the sun-warmed shallows, bird chicks take their first wobbly flights, bunnies get their first taste of the greens in my garden, and seedlings sprout and reach for the sky.

And then they die.

Predatory fish slash through the shallows. When April's young fish grow large enough to attract the attention of herons and kingfishers, death comes from above, too. Little fish are trapped in drying floodwater pools. Baby birds die when the weather turns cold and rainy, or are plucked from their wobbly flights by sharp-shinned hawks. House cats find rabbit nests and drag out the bunnies one-by-one until they're all gone. SUVs run over half-grown rabbits. Newly sprouted plants that aren't eaten by slugs or beetles or rabbits wither and die in the first hot spell. Then blight comes for the survivors.

These deaths are driven by the heartless arithmetic of population balance, which demands that deaths balance births. If nature were even a little kindhearted, and allowed a few more baby birds to survive, each year there would be a few more birds, and it wouldn't be long before we were up to our necks in chickadees. So if you make a lot of babies, a lot of babies must die.

Whether Death calls only rarely or is a daily visitor therefore depends greatly on how many babies are produced, which we biologists call "fecundity". Fecundity varies enormously across species, from species like humans (the average woman in the US has about two children over her lifetime), to very fecund species like cottonwoods (which can make millions of seeds each year for decades), fishes like walleyes (hundreds of thousands of eggs over a female's life), or freshwater mussels (tens of thousands to hundreds of millions of eggs over a female's life).

There is necessarily a correspondingly wide range in mortality across species. Here in the United States, about 99% of human babies reach adulthood. In contrast, something like 0.001% of walleye eggs and 0.000001% of cottonwood seeds will grow up to become adults. Most of these deaths occur in the earliest months of life, so for the many spring-breeding species, the slaughter of April's innocents is well underway by June.

Another big difference between species is the amount of care that parents can devote to their offspring. You may know how hard it is to roust just one or two kids out of bed, and get them dressed, fed, and sent off to school with the correct lunch money, homework, musical instrument, and special projects ("Dad, I need a President Taft costume tomorrow"). We can lavish care on our children because we have just a few kids at a time. Now imagine that you have a hundred thousand children to look after. There is just no way that each of those kids is going to get lunch money or a clarinet! So for a species like the walleye, "parental care" consists of laying your eggs in a likely spot and hoping for the best.

Cottonwood seeds, almost all of which will die by the end of their first year. Credit: G. Edward Johnson, via Wikipedia.

There are some advantages to having a lot of offspring, though. When you are very fecund, you can win the lottery in a way that species with few children cannot. For instance, in most years only a few of a cottonwood's innumerable seeds will survive to their first birthday, and none will make it to adulthood. But maybe one year, just maybe, a meandering river exposes a brand new sandbar just as those seeds appear. In that lucky year, a thousand seeds from a single cottonwood tree might sprout and grow up to become adults on Cottonwood Island. No matter how good a year he has, Jeff Bezos won't have a thousand children that year who all grow up to become senior vice presidents of Amazon.

High fecundity also allows for rapid natural selection. If the environment changes abruptly – for instance, if humans start spraying DDT all over the place – the few individuals able to survive in that new environment can multiply rapidly. Such rapid adaptation is impossible for species with low fecundity. This is part of the reason that fecund insects like mosquitoes and houseflies became resistant to DDT in just a few years, whereas birds like eagles and osprey, which lay just a few eggs each year, declined.

But these advantages come at the cost of countless deaths in highly fecund species, many of them in the spring. Just as surely as spring is a time of new life, it is a time of death. In the end, which is the crueler month – April, when false promises are made, or June, when they are broken?

Great Lakes Echo, 3 June 2022

July: Stay Cool

July is our warmest month, its steamy days and sticky nights giving us a little taste of the tropics. When we look for ways to beat July's heat, we often end up in the water – sprinklers, backyard pools, or one of Michigan's many lakes. Even little kids know to head for water in the summer, but few of us understand why water is so cool and refreshing, or know just how frigid Michigan's waters can be on the hottest summer day. So let's take a few minutes on this hot July day to think about how cool water is.

First, water has the highest heat capacity of any substance you are likely to encounter in your everyday life, which means that it can absorb a LOT of heat without heating up much. It also transfers heat much faster than air. This explains why you cool down so much faster in a cool lake than in cool air, and warm up faster in a warm shower than in a warm room (and is the basis for that old bar bet that an ice cube melts faster at 60 degrees than at 70 degrees – put one ice cube on the counter in 70 degree air and the second in a big glass of 60 degree water, and watch what happens). Water is very, very good at absorbing heat from your suffering, sweaty body.

Second, when water evaporates, it absorbs even more heat. Evaporation is what makes you shiver when you step out of the water into a summer breeze.

The high heat capacity and cooling power of evaporation work on bodies of water as well as your body. Bodies of water are slow to warm up, even under a blazing summer sun, and are constantly cooled by evaporation. This leads us to the third reason that water feels cool – it feels cool because it is cool. In July, temperatures of lakes and streams often are much lower than the air.

This temperature difference can be large, as anyone who has gone swimming in Lake Michigan or Lake Superior (brrr) knows. The average July surface temperatures in these lakes are 67 degrees and 53 degrees, respectively, which is cooler than the average air temperatures in Lansing (72 degrees) or Marquette (66 degrees). More important to those of us seeking relief from the summer heat, the lakes are a lot cooler than the air on warm July afternoons, which typically are in the 80s in lower Michigan and in the 70s even in the U.P.

Some waters are even colder than this in July, but we don't often encounter them. Springs and seeps that emerge from deep soils and aquifers usually run year-round at about the average annual air temperature (from the low 40s to the low 50s, depending on where you are in Michigan). Spring-fed streams can be achingly cold, even in July. Trout seek out these cool refuges on the hottest summer days, and so do anglers. People used to use springs as refrigerators, building little springhouses (see the picture) over cold springs to keep meat, produce, and dairy products cool.

A springhouse in Pennsylvania. Credit: Michael H. Parker, Wikipedia.

The surface waters of our deep lakes may be pleasantly cool in July, but their bottom waters are downright cold. The deep waters of both Lakes Michigan and Superior are 39 degrees during the summer, no matter how hot the air is. Even small Michigan lakes have bottom waters in the 50s, if they are deep enough. Where does this frigid water come from?

Like most substances, water becomes less dense as it warms up. Water is densest at about 39 degrees, where a cubic foot of water weighs 62 pounds, 6¾ ounces. At 50 degrees, that cubic foot of water weighs 62 pounds, 6½ ounces, and at 80 degrees, it's 62 pounds, 3½ ounces. These tiny differences have big effects on lake physics and biology.

In the spring, the sun warms the surface waters a little. At first, winds are able to mix this slightly warmer, slightly lighter surface water into the rest of the lake, and the whole lake warms from top to bottom. If the lake is deep enough, though, eventually the surface waters become so light that winds can no longer stir them down. Even a difference of a few ounces per cubic foot can be enough to defeat the wind. Once this happens, the lake becomes "stratified" – the surface waters continue to warm up, but the deep waters (which lake ecologists call the "hypolimnion", meaning underlake) become insulated from the heating power of the sun and warm summer air. The underlake stays insulated from the heat until surface waters cool enough in the fall to allow the wind to again mix the lake. As a result, the deep waters of the lake can stay very cold all summer.

Stratified lakes thus provide a summer refuge for coldwater fish like trout, whitefish, and smelt that would otherwise not be able to tolerate Michigan's summers. But this refuge can also be a trap. Because the underlake is isolated from the air and the sunlight, it does not receive new stores of oxygen during the summer. It's as if the trout and whitefish are locked in a sealed room all summer, hoping that there is enough oxygen to see them through until the room is opened again in the fall. They can't go to the upper parts of the lake to breathe because it's too warm. But if the underlake is small, or especially if there is too much juicy plankton settling down from the upper waters of the lake and decaying in the underlake, oxygen will run out before the fall, and the fish will die. In most Michigan lakes, especially where a rich plankton is fed by nutrients running off from lakeside houses and lawns, oxygen runs out before the end of the summer. These lakes cannot support coldwater fish, even though the underlake stays cold.

Humans are damaging these cool refuges in several ways. Climate change is warming our lakes, so the Great Lakes are now breaking records for warm summers and falls. There are subtler effects as well. I already noted that nutrient pollution leads to oxygen depletion in the underlake, squeezing coldwater fishes between overheating and suffocation. Coldwater fishes are being squeezed in another way, too. As the climate warms, lakes stratify earlier in the spring and stay stratified later into the fall, so coldwater fishes have to stay longer and longer in that sealed room. And groundwater-fed springs and seeps dry up when we pump too much ground water out of aquifers or build too many hard surfaces (roads, parking lots, roofs) that cause rain and snow to run off instead of replenishing those aquifers. Like our other natural resources, coldwater refuges require careful management if we are to preserve them.

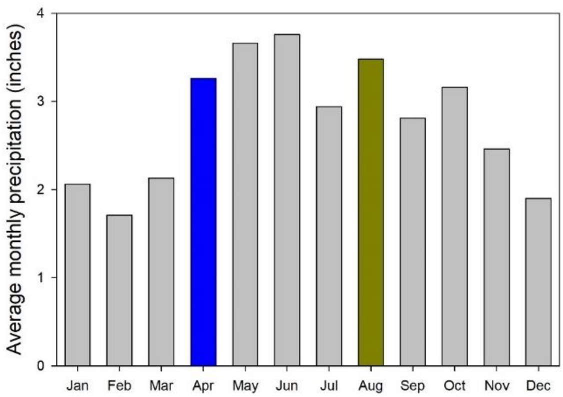
Glaciers left Michigan more than 10,000 years ago, and it has been a long time since any Michigander felt a cooling breeze coming off a glacier. But the glaciers did leave Michigan with thousands of lakes, and deep deposits of sand and gravel that are filled with cool ground water. These legacies of the ancient ice sheets still keep us cool through July's hottest days.

Great Lakes Echo, 1 July 2022

August: Dibs on the Water

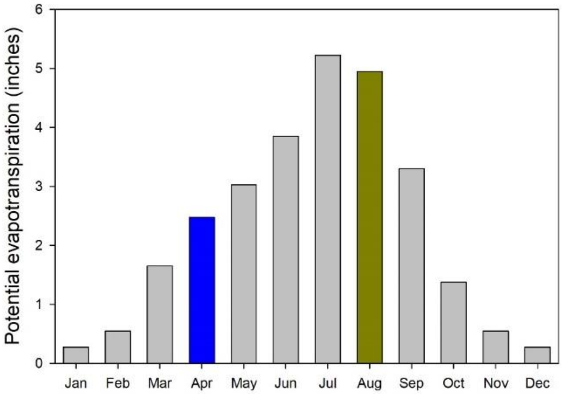
As anyone who lives in Michigan knows, March and April are the wet months, with puddles in lawns and fields and rivers overflowing their banks, while August, with corn wilting in the fields and lawns a crispy brown, is the driest. But like so many things that Anyone knows, this is only about half true. Yes, we can expect puddles in April and wilting corn in August, but not because it's rainier in April than in August. Instead, our feeling about how dry a month is has little to do with how the supply of water changes from month to month, and everything to do with how the demand for water changes through the year.

The amount of precipitation (the water in rain and snow) doesn't change much from month to month in Michigan. The first graph pictured below shows how much precipitation falls each month in an average year in Lansing. The wettest month (June) gets only about twice as much water as the driest (February). And surprisingly, August (the brown bar in the graph) is the 3rd-wettest month of the year, and actually gets a little more precipitation than April (the blue bar).



Average monthly rainfall at Lansing during 1991-2020, from NOAA records. Rather than being dry, August (brown bar) typically is one of the rainiest months of the year, and receives a little more rain than the "wet" month of April (blue bar).

If we get so much rain in August, why is it so dry? The answer is that the demand for water from evaporation and especially from plants changes a LOT from month to month. In the winter, plants use almost no water and evaporation rates are low. As a result, precipitation that falls in these months can built up in soils and aquifers, accumulate as snowpack, or run off into lakes and streams. So these months are wet, even though there isn't a lot of precipitation.

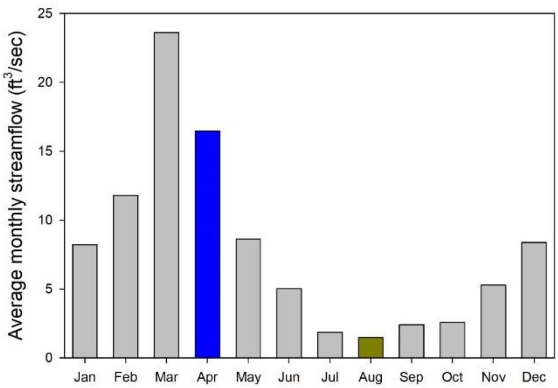


The amount of evaporation plus plant water use (which is called "potential evapotranspiration") that would occur if unlimited water were supplied in an average year near Lansing, from USDA. Note how much higher evapotranspiration is during August (the brown bar) than April (the blue bar).

Once spring really gets going, plants start to use a lot of water, and evaporation increases. By summer, demand for water outstrips supply by precipitation, and soils dry out, plants wilt, and streams wither. This drying trend continues until September or October, when plant growth and water demand slow.

Streams are fed by water that is left over after plants and evaporation take their first dibs on any precipitation that falls, so any water that falls during the summer goes first to the thirsty plants, and only what is left over gets to the poor fishes. As a result, streams can shrink dramatically, exposing their inhabitants to mortal peril.

As an example, the next graph shows how much water flows down the East Branch of Coon Creek in an average year. This graph doesn't look at all like the first graph showing the seasonal pattern of precipitation; instead, March and April are wet and July and August are dry. The huge difference between the precipitation graph and the streamflow graph shows how plant demand for water and evaporation control streamflow (and our perception of which months are wet and which are dry).



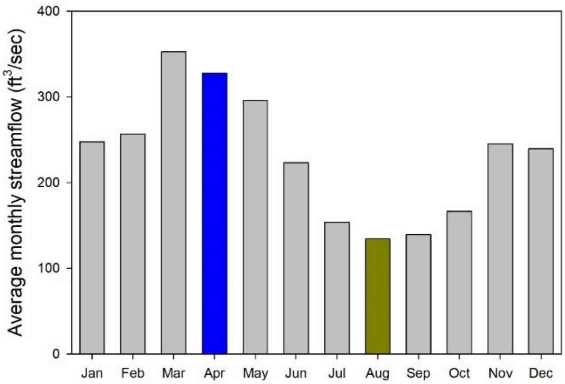
Average monthly streamflow in the East Branch of Coon Creek, a small stream in Macomb County that drains heavy clay soils. Streamflow is far higher in April (the blue bar) than in August (the brown bar). Data from USGS records.

When I visited the East Branch of Coon Creek one dry August day, the stream had stopped flowing altogether, and the "creek" had shrunken to muddy pools separated by long stretches of damp "streambed". And everywhere there were signs of the deadly effects of the dry season. The dry streambed was littered with shells of crayfish, mussels, and snails killed in place when the water disappeared. Decaying fish floated on the surface of the smaller pools, victims of the heat or suffocation. The larger pools were ringed by the tracks of raccoons, herons, and other predators drawn to the bonanza of fish and shellfish trapped in their dwindling refuges.

If water demand by plants and evaporation exceeds rainfall in most Michigan summers, why is there any water at all in our streams in August? The answer is that a lot of water makes it past the plants and evaporation to reach deeper layers of the earth, especially in October through April (when plant demand is low). The water held in these deeper layers of the earth (called aquifers) is gradually released through the year, feeding streams even in dry periods.

The more water in the aquifer, the more water in the stream during August. Landscapes where the water soaks in slowly or not at all (clay soils or pavement) or with shallow soils on top of the bedrock typically store only a little water in aquifers, whereas landscapes with deep deposits of sand or gravel store a lot of water.

It’s easy to see the importance of aquifers by comparing summer streamflow in the East Branch of Coon Creek, which flows through clay soils, with the nearby Huron River (the graph below), which flows through deep sand and gravel, with many water-storing lakes and wetlands. There is plenty of water in the Huron River even during the hot days of August, and its fish and shellfish never face the deadly perils of a withering stream.



Average monthly streamflow in the Huron River in Livingston County, which drains sandy soils, wetlands, and lakes. Streamflow in August (the brown bar) is only a little less than in April (the blue bar). Data from USGS records.

So although Anyone knows that Michigan’s streams dry up in the summer because we don’t get much rain, the truth is that streams dry up mostly because the plants (and evaporation) hog all of the water, and because aquifers in some parts of the state are too small to keep feeding the streams. Most of these aquifers are deep deposits of sand and gravel left by the glaciers, so once again we are reminded of the long shadows that the Ice Age still casts here in Michigan.

Great Lakes Echo, 5 August 2022

September: Connections

How we name things affects how we think about them. We name fields, and forests, and marshes, and streams as separate things, so we tend to think of them as separate things. But separating these habitats in our vocabulary and in our minds obscures the innumerable connections that bind these habitats into a single working landscape. Streams are especially well connected to other habitats, in ways both obvious and subtle.

Only a tiny fraction of the water in a stream falls from the sky directly into the stream. Instead, most of the water that runs down a stream falls on the surrounding landscape, then runs off or percolates through forests, fields, marshes, and cities before reaching the stream. In this process, it picks up chemicals that set the character of the stream ecosystem.

Here in Michigan, the limestone underlying much of the state, and the farm fields and cities on the land's surface, supply our streams with the calcium that nourishes shellfish and the nitrogen and phosphorus that nourish algae. If we somehow were able to sever all of the connections between the land and the stream, the stream would dry up and disappear. And when we changed the character of the land by replacing forests and marshes with farm fields and cities, we changed the character of our streams. These are obvious connections between streams and the surrounding landscape.

But connections can be far more subtle and wide-ranging, a point that was brought home to me one September day a few years ago when I was fishing at Weirs Rapids on the Maumee River. These rapids are packed with the larvae of net-spinning caddisflies, which were emerging that day, the air alive with fluttering gray moths. Somehow, the migrating purple martins and nighthawks had gotten word, and the air was full of birds. I am used to seeing one or two nighthawks on summer evenings, high overhead. Here there were perhaps 50 birds, swooping and slicing through the air just a few feet above the water. I can't even guess at the number of martins, but there must have been hundreds or even thousands of them, often close enough (but not slow enough!) to touch. I've never been in the midst of a great flock of birds like that, and it's hard for me to describe the wonderful sensation. The only comparison that I can make is that it felt a little like swimming with a big school of fish on a coral reef.

So here is a connection that runs uphill from the stream back into the surrounding landscape – the river is feeding the birds. But there is yet another connection here. The martins and nighthawks are gorging on Maumee River caddisflies to fuel their long migration south. This is a long-distance connection indeed; martins winter in Brazil, Bolivia, and Peru, and nighthawks winter in Argentina. As improbable as it may seem, this muddy river running through the flat Ohio farmland is directly connected to the Amazon rainforest and Argentine pampas. You could even think of Weirs Rapids as being a far-flung outlying district of South America.

Rapids of the Maumee River, Ohio, near the far northern edge of South America. Credit: Dave Strayer.

I go back to Weirs Rapids every September hoping to see those flocks of migrating birds, but I've never gotten the timing right, and I guess I won't see them again. But it's easy to see other, less spectacular, examples of how the stream and its surroundings feed one another. All summer, you can see cedar waxwings and bats flying over streams and rivers, hawking insects. Spiders build their webs on streamside branches to capture the insects that escape from the birds. In turn, fish are alert to grasshoppers, ants, and beetles that fall into the water, and grow fat on these meals supplied by the surrounding land. In the fall, streamside trees supply additional food in the form of leaf-fall, which fuels the stream food web for many months afterward. There is no separating streams from their landscapes.

These connections complicate how we manage our world. We have to be careful about breaking connections that link different habitats. When we remove streamside vegetation and replace it with lawn or soybeans, we rob food and cooling shade from the stream's inhabitants, and make it harder for terrestrial predators to forage for emerging stream insects. When we build streamside barriers like walls or steep embankments, we make it difficult for animals like turtles and raccoons to get what they need from both the stream and the land. Such activities can weaken the links between the stream and its landscape, to the detriment of both.

Long-range connections matter, too. If we want to keep Lake Erie from filling up with toxic algae, we need to watch how we manage cornfields many miles away, far out of sight of the lake or indeed any stream. Protecting "our" songbirds means protecting habitats in Michigan, South America, and everywhere in between. Successful management of our natural resources will challenge us to think beyond the artificial boundaries imposed by our language, our politics, and our minds.

Great Lakes Echo, 2 September 2022

October: The Smells of Autumn

It's October, and the stink bugs are moving into my house for the winter. They're hanging onto window screens, hiding in dark corners, and crawling ponderously around the bathtub. And woe unto you if you squash one. Last week, a stink bug was hiding in my washcloth, though I didn't know it, so I ran hot water over it and rubbed it around on my face. It was a memorable experience for both of us. Let me just say this – it'll never be popular as a men's fragrance.

Most of the stink bugs I see are brown marmorated stink bugs (see the photo), which were accidentally brought to the United States in the 1990s. These animals are major pests, causing millions of dollars of damage each year to apples, berries, corn, and other crops.

Stink bugs move into our houses in the fall because they're looking for a cozy place to spend the winter. If it weren't for your house, they'd probably overwinter in a nice woodpile or under the bark of a tree. They think your house is the biggest, coziest woodpile they've ever seen, so they arrive in droves – 26,205 stink bugs moved into one house in Maryland. And they're not the only animals hoping to spend the winter in our houses. Fall is a big time for house mice and other rodents to turn up in attics, pantries and basements, and sometimes ladybugs can show up by the hundreds.

Catherine the Rank, a brown marmorated stink bug. Credit: Hectonichus, via Wikipedia Commons.

But of course the big thing about stink bugs is their smell; after all, "stink" is right there in their name. (And I like to imagine that they have appropriate individual names like Thomas the Vile, Lawrence the Pungent, and Carlotta the Revolting.) Stink bugs smell bad to repel predators. There are plenty of other examples of this sort of thing – opossums, garter snakes, and millipedes all emit distasteful odors when bothered, for instance. Of course, the outstanding local example of an animal with a stinky defense is the skunk, whose pungent odor even our poor human noses can detect from blocks away. For a dog, whose nose is something like 10,000 times more sensitive than ours, being sprayed by a skunk must be like being hit with a flashbang grenade.

So, many things stink in a deliberate attempt to be repulsive. Other things stink to be attractive, but because they're not trying to attract us, we may not like their aromas. A few years ago, October rains brought up three kinds of stinkhorns in my front garden, including the wonderfully named "stinky squid" (see the photo). Stinkhorns are mushrooms easily recognized by their foul odors and their bizarre and sometimes X-rated shapes (no, I'm not going to describe them to you – go look them up for yourself). Stinkhorns use their odors ("like fresh pig manure", "like cat feces", "carrion-like") to attract insects to disperse their spores. If these odors don't appeal to you, too bad – it's not you that the mushrooms are trying to impress.

The stinky squid mushroom. Credit: Jon (watchcat) via Wikipedia Commons.

In some cases, such "attractive" odors are very revolting to us. "Corpse flowers" or "carrion flowers" produce the fragrance of rotting meat to attract the flies and beetles that pollinate them. This smell can be powerful and very unpleasant. My brother's college roommate had one of these strange plants, which over a period of weeks produced a larger and larger flower bud. When the bud finally opened, the smell was so bad that they immediately moved the plant out of the room (and you know that it must have been really bad if a couple of male college students thought that it was too repulsive to keep in their dorm room).

The spectacular and vile-smelling corpse flower, Amorphophallus titanium. Note the absence of human visitors in its immediate vicinity. Credit: Rhododendrites, via Wikipedia Commons.

To make the flower even more attractive to insects, it may look as well as smell like a piece of decaying meat (see the photo). Some species even heat their flowers up to human body temperature to help spread their delightful fragrance. So, surprisingly, some of the stinkiest smells in the natural world are designed to attract, not repel.

Fall can be a time of interesting aromas as well as beautiful sights. By all means enjoy your favorite smells of autumn – pumpkin spice, burning leaves, mulled cider, and that last rose of summer. But maybe take the opportunity this October to have a little olfactory adventure too – take a little whiff of a black walnut husk (citrusy), sassafras leaf (lemon-tropical), spicebush leaf (well, spicy), or even a stink bug or a stinkhorn, to broaden your sensory experience. And look twice before using your washcloth.

Great Lakes Echo, 7 October 2022

November: What's For Thanksgiving Dinner?

We all have different Thanksgiving favorites. Some people really look forward to that big turkey, some crave sweet potatoes, and I have to admit that I head straight for the pies. But today, I want to talk about that old Thanksgiving favorite – wet, rotting leaves.

Thanksgiving, of course, is a harvest festival, when we give thanks for the bounty of growing season that just ended, and sample some of that bounty. In our case, that means turkey and sweet potatoes and pies, but for our friends in the stream, it means wet, rotting leaves.

All summer long, the insects and fishes that live in our streams browse on the algae that grow on the stream bottom (that's the slippery stuff on the rocks that makes it so hard to wade across a stream without falling down), and slurp up the succulent bugs that fall into the stream. But the really big delivery of food to our streams comes in the fall, when falling leaves fall or blow into the water.

Just like your Thanksgiving dinner, these leaves are the products of the last growing season. They make their way into the stream's food web in a couple of ways. First, right after autumn leaves fall into the water, they release a lot of dissolved organic matter – a sort of leaf tea. You can see this leaf tea as the brown water in leaf-filled puddles on the sidewalk. This tea can amount to more than 10% of the weight of the leaf, and is good food for the bacteria and fungi that live in the stream. In turn, stream insects like mayflies and caddisflies are very happy to eat these bacteria and fungi.

What happens to the rest of the leaf? Stream insects don't like to eat freshly fallen leaves. Instead, bacteria and especially fungi first colonize the leaves and begin to feed on them. After a few weeks, the unpalatable wet leaves have been transformed into delicious wet, rotting leaves by the fungi (I suppose they must be like little portabello mushroom sandwiches now, from the viewpoint of stream insects), and many stream insects start to eat them. This occurs around Thanksgiving each year.

The insects that feed on the wet, rotting leaves are called "shredders", and include some of the stoneflies and caddisflies, crane fly larvae, and crustaceans. When shredders are done with the leaves, they've transformed big, rotting leaves into little, rotting leafy bits, which are good food for invertebrates called "collectors" such as many of the caddisflies and mayflies, as well as the tiny midges and many others. And of course, all of these stream insects, regardless of their feeding habits, feed the trout and many other kinds of stream fishes that we care about.

Delicious wet, rotting leaves in a stream. Credit: Stroud Center (www.stroudcenter.org)

The annual leaf-fall is so important to streams that some shredders live only in forested regions, and even organize their lives around this important event. For instance, winter stoneflies are shredders that become active in the fall, grow fat through the winter, feeding on decaying leaves, and emerge onto the snow in late winter. Their eggs hatch into tiny larvae in very early spring, which sleep through the warm summer awaiting the autumnal leaf-fall.

It should be pretty obvious that when we cut streamside trees, we deprive the stream of its Thanksgiving dinner. We can also take food away from our friends in the stream when we "clean out" streams by taking out snags and debris, or straighten the stream. The snags and bends in a stream catch and hold leaves, and keep them from washing downstream. When you "clean out" a stream, you starve the ecosystem just as surely as if you cut down the streamside trees.

So now that you understand the importance of wet, rotting leaves to our streams, perhaps you should try serving them to your guests this Thanksgiving. At least, you won't have to host the family Thanksgiving dinner next year!

Poughkeepsie Journal, 18 November 2012, reprinted in modified form in the Great Lakes Echo, 4 November 2022

December: A Visit to the Museum of Ice

"I have the world's largest collection of seashells. I keep it on all the beaches of the world... perhaps you've seen it." – Steven Wright

We have museums for all kinds of beautiful or interesting things – paintings, gems, music, archaeological artifacts; here in Ann Arbor, we even have a museum of old and uncomfortable-looking dental devices. Often, these museums have special facilities to accommodate their special subjects. Temperature, humidity, and light are carefully controlled, objects may be displayed on archival acid-free paper, and so on.

So when we were thinking about a new museum devoted to one of the most beautiful and interesting things on our planet – ice – we had to think hard about how best to display and preserve this delicate substance. Obviously, the museum would have to kept cold, so first we thought about a big walk-in freezer. Then we realized that we'd have to lend coats, boots, and mittens to all of our visitors, and provide bright light to really show off the spectacular beauty of ice. Everything seemed so complicated that we were about to give up when we had a brilliant idea – not a walk-<u>in</u> frozen museum, but a walk-<u>out</u> frozen museum.

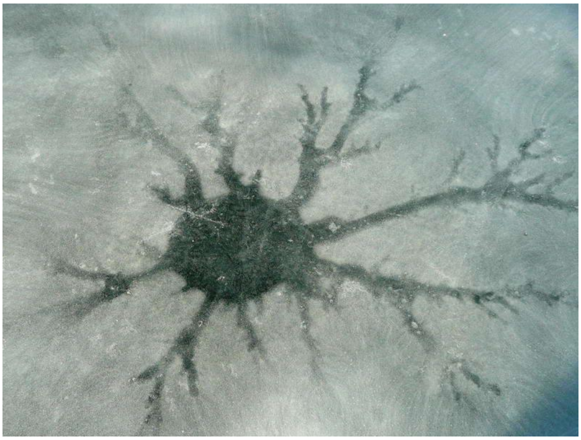
So welcome to the Museum of Ice, Michigan's largest museum, open daily (weather permitting) between December and March. Just step outside anywhere in the state and you're in the museum.

Blue glacial ice in Greenland. Credit: Visit Greenland, via Wikipedia.

You'll see ponds and lakes covered in beautiful black ice, as transparent as glass, through which you may see underwater plants, insects, or even a fish. Search for imperfections in the ice – bubbles trapped in mid-flight, leaves frozen into the ice, black "ice-spiders". Have one of our docents chip out a chunk of black ice for you, so that you can appreciate its diamond brightness.

Maybe you'll see some blue ice. Ice is optically similar to liquid water – in small pieces (like an ice cube), it looks clear, but if you see a thick piece that is free of air bubbles and snow, it's as blue as a lake on a summer's day. The best place to see blue ice is in a glacier or iceberg (which we don't have in our current collection at the Museum), but the ice in Lake Michigan's ice caves, or the thick chunks of ice piled up on the shores of the Great Lakes may look distinctly blue.

If you're feeling adventurous, bundle up and go down to a fast-moving stream the morning after a clear, frigid night to see frazil ice. A lot of people think that moving water doesn't freeze, but even fast-moving water freezes if it gets cold enough. After a bitter cold night, the streamwater will be steaming, and long needles and feathers of ice ("frazil ice") will be crystalizing all through the water. These crystals are sticky, and pile up on stones and logs, instead of forming a solid skim on the water's surface.



An ice spider (these are also called lake stars or octopi). Credit: Lake Ice website (http://lakeice.squarespace.com/ice-stars/), a great source of information for ice enthusiasts.

If you're not feeling that adventurous, check out the frost around your home. Especially after cold, clear nights, you'll see lovely silvery fingers of frost on your windows and delicately encrusted on twigs.

Don't forget to visit the exhibit on the Sounds of Ice. Here, you can hear the common, everyday sounds of ice - the sharp crackling of breaking skim ice, and the crunching of cold snow underfoot beneath a dark, starlit sky. But there are rarer and more exotic sounds. When the ice covering a lake expands and contacts, it booms and groans, the ice sheet acting as the soundboard of an immense musical instrument. If you're really lucky, you might hear the restless chiming of ice washing in the surf of the Great Lakes, or the rhythmic singing of waves running up under a thin ice margin. Keep your ears open when visiting the Museum!

Ice is dangerous as well as beautiful, and the deadly side of ice is also on display in the Museum. Ice-covered lakes and streams can be treacherous. The usual advice is that sound black ice three or four inches thick is safe to walk on, but when the ice is white – slushy or snowy, all bets are off. Late-season ice forms long vertical crystals the size and shape of a pencils or candles. This "candled" ice easily breaks along the junctions between the crystals, so it has no strength and is very dangerous. I once chopped through 18 inches of candled ice with just three strokes of an ice spud before retreating carefully to a safer place. The ice on rivers and streams is unreliable too, because its thickness can change from a foot to an inch in a single step.

You don't have to go out onto a lake or river to be exposed to the dangers of ice. The other kind of "black ice", the nearly invisible coating of ice on road surfaces resulting from the freezing of light rain or the moisture in the pavement or vehicle exhaust, causes traffic accidents and deaths every winter. Freezing rain produces perhaps the most beautiful and damaging form of ice, glazing every surface with a glittering and impossibly slippery coat. The weight of this ice can tear down branches, trees and power lines, and take down the electrical grid for days or even weeks. Freezing rain is so slippery that driving or even walking can be close to impossible.

Damage from freezing rain. Credit: Wikipedia.

So be careful when you visit the Museum of Ice this winter. But do visit, because ice in all of its forms is worth seeing. And here's a bonus – no matter where you live in Michigan, this museum is just around the corner.

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