

41°N

WATER

41° N**EDITORIAL STAFF**

Monica Allard Cox, Editor
 Judith Swift
 Alan Desbonnet
 Meredith Haas

CONTRIBUTOR

Nicole Rohr

ART DIRECTOR

Ernesto Aparicio

PROOFREADER

Beth Ayer

COVER & BACK COVER

Photograph by John Supancic

ABOUT 41° N

41° N is published twice per year by the Rhode Island Sea Grant College Program and the Coastal Institute at the University of Rhode Island (URI). The name refers to the latitude at which Rhode Island lies.

Rhode Island Sea Grant is a part of the National Oceanic and Atmospheric Administration and was established to promote the conservation and sustainable development of marine resources for the public benefit through research, outreach, and education.

The URI Coastal Institute works in partnerships to provide a neutral setting where knowledge is advanced, issues discussed, information synthesized, and solutions developed for the sustainable use and management of coastal ecosystems. The Coastal Institute works across and beyond traditional structures to encourage new approaches to problem solving.

Change of address, subscription information, or editorial correspondence: 41° N, Rhode Island Sea Grant, University of Rhode Island, Narragansett Bay Campus, Narragansett, RI 02882-1197. Telephone: (401) 874-6800. E-mail: 41N@gso.uri.edu

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THE
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WATER EVERYWHERE

A CENTURY HAS PASSED SINCE RESIDENTS OF SEVERAL VILLAGES in Scituate, Rhode Island, received notices that their properties were being condemned, and would be flooded, in order to create the Scituate Reservoir, a water supply that would provide for the needs of 60 percent of the state's population. Author Maury Klein chronicles both the heartbreak of the families who lost homes, farms, businesses, and even family graves, as well as the pressing need to provide residents with a safe, adequate water supply.

Today, as Hugh Markey writes, the prospect of altering the flow of water in Rhode Island's rivers by removing decrepit dams evokes a visceral response from neighbors, who have strong connections to the ponds that these dams created decades, even centuries, ago. Though restoring river habitats and fish runs would provide ecological benefits, people have keen feelings about the waters they consider theirs.

This issue of 41°N considers water in some of the many ways it permeates our lives—as supplying a fundamental need for all living things, as a conduit for international trade, as a source of refreshment and recreation, and even as the hidden essence of a millennia-old fermented beverage.

Drink it in, and as always, please let us know what you think.

—MONICA ALLARD COX
Editor

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Follow the Fish

FISHING INDUSTRY, FISHERIES MANAGERS
FOCUS ON TRACKING SPECIES
SHIFTS DUE TO WARMING OCEAN WATERS

by **Chris Barrett**

Photographs by **Michael Cevoli**



LIKE DETECTIVES FOLLOWING LEADS, FISHERMEN

follow sea temperatures. The rise and fall of the ocean's warmth offer clues to where fish hide. But rising average sea temperatures have made tracking and catching fish more complex.

"Climate change is real, and it is real in the ocean," says commercial fisherman Richard Fuka, who heads the R.I. Fishermen's Alliance. "Fishermen are throwing their old logbooks out the window."

In his 2015 State of the Union address, President Barack Obama called climate change the greatest threat to future generations. The statement came four days after NASA reported that 2014 was the warmest year since 1880, and that average surface temperatures increased 0.8°C in that timeframe. NASA blamed the trend primarily on increased carbon dioxide and other human-driven emissions.

For the world's oceans, rising temperatures matter. The United Nations Intergovernmental Panel on Climate Change concluded with "high confidence" in 2014 that freshwater and saltwater fish are adjusting migration patterns in response to changing sea temperatures. Worse, some species face higher mortality rates and others could become extinct.

"This is going to change things, no doubt," says Fred Mattera, a retired fisherman who heads the Point Club, a Rhode Island-based fishing insurance cooperative.

The United Nations report warned that climate change is already impacting the chemistry of the ocean, from the salt content to acidification. Areas with little oxygen are expanding in the tropical Atlantic, Pacific, and Indian oceans because warmer water contains less dissolved oxygen than colder water, which in turn limits where fish thrive. Coral cover that provides an important home for marine species has diminished and may be growing at a slower rate. In short, the entire ecosystem is transforming.

"The change in temperature is changing the way the energy is processed in the food web," says Jeremy Collie, a professor of oceanography and a fish expert at the University of Rhode Island Graduate School of Oceanography. "It's tipping the balance from one species over another and results in there being winners and losers in the food web."

A study by Collie and his colleagues found between 1959 and 2005 an increase of 1.6°C (2.9°F) in Narragansett Bay. The same study showed shifts in the population of at least 24 species of fish. By

measuring fish catches at stations in lower Narragansett Bay and Rhode Island Sound, researchers found a swing to pelagic (water-column) fish and squid from demersal (bottom-dwelling) fish.

South of Whale Rock in Rhode Island Sound, URI researchers recorded more than a 100-fold drop in cunner. Red hake, longhorn sculpin, sea stars, and silver hake all experienced drops of more than 50 percent. Conversely, a more than 100-fold increase in butterfish, striped sea robin, and longfin squid, which prefer warmer waters, came along with the upswing in temperature.

A shift in temperatures and species extends to the larger Gulf of Maine, the vast expanse of water between Cape Cod and Nova Scotia that many Northeast fishermen call home. Situated between two ecosystems—the colder North Atlantic and the warmer mid-Atlantic—rising temperatures threaten to push out the fish that prefer chillier temperatures.

The Gulf of Maine Research Institute found that temperatures in the gulf are rising faster in recent years than they have over the past three decades. Comparing it against a global dataset, researchers discovered a worrying trend: over the past decade, waters in the gulf warmed faster than 99 percent of the world's oceans.

Kathy Mills, an associate research scientist at the institute, says that integrating knowledge of sea temperatures with fisheries policy is crucial to ensuring a sustainable fishing industry.

"We're starting to see ways in which thinking about temperature really could have some immediate effects on the science that guides fisheries management," Mills says.

Federal law requires regional fisheries management councils to implement policies—usually boiling down to catch limits—that rebuild stocks within a decade. To do that, scientists need to understand the mortality rates of species, and they are finding temperature—as well as fishing—affects that rate.

Mills says temperature changes may stunt fish growth and small fish may lay fewer or less viable eggs.

"I think we're just starting to crack the surface of really understanding some of these changes and using them to look ahead to what things might look like in the future," Mills says.

Owners of party and charter fishing boats already have some idea what that future may look like. Twenty years ago they saw cod all but disappear from the re-

gion. Once a year-round industry that primarily chased cod, charter fishing had to change to a seasonal business that diversified among species.

"We tend to be an innovative group of fishermen in Rhode Island, and we will adapt to whatever happens," says Rick Bellavance, president of the 65-member Rhode Island Party and Charter Boat Association.

Rhode Island Commercial Fishermen's Association President Christopher Brown, who's been fishing since 1976, agrees. "Everyone assumes that climate change is going to produce an infinite list of losers biologically, but I don't see that being plausible," he says. "It's simply going to increase the stocks for some species."

If the public demands those species, fishermen will chase them. Brown says some in the industry grumble about spending money to purchase new nets or other equipment to catch a new species. However, the industry long ago learned it must stand ready to rapidly adjust in the face of tightening government regulations and the shifting taste buds of Americans, he says.

But Bellavance and his commercial fishermen counterparts say they also need regulations to change with the changing sea temperatures.

The National Oceanic and Atmospheric Administration (NOAA) is trying to do just that. NOAA collects the data on fish populations that serve as the basis for fisheries management policy. Under pressure from the fishing industry and public to refine its models, NOAA started examining how to incorporate temperature data into its formulas, says Jason Link, a top fisheries scientist at the agency.

"We're really taking a look at the effects of how temperature is changing in the ocean and how it relates to all of our trust species [the species NOAA is charged with overseeing], not only the groundfish but also protected species and even species that are ecologically important," Link says. "The Northeast region was the first to pilot climate vulnerability analysis to see which species would be most vulnerable to temperature and other changes."

Scientists continue to compile the results of that analysis. In the meantime, Link says NOAA successfully factored climate change into its stock assessment of butterfish. A scientist in a New Jersey NOAA Fisheries Laboratory worked with university colleagues, commercial fishermen, and others to revise the assessment. The research played a role in the Mid-Atlantic Fishery Management Council's decision to increase catch limits of the species.

Link says all the regional councils will soon see assessments that account for temperature change

Christopher Brown, aboard his vessel *Proud Mary*, says that climate change "is simply going to increase the stocks for some species."







because it's occurring throughout U.S. waters with varying consequences. For example, in the Gulf of Mexico, species attempting to escape warmer waters by moving north are stemmed by land. So instead they head to deeper or more western waters. In Alaska, melting sea ice changes the salinity in the water and shifts temperatures, putting some species at risk.

"We need to step back and provide broader context and more regularly do more of these vulnerability analyses," Link says. "Then we can begin to prioritize and develop mitigation strategies and emphasize how to respond to some of these changes that will be beyond our ability to control."

Implementing those strategies may be a challenge. More than three decades of fisheries management set catch limits and developed days-at-sea regulations that some fishermen complain ruin their livelihood. In the

Northeast, an unsuccessful plan to rebuild the iconic cod stock left many fishermen skeptical of both government intervention and the science behind it.

Brown says fishermen are willing to limit their hauls if it means protecting their long-term survival.

"But as it is right now we have very little faith in the science" behind the catch limits set by the New England Fishery Management Council and its regional peers, he says.

Any adjustment in quotas or days-at-sea regulations inevitably causes controversy. Few researchers think that climate change will mean the end of all fish, but Mills, from the research institute, worries a shift in species will introduce new questions about fairness.

Currently, aforementioned regional fisheries councils enforce fisheries policies. Councils typically set catch limits and award licenses on a regional basis.



Setting minimum mesh sizes is another fisheries management tactic intended to help rebuild stocks.

When a species leaves the human-drawn regulatory zone, perhaps because of temperature changes, fishermen may not be allowed to follow them into the next zone.

“It creates these really difficult questions about how you deal with fairness and equity,” Mills says.

Should local councils allow in fishermen from outside their home regions? What about fish that transverse international boundaries or head into non-exclusive fishing zones? These are tough questions that regulators are just now considering in the face of species permanently moving.

To try to answer those questions, the New England Fishery Management Council has hosted workshops

with stakeholders and started discussing possible solutions internally. Still in the early stages of discussion, one possible solution is to reach compacts with its neighbor, the Mid-Atlantic Fishery Management Council, on regulations.

Chris Kellogg, the council’s deputy director, says new information on climate change has also spurred the council to look at species management with a wider lens.

The council “supports the research underway on the issue and is working on ways to use that information to evaluate changes that might be relevant to the fisheries it manages,” he says. “In the larger context, work continues on an ecosystem-based fisheries management program that will examine New England fisheries spatially across all fish species rather than on a single-species basis.”

MILLIONS DEPEND ON THE OCEAN FOR FOOD

For fishermen it’s big business. Rhode Island-ported vessels sold over \$200 million in fish in 2011, according to a Cornell University study. Add on sales associated with fish imports, and the Ocean State sees a \$763 million economic impact from the fishing industry. The same study said the state’s fishing industry employed nearly 7,000 people, and of those, about 2,500 are full or part-time fishermen.

Nationally, commercial and recreational saltwater fishing produced nearly \$200 billion in sales and supported 1.7 million jobs in 2012, according to NOAA. Worldwide, fisheries and aquaculture supported jobs for some 60 million people, according to the Food and Agriculture Organization of the United Nations (FAO).

The issues, however, go beyond money, says Collie, the URI researcher. Fish are a major world food source. The FAO reported that fish consumption per capita rocketed to 42 pounds in 2012 from 22 pounds per person in the 1960s. Fish provided 17 percent of the world’s population intake of protein. For small coastal nations, fish provide protein for as much as 70 percent of the populace.

The U.N. projects, with what it calls “high confidence,” that climate change will undermine food security, including the sustained productivity of fisheries.

“There is this question about feeding people,” Collie says. “Globally there are millions of people who depend on the ocean for food.”

Remove all Obstructions

THE LONG, SLOW ROAD TO RESTORING RHODE ISLAND'S RIVERS

by **Hugh Markey**

Photographs by **Sal Mancini**

FOR THE HARDY SOULS WHO SURVIVED THE BRUTAL WINTERS OF COLONIAL New England, there was only one choice: tame the new land. Build farms, mills, and factories that would feed families and ensure that investors back in England would be repaid for the cost of sending settlers to the New World. And building meant changing the landscape, clearing woods, and bending rivers to the needs of the colonists. Water was needed to turn the massive granite stones that would grind the grain they had struggled to raise. Water was needed to power the machines and factories that would, in the years ahead, turn the land from a tiny, struggling colony to a mighty world power. Dams were built everywhere because there was work to be done, fortunes to be made, and surely there were more than enough plants, wildlife, and fish to compensate for any losses incurred by halting the natural flow of water.

Whether that assumption was true or not, the building went on. And on. And as years turned into decades turned into centuries, the dams that provided such a vital link to colonial success fell out of use. New sources of power made the dams obsolete. Yet the dams remained, because communities didn't consider it worth the bother and the expense to remove them, and what harm would they do? In the 21st century, it turns out that the answer to that question is simple: plenty.

From source to sea

Jim Turek, an official with NOAA's Habitat Restoration division, says that even here, in the smallest state in the country, there are at least 800 dams still in existence, and "those are known ones." Some still stand in the centers of towns, such as in Wakefield or West Warwick. Yet many others have been forgotten as their owners died off or moved away. "There are many others that are abandoned out in the

Construction of the Slater Mill Dam in Pawtucket was completed in 1793, and marked the beginning of the American Industrial Revolution.





woods. I can pretty much guarantee that if you go for a walk in the woods somewhere, you'll find an old decrepit dam."

These dams, along with poorly designed culverts, affect what's known as hydrologic connectivity. According to Catherine Pringle, a research professor at the University of Georgia, hydrologic connectivity is "water-mediated transfer of matter, energy, and/or organisms within or between elements of the hydrologic cycle." Artificial water impoundments change the way organic materials, from sediment to plants to fish, are distributed within a watershed. The trouble is, the trail leading to the ownership of those impoundments that inhibit hydrologic connectivity is often a murky one.

Rachel Calabro, community organizer and advocate with Save The Bay, says there's a term for these dams: orphans. "A lot of these dams are orphan dams. You go back through the records, and it's unclear who owns it. (Because of the financial burden of maintaining them) the state doesn't want to take them, the town doesn't want to take them. The responsibility has to lie with somebody."

It is those dams, the tiny ones that turned mill wheels two centuries past, as well as those much larger ones around which cities and towns were built, that affect us today. Picture the 100-year floods of 2010, or Superstorm Sandy of 2012—two of the most significant weather events to hit Rhode Island in decades. In Charlestown alone, Sandy saw to it that there were only six houses in the whole town with lights on the night the storm struck. But the biggest impacts were from water. A report from the Wood-Pawcatuck Watershed Association (WPWA) says the three storms in March 2010 dumped over 16 inches of water on the state. Damage from Sandy was well into the tens of millions of dollars. That damage was due in part to the dams built so long ago, now obsolete but still obstructing rivers, still changing fish migration habits, and still causing floods.

Those massive storms did prompt an influx of money from the federal government, which was intended not only to repair the damage the storms inflicted, but also to ameliorate the potential for future flooding. Flooding occurred, according to reports compiled in the aftermath of the two events, because dams that were no longer in use prevented the water that had poured into Rhode Island from being quickly carried downstream. Impoundments had created conditions that made ponds, and these ponds quickly overran their banks in the storms. With no way of moving the excess water, it inundated places like the Warwick Mall, which had to be closed for months after it was flooded by the nearby Pawtuxet River.

"There's a safety issue here," says Rachel Calabro. "A lot of these dams are crumbling. They're hundreds of years old. They're way beyond their design life.

They're not being used for any active purpose; they're just a safety hazard. Then the people who own them do not want to own them (because of costs involved in repairing them). The town or the city does not want to put the money into taking care of them. Everyone's trying to pass the buck and pretend that it's not their problem that the dam's failing. In those cases, it's of-





ten to everyone's benefit that these dams are removed. Then you don't have to worry about a catastrophic event (the dam failing), and you don't have to worry about flooding. For the health of the river, it turns the river back to a river again, rather than being a pond." Before that happens, though, there is the matter of establishing just who owns the dam.

A fish ladder was constructed at Horseshoe Falls Dam in the Pawcatuck River to allow fish to migrate upstream.

Calabro spent years involved with the Pawtuxet River dam removal project. Save The Bay had to determine just who would be affected by removing the dam, which meant laboriously wading through deeds that

"WE'RE EMOTIONALLY INVESTED IN THESE PLACES"

sometimes drew boundaries by landmarks no longer in existence. An 1870 deed instrumental in establishing the Pawtuxet River dam cites boundaries such as "the foundation wall of the Grist Mill, formerly standing thereon" and "the east side of a crib standing on an adjoining lot", and another direction "following the thread or middle of the river, till it strikes the bridge." Since the person or entity who owns the dam is likely to be held responsible for the costs involved in removing it, great care has to be taken in tracing ownership. Only once proper ownership is established will agencies move on to the next step: gathering public input on taking out that dam.

Bass and flat water

Then there is the issue of what some have called emotional constraints on removing the dams. "People like to go warm-water bass fishing, or they have nice memories of seeing a tranquil pond, if you will. Because people have grown up along the impoundment or like going to the impoundment, those are more social challenges that you have to deal with, too," said Turek. He uses a recent Wakefield dam modification as an example.

"That pond in Wakefield had become more of an icon of the community. It's difficult to convince people that 'Hey, that icon is not as important as a fish passage or other ecological services involved with restoring it to what it was.' Most organizations (like The Nature Conservancy, NOAA, Save The Bay and others) would much prefer removing the dam than having to build a fishway, but sometimes that's just not practical."

Chris Fox, executive director of the WPWA, witnessed similar concerns several years ago, when the prospect of altering dams in the upper Pawcatuck River went for public comment. "There were rumors around that removing (one of) the (dams) was going to drain Worden Pond," he said. "Of course, that simply wasn't

so, but that's the kind of emotional reaction you have to deal with."

Save The Bay's Calabro concurs: "We're emotionally invested in these places, and we're invested in the animals, but we're also invested in the landscape. When we were working on the Pawtuxet dam removal, there were a lot of people who were talking about canoeing or taking out paddle boats on the river. We said, well, you're not going to lose the flat water. It's just that the flat water becomes narrower and a more natural river, where you get a more natural floodplain, rather than an impoundment."

Regarding the Pawtuxet, Calabro points to a May 24, 1924, *Providence Journal* story that states that, even back then, canoeists were concerned about water level changes resulting from the construction of the dam. After the Providence General Assembly created the Water Supply Board, canoeists got a clause inserted in the regulations that gave Providence the responsibility to maintain that depth.

"There was an old timber dam at Pawtuxet Falls that was leaky and could easily break, so they took the opportunity to have a new watertight dam built at the expense of Providence, and not Cranston. Providence did not complain because the cost was fairly small overall."

"Forty shillings"

Aside from emotional concerns, there are laws affecting the fate of Rhode Island dams. "Any dam more than 50 years old is potentially a historic feature through the National Historic Preservation Act of 1966," says NOAA's Turek. "If we're going to take any federal action, we are required to coordinate with a historic preservation and/or tribal preservation society to determine whether there will be any adverse effects projected. We have to have a historical archaeologist do a preliminary survey on the sites." Turek points out that this is yet another hurdle to overcome in the removal or modification process: "What dams aren't more than 50 years old?"

In some cases, the laws are simply outdated. Calabro cites a law against obstructing fish passage that dates back to October 1719. It was intended to "... remove all Obstructions made by Rivers, that prejudice the Inhabitants, by stopping of Fish from going up the same ... and whoever shall, build or erect and dam or Weir, across, or in any River, or draw any sein or net in the same, in a Town within the Colony, whereby fish in the accustomed course are hindered from going up the same ... shall forfeit for every offence, the sum of Forty shillings." According to Calabro, "The act was repealed

The Hope Dam on the Pawtuxet River is a legacy of the manufacturing village of Hope that sprang up in Scituate in the 18th century.





in 1780 for the Pawtuxet River, and was largely ignored elsewhere. The first dam and gristmill at Pawtuxet Falls was actually built in 1638 by Stephen Arnold and Zachary Rhodes. The first fishway in Rhode Island was built (into that) dam in 1874, but the dam was breached in 1899.” While the level of protection afforded fish in centuries past was spotty, the design of today’s dam modifications and removals, as well as the funding for them, places a great emphasis on native fish passage and restoration.

Riverbank restoration

Even with emotional and historical concerns attended to, there are other issues that need to be addressed before adjustments to the dams can be made. In some cases, the dams may be 200 years old, and the sediment behind them may contain toxins that have built

The Barden Dam on the Ponaganset River was built in the late 19th century for the Ponaganset textile mill.

up over the centuries. “We have a legacy sediment problem then. The question becomes, ‘What are we going to do with all this sediment?’” says Calabro. “Most of the time, the sediment is contaminated. In some cases, the sediment can just go downstream (provided it is deemed safe). Where it ends up can be an issue, because you don’t want to have some other area become silted. The sediment may need to be removed and placed somewhere else.”

As the river shifts to a more natural state, the newly formed banks are initially barren. Plants are chosen both to replicate the former, natural state, and to play their role in restoring the overall environmental conditions. They shade the river, decreasing water

temperatures and evaporation rates—important in light of climate change, Turek says. And when storms hit, “the vegetation cover (slows) the peak discharge. You have far fewer homes getting flooded. With climate change ... there’s a greater frequency of peak discharges: more intense storms at more frequent intervals. We’re only going to see more of those. It will be more of a service to have these communities become more resilient,” he adds.

Just add fish

Once the dam is altered, the sediment issues are addressed, and the riparian changes have begun, there is one last item to complete the transformation—and often its role in acquiring funding for projects like these is the most influential. It is the restoration of fish. Species such as alewife, or blueback herring, while no longer listed as endangered, are still being actively reintroduced to freshwater habitat. That reintroduction means an infusion of federal funds into Rhode Island projects.

Phil Edwards is a supervising fisheries biologist with the R.I. Department of Environmental Management (DEM), and is tasked with initiating and monitoring fish migration in situations where drastic changes have been made to the aquatic environment. In many cases, construction of dams meant that the anadromous fish population could not make the return migration to spawn that was essential to its life cycle. Fish like herring or shad may hatch in an upriver location. When they are ready, the fry make their way to salt water, where they will spend their time until reaching sexual maturity. “It takes 3 to 4 years before river herring return to a spawning area, and 4 to 5 for shad,” Edwards says. At that time, they follow their genetically programmed sense of direction to attempt to spawn in the same freshwater location in which they were born. If obstacles such as dams or outdated fishways interfere with that migration, few if any of them may survive to spawn. Modifying or removing a dam restores the environment to something approximating its original state, thereby allowing fish to move freely.

Even before a dam removal takes place, according to Edwards, DEM may jumpstart the migration process by placing fry in the headwaters of that river. When the time comes for them to move to the sea, the seeded fry will have imprinted the region of their origin, which will encourage their successful return migration. From there, DEM tracks the program’s success using U.S. Fish and Wildlife staff or volunteers. “It’s basically asking the question, ‘Are fish using the new fishway?’” Edwards says, and includes measurements such as counting the number of fish sighted in a given location per hour.

In the case of the Pawtuxet dam removal, DEM staff set out to use electrofishing in order to determine

“YOU HAVE FAR FEWER HOMES GETTING FLOODED”

whether the fish that had been seeded in the headwaters above the dam several years earlier were returning to their spawning grounds. The process involves using a boat and a kind of backpack that a staffer uses to produce an electrical charge in the water. The charge temporarily stuns the fish, allowing them to be collected and monitored before being returned to the water. Similar techniques are used in parts of the Pawcatuck River as well. This monitoring seems to indicate that, once a dam alteration or removal takes place, anadromous fish that once populated the headwaters and rivers make a successful return. And while fish such as freshwater bass may be displaced by cooler, faster water, others will take their place.

“When we remove warm water species, we often return cold water (species), such as brook trout,” Turek says. “We lose the natural riparian community in a dam, but when we take the dam out, we see the riparian community repairing itself.”

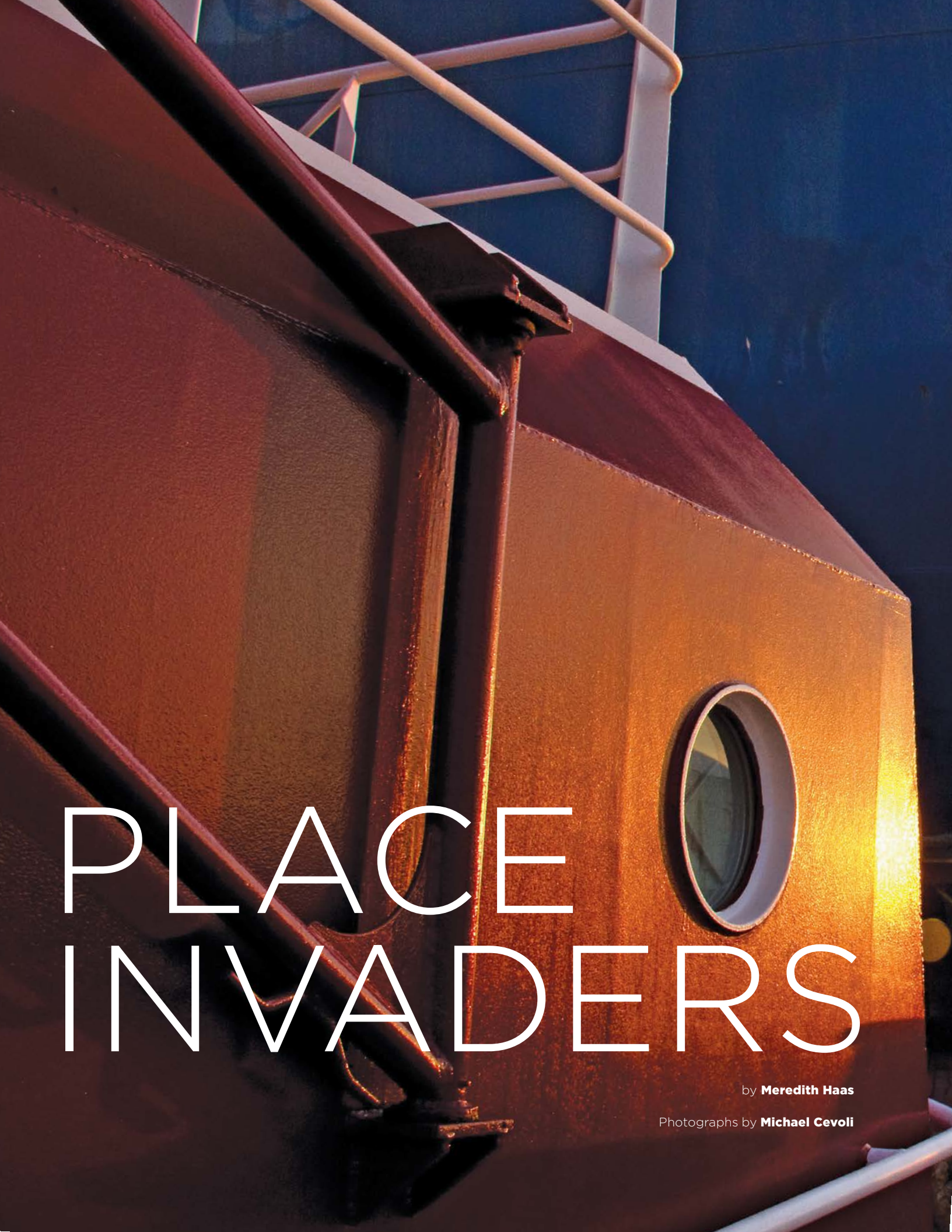
Nature, or nature-like?

The process of repairing 300 years’ worth of anthropogenic influence through dam removal or amendments will take years. Simply deciding on the best choice, given historical, emotional, and physical constraints is a constant source of conflict, according to Turek.

“The preference is full dam removal. More commonly, though, will likely be hybrid sites, where we adjust a dam, but create a better design ... with a notch big enough for fish to get through, along with a fishway down below the dam.”

These choices rarely please everyone. “How do you look at hybrid projects? Are nature-like projects good or bad? Half of the people you ask will say they’re bad, because we can’t guarantee what will happen without removing the dam. But half will say that they’re good, because they’re a trade-off,” Turek says.

WPWA’s Chris Fox agrees that perhaps the single biggest factor in restoring hydrologic connectivity is ensuring that the public understands the benefits of these changes. “WPWA’s job (in the Pawcatuck River dam changes) was to make sure everyone’s interests were represented.” That recognition that projects will address as many concerns as possible is perhaps the single biggest influence in any dam project’s success, according to Fox. “To get these projects done, you have to hang your hat on trust.”



PLACE INVADERS

by **Meredith Haas**

Photographs by **Michael Cevoli**

A large cargo ship is docked at a pier, its massive hull dominating the left side of the frame. The ship's surface is a mix of dark blue and weathered, rusted metal. In the background, several large, cylindrical industrial storage tanks are visible, along with a flagpole flying the American flag. The scene is set during sunset or sunrise, with a warm, golden light illuminating the sky and the ship's hull. The water in the foreground is dark and calm.

GLOBAL SHIPPING'S AQUATIC STOWAWAYS WREAK HAVOC IN LOCAL WATERS

THE COBBLESTONES THAT LINE THE HISTORIC thoroughfare that is Thames Street in downtown Newport, Rhode Island, are remnants of the city's seafaring past. Some were once used as ballast to stabilize large, seafaring vessels from Europe in the 1700s and 1800s, and today are evidence of a long-standing heritage of marine transportation and trade in Rhode Island.

Today, there are about 22,000 ships, at any time, coming and going from New England waters. It's not uncommon to see transatlantic cargo vessels and tankers delivering material goods and fuel to Newport or Providence, the second deepest port in the region and the energy hub for southern New England, as well as to the port of Davisville, the 7th largest auto importer in North America. Daily, 200-foot commercial tankers and bulk cargo carriers travel into Narragansett Bay delivering over 2,000 tons of petroleum, scrap metal, automobiles, food, and dry goods from all over the globe.



But since the introduction of steel-hulled vessels about 120 years ago, ballast tanks filled with millions of gallons of seawater have replaced large stones to stabilize oceangoing vessels in transit by weighing down the vessel's center of gravity. When the ships reach the shallower waters close to the destination port, they discharge some of that ballast water, and along with it, any tiny living things that stowed away for the voyage. Most of these organisms—ranging from crabs and fish to microscopic plants and pathogens—will fail to gain any foothold in their new environment, but those that do can end up radically changing the marine landscape and can mean disaster for the local environment, economy, and public health.

“When the contents of Tokyo Harbor dump out in Narragansett Bay, most of it dies, but a small percent-

age lives,” says Kevin Cute, marine resource specialist for the R.I. Coastal Resources Management Council (CRMC), explaining that the local conditions may either be too hot, cold, or inhospitable for non-native species. “Most non-native species don’t survive, but when they’re successful, they’re famously successful.”

Some of these newly introduced species are better equipped at competing for food and space than native species, and some are able to spawn for longer periods of time. Also, native predators often don’t recognize these new species as potential prey. Soon, these “invasive species take over critical habitat for native species,” Cute says.

Aquatic invasive species (AIS) are one of the leading threats to biodiversity and to the world’s oceans, according to the International Maritime Organization



(IMO), the United Nations' agency responsible for improving maritime safety and preventing pollution from ships.

The zebra mussel, native to Russia and introduced to North America in 1988 via a transatlantic freighter, is one of the most well-known invasive species for having spread to all five Great Lakes within 10 years of its introduction, causing about \$5 billion in damage to harbors, waterways, fisheries, recreation and water treatment systems according to the U.S. Fish and Wildlife Service. This prolific species out-competes native species and attaches to manmade structures, particularly pipelines, impeding water movement through hydroelectric turbines and intake structures for drinking water and irrigation systems.

Although they have not been documented in Rhode

Island, zebra mussels are a species of concern because they are found in the Connecticut side of the Housatonic watershed and near the Massachusetts border, and are expected to invade every freshwater habitat in the nation within the next 20 years. The primary threat for spreading zebra mussels in Rhode Island is now the recreational boater, according to the R.I. Department of Environmental Management.

Additional studies suggest that other invasive mollusks cost the U.S. more than \$6 billion per year in environmental damages and losses, while some estimate a \$120 billion financial loss every year in the United States alone due to "bio-invasions."

For Rhode Island, the most problematic invasives thus far, which were introduced directly by ballast water in state waters or in neighboring waters, include the

European Green Crab, the Asian Shore Crab, the Chinese Mitten Crab, several types of colonial tunicates, and the Oriental Grass Shrimp, according to Cute.

Colonial tunicates “are really impacting eelgrass, which is scary,” Cute says. These marine invertebrates, also known as sea squirts, wreak havoc on shellfish and eelgrass beds by growing rapidly to form colonies of hundreds of organisms that spread like mats, engulfing their surroundings. They don’t directly kill shellfish or eelgrass, which provides essential nursery habitat for healthy fisheries, but they can block out sunlight and out-compete for vital oxygen and nutrient resources, changing the entire ecosystem.

Squatter rights do not apply

The European green crab is one of the most successful coastal invaders, and has established itself in coastal habitats on the East and West coasts of the U.S. It’s been over two centuries since the green crab ventured from Newfoundland waters to establish itself on five continents. With an epic appetite—able to consume 40 clams in a day—these 2 to 4 inch critters destroy eelgrass beds and shellfish populations, and have been implicated in the destruction of the soft-shell clam fisheries in New England, according to the U.S. Geological Survey. It is estimated that between 1997 and 2005, East Coast shellfishermen lost between 67.5 and 77 million pounds of quahogs, soft-shell clams, blue mussels, and bay scallops to green crab predation every year, according to the U.S. Environmental Protection Agency (EPA).

Even though the European green crab has been taking up residence in local waters since the mid-1800s, squatter rights do not apply.

“Invasions are invasions, no matter how long ago they occurred,” said James Carlton, the world’s leading expert on aquatic invasive species and professor emeritus at Williams College, at a 2012 aquatic invasive species conference held by CRMC. “Invasive species do not become native or naturalized, even after hundreds of years. An understanding of ‘historical invasions’ is critical for interpreting community and ecosystem history.”

In other words, says Niels Hobbs, a Ph.D. student at the University of Rhode Island studying the impacts of invasive species, it’s important to see how the morphology of native species changes in response, as well as the environment as a whole, so when another new species does arrive, “we have a better idea of what to expect, and how to better manage those impacts.”

“We need to keep a fairly fine finger on the pulse of change in biodiversity,” says Carlton, whose recent work has taken him from Maine to Long Island Sound surveying ports, docks, harbors, and marinas to obtain a baseline of current invasives. He says the “hope” of the survey team is not to find anything new, but he

adds that if they do, they must study the new species, its distribution throughout the area, and its impact on native species.

About one to two new species are discovered in Rhode Island waters each year, according to Cute, who says it’s difficult to know when they were introduced since the state only started a volunteer monitoring program in 2009 at docks located at five sites: Save The Bay in Providence, Allen Harbor, Point Judith Marina, East Bay Yachting Center, and the Fort Adams Boat Basin.

“These floating docks are excellent proxy habitats and are the foundation of our understanding of invasive species in the bay,” says Cute, explaining that one of the main purposes of the monitoring program is to determine whether these species are spreading in Narragansett Bay. “We need volunteers to find that answer.”

Globe hopping

While many non-native species are beyond eradicating, efforts are being made to control current populations and prevent the arrival of new species. Understanding how these species arrive is the most crucial part, says Carlton.

In addition to ballast water, invasive hitchhikers have many means of transportation to local waters, from aquarium and ornamental trades to aquaculture and recreational boating, as well as expanding ranges due to climate change.

But ballast water management has been given greater attention in recent decades because of the sheer volume—more than 2 million gallons of ballast water (equivalent to three Olympic-sized swimming pools) are released in U.S. waters every hour—that is 555 gallons a second—according to the Narragansett Bay Research Reserve.

Currently, mid-ocean (200 miles out from shore) ballast water exchange is the only internationally accepted, and required, practice. This involves either overflowing the tanks or emptying and flushing them with mid-ocean water taken from at least 200 meters deep. If done correctly, this can eliminate nearly 99 percent of the biological content. However, this process can be dangerous and ineffective in inclement weather and rough seas. Other factors impacting the effectiveness of mid-ocean exchange include equipment failure and biota living in sediments that accumulate in ballast tanks that may not get flushed out. Onboard alternative treatment systems that either use chlorine or UV light to render organisms harmless are encouraged for this reason.

But even now, when ships are required to dump and exchange their ballast water out in the open ocean to rid themselves of potentially invasive species, the spread of invasives continues to grow. This is because



in a new globalized economy, shipping accounts for 90 percent of the world trade.

“It’s Russian roulette,” Hobbs says, explaining that increased commerce ups the odds on invasive species establishing themselves. “It’s stacking the deck in favor of more successful species.”

Since 2012, all oceangoing freighters entering American waters are required by the U.S. Coast Guard to install onboard treatment systems that filter and disinfect their ballast water. This final ruling sets the upper limit for allowable concentrations of organisms in ballast water depending on species type and size, as well as vessel size and design. However, there are currently no treatment systems that meet the Coast Guard’s standards, says Gavin Black, legal counsel for Moran Shipping, based in Providence, explaining that there are procedures for vessels to receive a “temporary pass,” if outfitted to international standards, which have yet to be formally instituted.

While Carlton admits current regulations and technology haven’t “nailed the lid” on the introduc-

Ships converge in Providence Harbor, the energy hub for southern New England. Daily, cargo ships carry over 2,000 tons of goods into Narragansett Bay.

tion of invasive species from ballast water, he believes that other factors, such as biofouling (where organisms attach to the hull of the ship), climate change, and other vectors beyond shipping are contributing to an increase of invasive species.

With global climate change, Carlton says, Rhode Island can also expect to see southern species crop up in Narragansett Bay in a “Chesapeake [Bay] invasion.”

“We have to know how they’re getting here,” he says, explaining that understanding all the ways in which invasive species are transported is crucial for management. “The real question is, is it preventable or inextricable?”

And if we can’t control invasions, we’ll have to adapt, says Cute. And how we adapt will be based on what we know ecologically about these species, which in many cases is nil.

The Scituate Reservoir:

A REMINDER OF THE PRICE OF PROGRESS

by **Maury Klein**

Aerial photographs by **John Supancic**

ALTHOUGH SHE LIVED TO BE 94, “GRAMMA” HELEN O. LARSON NEVER forgot her roots in a small village that ceased to exist when she was still a child. She was born in 1910 in Rockland, one of several mill villages that were a part of Scituate, Rhode Island. It happened to be among a handful of those villages doomed to be dismantled and submerged beneath the Scituate Reservoir. Every building in those unlucky villages was demolished and all the people who lived there had to move elsewhere.

Throughout her long life Helen Larson took to writing poems. She did her first one on the school blackboard at the age of 12 even as workers had begun tearing down the building, and she penned her last one only two days before her death.

While her poems roamed across the range of her experience, many of them looked back to the world of her childhood that had vanished so abruptly.

One of them, titled “The Scituate Reservoir,” began this way:

*“The land was condemned the people were told
Everyone felt sorry for the folks who were old
People in Providence needed clean water to drink
The city bought five villages; people had to sign with pen and ink
Some folks were born there, some lived there for years
They just couldn’t seem to shake off their tears . . .”*





THE PROBLEM OF WATER SUPPLY IS AS OLD AS CIVILIZATION ITSELF

Sorrow and nostalgia echo repeatedly throughout this and other poems Larson wrote about the lost world of Rockland and its neighboring villages. She was hardly alone in these feelings. The experience left many, if not most, of these displaced persons embittered for the rest of their lives. What was it about a reservoir that was important enough to wipe their homes and their past from the face of the earth?

Anyone who played Monopoly as a child will remember the Water Works as one of the utilities. Compared to other, grander properties it was cheap, but in the real world of growing cities, nothing was more crucial than the water supply. Peruse a map of these United States and you will find some body of water adjacent or close to every large city. Apart from being a necessity of life, water was needed for many types of business, for sanitation, and for fighting the most dreaded scourge of city life: fires. Individuals or groups might dig a well or two to provide for their needs, but the demands of expanding urban populations far exceeded that approach.

When Providence was founded in 1636 on the east bank of the Providence River, its residents relied at first on private wells. More than a century of growth led to the realization that some sort of central water supply was needed. A fountain society was created in 1773 to provide water for the town through a network of underground hollowed out logs. In May of 2014, a crew installing drainage pipes at Richmond Street unearthed the remnant of one such log. Like other cities, Providence soon found it necessary to come up with a broader program to meet its soaring demand for water, not only for personal needs but for factories, mills, other businesses, sewage disposal, and firefighting.

The problem of water supply is as old as civilization itself. Ancient Crete used underground clay pipes for water supply and sanitation. The Romans became famous for their sophisticated aqueducts that carried fresh water long distances to the city. Both the Greeks and the Romans had forms of indoor plumbing. Beginning in the 18th century, London obtained water from a number of private waterworks companies. In

this country, Philadelphia pioneered in urban water systems with the Fairmount Water Works, built on the Schuylkill River between 1812 and 1815, and augmented by the Fairmount Dam in 1822.

New York City completed its massive Croton Distributing Reservoir in 1842. Located at Fifth Avenue and 42nd Street, the present site of the New York Public Library, the reservoir created a 4-acre lake holding 20 million gallons of water within 25-foot-thick granite walls 50 feet high. A promenade circling the top of the reservoir became a popular place for strolls with a view. Smaller cities faced the same problem of assuring a reliable water supply. As early as 1797, Portsmouth, N.H., incorporated its first public water system, the Portsmouth Aqueduct, which carried water 2.5 miles through wooden pipes to the town.

Many of the water companies were privately owned and operated in the 19th century, but several factors led to a growing trend toward the creation of public facilities. The sheer scale of urban growth overwhelmed the ability of small, scattered private companies to keep pace with demand. An increase in the number of utilities—gas, electric, streetcars—and the large fortunes made from them led to a clamor for public ownership to keep rates reasonable. Most important, progress in discovering how certain diseases were transmitted led to the realization that entire communities could be devastated by contaminated water supplies. This insight spurred both state and federal officials to seek ways of monitoring the purity of water systems as well as ensuring a reliable supply.

In many cities, Providence included, the construction of public water systems faced stiff resistance from taxpayers slow to grasp the need but quick to see the expense. In March 1853, the City Council appointed a committee to look into and report on the matter of a suitable public water supply for Providence. The committee responded with a recommendation that the city take water from the Ten Mile River in East Providence. The council dutifully authorized the acquisition of the necessary lands and rights only to have voters reject the proposition. During the next 15 years, five separate committees submitted six different reports urging action, without results. The final report in 1868 stressed the need for an abundant water supply to develop and protect the city. On February 15, 1869, when the question went before the voters for the fourth time, they finally approved taking water for Providence from the Pawtuxet River.

Construction began in the spring of 1870 on the first facility, which drew water from the Pawtuxet River at Pettaconsett in Cranston. On December 1 of the following year, water began flowing through the first service pipe. For more than 30 years, the water was pumped directly from the river and into the system without any attempt to purify it. The notion of clean-

ing the water was hardly new; the Greeks and Romans practiced certain filtering techniques such as settling, running it through sand, and storing it in copper pots even though they knew nothing of the scientific basis for doing so. Not until 1906 did Providence install its first slow sand filter water purification system.

Once completed, the filters treated water drawn from the river, after which it was pumped to the Sockanosset open distribution reservoir, located in what is now the Glen Hope High School in Providence. The Hope Reservoir had a capacity of 76 million gallons and pumped water to the city's system and to yet another storage facility, the Fruit Hill Reservoir in North Providence, situated on the site occupied today by Our Lady of Fatima Hospital. One key function of the Fruit Hill Reservoir was to furnish water for the

special fire service that protected the business district and the congested Woods Development of Cranston. This reservoir held 55 million gallons and moved water by gravity to a second facility that stood on the ground now occupied by the manufacturing district where fire was always a threat. Although owned by the city of Providence, the system supplied water to North Providence, Cranston, Warwick, and Johnston as well.

Impressive as this distribution system seemed at the time, the growth of Providence and surrounding communities strained it by 1910. Increased demand raised concerns that the flow of the Pettaconsett River

This aerial view shows the Providence Water Supply Board's Philip J. Holton Water Purification Plant with the Scituate Reservoir beyond.





Land for the Scituate Reservoir was taken by eminent domain, a process “older than the nation itself.”

was inadequate. During dry spells, when its output could not meet demand, the shortfall was covered by drawing water stored in small reservoirs owned by upstream mill companies. Another problem complicated the search: The Pawtuxet River over the years had grown increasingly polluted from a rising level of sewage and industrial pollutants in the ground water system as well as the river itself. Across the nation, nearly every city confronted this same problem as their sources of water suffered contamination. In 1901, Providence became only the third city to build a sewage treatment plant, but the Fields Point facility was soon overtaxed.

Convinced that these problems would only grow worse, the City Council in 1913 appointed another committee to explore ways of developing a larger, safer, and more reliable water supply. Once again the issue became a matter of scale. The larger and more industrialized grew Providence and its surrounding communities, the larger and more expensive became

the resources needed to serve it. Unlike some cities in larger states, Providence could not pipe water in from distant parts of the state. It had only a network of rivers already tapped by mills as well as by towns. Nor could it easily expand the existing distribution system. These and other limitations imposed on the committee a need to devise some broader and more original approach to the problem.

From this thinking emerged a daring and bitterly controversial plan to solve the water shortage by creating a major reservoir within the state to assure a continuous supply of water. To do this required not only undertaking a costly and enormous construction project but also acquiring a large parcel of land on the most suitable river to dam and transform into a good-sized lake. In a state as small as Rhode Island it was highly likely that such land would already be occupied. It would have to be acquired by eminent domain, a legal process older than the nation itself. Eminent domain gave the government, federal or state, the right to seize land deemed necessary for some public use provided that it paid fair compensation for it.

Although uses of the process varied widely, in the past it had been used primarily for such purposes as

government buildings, roads, railroads, military facilities, and utilities. Applying it to something as large as a reservoir could not help but generate strong opposition. In most cases the taking of someone's private property affected a small number of people at most; a reservoir, depending on where it was located, could impact whole villages. Between 1827 and 1853, private interests in Smithfield had created three reservoirs covering about 566 acres to increase waterpower for mills. The bill to create what became the Scituate Reservoir called for the taking of 14,800 acres, or 38 percent of the town of Scituate. Nevertheless, on April 21, 1915, the General Assembly approved it, and condemnation notices began going out that year.

The town of Scituate had deep roots going back to its founding in 1710. Like many other Rhode Island towns, it contained a cluster of smaller villages, most of them built around mills or manufacturing companies. The reservoir project required the condemning of 1,195 buildings, including 375 houses, seven schools, six churches, six mills, 30 dairy farms, 11 ice houses, post offices, the Providence and Danielson electric trolley system, and 36 miles of road. Roughly 1,600 people would be displaced. The small villages of Kent, Richmond, Rockland, South Scituate, Ashland, Saundersville, and Ponaganset would disappear under water along with parts of North Scituate and Clayville. Residents whose roots traced back generations in these hamlets would see their homes and heritage vanish forever. Cemeteries would also be affected. Most graves would be relocated outside the reservoir area; others would simply be covered by the water.

No concept of fair compensation could calculate the value of what Abraham Lincoln called "the mystic chords of memory." Who could measure the sentiments attached to homes where past generations had often been born and died, or to the land itself, let alone the family graveyard? News of what was to come devastated residents in the doomed villages. Rockland arose when the Rockland Mill was built in 1812 along a branch of the Ponaganset River. Two other cotton mills were established in the village, along with several small businesses and later the powerhouse of the Providence and Danielson trolley line. Richmond, the largest village, had four mills, tenements that housed 600 workers, a town hall, and a school. All of it and more had to be demolished.

Prior to the start of work, the Providence Water Supply Board hired a photographer, John R. Hess, to capture on film all of the structures in the proposed area of the reservoir before they were dismantled. Hess did his job well, leaving behind a visual historical record of the lost world of these villages. Some of the photographs have been reproduced in a series of short books by Raymond A. Wolf dealing with the villages and the coming of the reservoir.

The condemnation notices confused people in every village. One farmer went to court in Providence to fight his eviction but lost. He came home, told his daughter they had to move, then went out to the barn and hanged himself. Another farmer slit his throat rather than leave his home. One local claimed to have documented eight suicides among the residents of the condemned villages. Still another family named Knight sold their two houses, two barns, sawmill, and ice house on 406 acres to Providence for \$12,150 and proceeded to burn one of the family homes down themselves. Other properties, especially commercial buildings, were auctioned off cheaply to whoever wanted the materials. The trolley tracks were taken up, the electric power lines removed, and mill machinery carted away to other mills before the buildings were torn down.

SCITUATE'S ROOTS GO BACK TO ITS FOUNDING IN 1710

To create the reservoir, a mostly earthen dam was constructed across the Pawtuxet River on the site of Kent village. Known at first as the Kent Dam, it was later renamed the Gainer Dam after Joseph H. Gainer, the Providence mayor who presided over the project. The dam stood a hundred feet high and stretched about 3,200 feet. Once the dam had been completed, all the buildings had been destroyed or removed, the people had packed up and gone elsewhere, and as many graves as possible relocated on higher ground, water was released into the site on November 10, 1925. It took nearly a year to fill the reservoir with water that averaged 32 feet in depth and reached a maximum of 87 feet at its deepest point. The reservoir has a capacity of 39 billion gallons and covers a surface area of 5.3 miles. The largest freshwater body in the state, it cost \$20 million to build and drains about 94 square miles of land. Over time some 7 million trees were planted around the watershed.


An aqueduct fed water from the reservoir to a treatment plant that went into service on September 30, 1926. The original pipe was 90 inches wide and traveled 4.5 miles to Cranston, including 3.3 miles of tunnel. Not until the 1970s was a second aqueduct built, this one 9.5 miles long with a 102-inch pipe. Flow from the source proceeded entirely by gravity,





At periods of low water, the Scituate Reservoir reveals remnants of the stone walls, mills, and other structures from the villages that were submerged to provide water to 60 percent of Rhode Island's population.





and delivery within the distribution system occurred 75 percent by gravity and only 25 percent by pumping. In supplying drinking water to more than 60 percent of Rhode Island's population, it remains an indispensable source of a precious commodity that is too often taken for granted.

The Scituate Reservoir may also have played an important role as a precedent for a later, much grander project. In 1933, Congress passed an act creating the Tennessee Valley Authority (TVA), which undertook to transform a blighted section of the Southeast with a series of dams for flood control, electric power, recreational facilities, and an overall transformation of one of the most economically backward regions of the nation. TVA built eight dams and acquired an existing one. The first of these, the Norris Dam, was begun in the fall of 1933 and completed three years later. For that dam alone, TVA acquired 144,913 acres of land, relocated some 2,899 families, and "impacted" about 5,000 graves, meaning that some were moved and others submerged.

In all, construction of the eight dams created 26 reservoirs that required relocation of 15,435 families and the removal of at least one entire small town. The scale of TVA dwarfed that of the Rhode Island experience, but the Scituate Reservoir was an early pioneer in a process that would be repeated elsewhere as critical needs for water and flood control arose. Like the Scituate Reservoir, the TVA projects aroused bitter controversy and in some cases dogged resistance from those being forced from their ancestral lands. For them, as for their peers in Rhode Island, the price of progress proved not only high but uneven.

The concept of the "greater good for the greater number" may have been hard to swallow for the dispossessed, but few people care to imagine what Rhode Island's water supply situation would be today without the Scituate Reservoir. Still, it is worth remembering the last lines of Helen Larson's poem cited at the beginning of this piece, if only to remind us of the price some paid for progress:

*"One by one each family moving away
Friends and neighbors moved far apart
I go back now and then, the foundations are still there
I turn around and walk away, in my heart a silent prayer
We all know the reservoir has been there many years
And I still believe it was filled with the people's tears"*

Passing the DNA test

New testing method will quickly identify beach contamination—and its source

by **Tim Faulkner**

Aerial photograph by **John Supancic**

BEACH CLOSURES ARE DECLINING across Narragansett Bay, a trend that shows pollution-control measures are working. But is more testing needed to ensure beaches are truly safe?

In 2014, beach closures in Rhode Island hit a record low of 52 days, down from a high of 503 days in 2000. This improvement is occurring as the average number of rainy days per summer steadily increases. Rain produces runoff, which carries pollutants—specifically of concern is *E. Coli*—across streets and parking lots, through storm drains, and into waterways and beaches where they can make swimmers sick.

“Anything on the pavement just washes right off every time it rains,” says Amie Parris, beach coordinator for the R.I. Department of Health.

Beach closures harm tourism as well as reduce opportunities for recreation and just cooling off, especially for urban residents seeking to escape the city heat.

Efforts to collect and treat runoff have paid off in the Providence area through a public works project to clean up the stormwater discharge flowing into upper Narragansett Bay. Since 2008, the \$467 million combined-sewer-overflow, or CSO, project has diverted billions of gallons of untreated waste and stormwater from the bay and reduced closures at public beaches. Run by the Narragansett Bay Commission—the sewage treatment agency for 10 Rhode Island cities and towns—the project is funded by the commission’s 350,000 ratepayers. On a smaller scale, new stormwater contain-

ment and treatment systems at problematic beaches in Newport and Bristol have also increased swimming days during the summer.

Closures are down at Easton’s Beach and the Atlantic Beach Club after Newport invested \$6 million in an ultraviolet disinfection system that cleans runoff from nearby Easton’s Pond. Closures at Bristol Town Beach went to zero in 2014 after innovative retention and filtration alterations were made to storm drains and a public parking lot.

The steep decline in closures is the result of targeting a single category of pollutants. Current testing in Rhode Island and at beaches across the country targets enterococci, bacteria that show the presence of fecal contamination. Fecal bacteria can afflict beachgoers with dysentery, hepatitis, and respiratory illnesses, among several waterborne health issues.

The test, however, does not reveal the source of the bacteria, such as whether the contamination emanated from leaky septic systems or Canada geese, pets, or farm animals. Identifying the source of pollution, which can be done with DNA-based tests, advances corrective action upstream from the coast and ultimately leads to cleaner beaches.

Environmental groups such as the Natural Resources Defense Council have called for improved testing, a plea that was answered in 2014 when the Environmental Protection Agency (EPA)—which has also established new guidelines that set a more stringent standard for

contamination levels—approved the use of the quantitative polymerase chain reaction (qPCR) test. The new test uses DNA tracking and delivers results in a few hours instead of the current 24-hour wait needed in tests done by the Department of Health (DOH). According to DOH, this method may also serve as a tool to find and eradicate sources of contamination as they are occurring. The DOH is working to adopt the new EPA test and testing standards, but in the meantime, the existing slower test potentially exposes beachgoers to contaminants as they wait for test results. The delay also keeps people off beaches even after the harmful bacteria may have dissipated.





Thanks to ultraviolet disinfection, closures at Easton's Beach, above, have been reduced. The red seaweed in the photo is not, as it is sometimes called locally, "red tide," and is harmless.

The DOH oversees the testing and monitoring of Rhode Island's 69 permitted fresh and saltwater beaches. Testing is done between once and five times per week, with more tests occurring at pollution-prone sites. In all, some 1,500 to 1,600 tests are performed each year between Memorial Day and Labor Day, a timeframe established by the EPA, which funds the monitoring programs and sets the season to 92 days for permitted beaches across the country. While the

beaches remain open to the public, beachgoers swim at their own risk after Labor Day.

John Torgan, director of Ocean and Coastal Conservation for the Nature Conservancy in Rhode Island, says that Narragansett Bay and Rhode Island's beaches are significantly cleaner and healthier today than just a few years ago. Upper Narragansett Bay has improved so much in recent years that work is underway to open a public beach at Sabin Point in East Providence.

"That's something I never thought I'd see in my lifetime," Torgan says.

Torgan noted that the most critical part of beach monitoring is gathering data. Although he occasionally hears

that closures harm a beach's reputation with tourists, he says the information learned from testing helps find and stop pollution and ultimately keeps the water cleaner and healthier. In the long term, the state's natural places and economy see the greatest benefit. Twenty years ago, he says, Rhode Island beaches were much worse off, and testing occurred only once a year at the start of the summer. Today, he says the testing is safe, sensible, and effective.

"We've made really dramatic strides in the way we test and report on swimming water quality in Narragansett Bay," he says. "Let's recognize the monumental progress we've made to reclaim these public waters."

BREWING LIQUOR

From Water to Beer

by **Aaron McKee**

Photographs by **Jesse Burke**





WHEN BREWING BEER, THERE ARE FOUR BASIC ingredients that are essential: water, malt (or cereal grain), yeast and hops. Modern conveniences have made obtaining these four ingredients wonderfully easy. All one has to do is go online and hundreds of types of malts and grains, hops, or yeast, can be purchased for small batches and large-scale brewing alike. How then, do brewers select the water that they will be using? Does it matter? Well, the average beer is conventionally understood to be composed of about 95 percent water. Such would include lighter styles, such as pale and amber lagers, German Kölsches, or the trendy session India pale ales (IPAs), which are notably low in alcohol by volume and body—the latter a catch-all term to informally refer to how a beverage feels in the mouth as it is being consumed. For a beer that may be considered light bodied, this 95 percent figure holds up well. Obviously, a beer that is 10 percent alcohol by volume cannot be more than 90 percent water, and more accurately would have to be a bit less than that in order to account for the substances within that make it, well, beer.

Fundamentally, water is the main ingredient in beer, yet it is the easiest ingredient to overlook for its significance, utility, and overall effect on the finished beverage. Your average beer enthusiast or critic, when reviewing a beer, will likely omit any description of the water, known as brewing liquor, while sometimes yammering endlessly about the aromas of its hops or the depths and complexity of its malts. Water is tacitly assumed to rarely directly affect the taste of a good beer, so why bother discussing it in a review? In truth, the composition of the water used during brewing has a substantial and underappreciated effect on the finished brew.

A novice brewer will tend to stick to the basics, brewing styles of beer that do not require the water to be of a specific chemical composition. Homebrew kits that can be purchased from a local brewing supply shop often contain malt extracts that simplify the brewing process and allow for a more diverse range of water compositions. The downside is that a very simple beer will be the result, with little defining personality of its own. Another method, certainly involving a degree of resignation, is to treat the available water sources for brewing as a vintner would terroir. After acquiring and assessing a water quality report for the locality, the brewer then only brews styles of beer that are agreeable to the composition of the water available. This is a self-limiting way to go about brewing. Unlike terroir, which even if possible to alter would result in immense community backlash, water can be adjusted to better suit the brewing process. Beyond this, a skilled brewer or chemist can adjust the composition of water to mimic the waters found in regions of the world famous for particular styles.

Aaren Simoncini of Beer'd Brewing Company recognizes that the mineral content of his water source changes with the seasons.

A.J. DELANGE NOTES IN *WATER*:

A Comprehensive Guide for Brewers

If a brewer finds a particular malt to have too much protein, or a yeast strain to throw too much diacetyl [a slick, buttery compound, avoided in most beer styles] or a hop variety to be too low in geraniol [a compound that produces a rose-like floral flavor and aroma], there isn't much he can do about it other than select different materials, or dilute or

augment with materials that have more or less of the desired properties. Water is quite different. While the brewer cannot easily obtain water from a different source, what's available can be modified. In fact, he must do exactly that if he wants to make excellent beers free from the limitations of the terroir school. (xix)

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Brewing beer has come a long way in its over 5,000-year history. For a majority of that time, brewers were limited to the malts, hops, and water available in regions of relative proximity to where they brewed. Forget yeast—no one knew about that until Louis Pasteur discovered fermentation in 1857. Due to these geographic and economic restrictions, the water sources around a given brewery had a much more defining role on what qualities its beers would have, and which styles could be brewed. This has led to some interesting historical styles, some of which require specific water compositions to brew, and even a few whose flavor is in part characterized by the type of water that is used.

It is important to emphasize that water that tastes good by itself is not necessarily appropriate for brewing beer. Throughout the brew, the water that is used will be undergoing chemical and mechanical changes. Water interacts and exchanges ions within the mash—the hot-water-saturated grain whose enzymes convert complex starches into more simple sugars, ideal for fermentation. Calcium, magnesium, and zinc are important nutrients for yeast, aiding its metabolism, and are important parts of a beer's water profile. The final product is, in part, a result of these interactions, so water is selected or altered to suit the types of malts used and promote the health of the microorganisms (usually yeast, but several species of bacteria are also used in some styles of beer) that are metabolizing the sugars in the wort, which is the sugar-rich liquid derived from the mash that goes on to be fermented. Hops do not stand alone either; mineral composition in water will affect a number of their properties as well. Therefore, a beer of excellence will come about by catering the water to these needs, not to the ideal taste of water as consumed apart.

A wise first step to proper water usage during brewing is to acquire a water quality report from the municipality that is home to the brewery and its water source. These reports provide a rundown of the mineral content of the local water as it is being drawn from its source, and will indicate to the brewer what adjustments need to be made before the water can be utilized for the brew.

Water precipitates, and then spends time as surface water in lakes, reservoirs, and rivers before seeping below and becoming groundwater in wells and aquifers. Through this process the chemical composition is defined. As surface water drains down into deeper geological layers, different localities will impart lower or higher concentrations of minerals.

Hot water is run over the grain, in a process called sparging, to extract the sweet liquid, called wort, that will be fermented into beer.

For example, the city of Pilsen, from which the pilsner beer style originates, is famous for its soft water, meaning that it is lower in mineral content. Also low is the water's alkalinity, as well as its sulphate content. While the pH of the water itself is not directly relevant, it is very important in the mash for the conversion of starches into simple, easily fermentable sugars. Generally, most beers are benefited by a slightly acidic mash pH, while most municipal water sources have a pH that is ever so slightly alkaline. Using water with an inappropriate pH will affect fermentation, resulting in a beer that is at best not true to its style, and at worst tastes terrible. The low alkalinity of Pilsen water blends with traditional pilsner base malts (base malts are those with easily accessible sugars, contrasted with specialty malts) creating a soft mouthfeel and the bread-like maltiness characteristic of a delicious pilsner. Pilsen water's lower sulphate content keeps the bitterness from the hops in check, balancing the famed lager without removing its noble hop aroma. Using water more acidic in its nature will result in a different product than a traditional pilsner-style beer.

In sharp contrast, Burton-on-Trent, which celebrated a thousand years of brewing history in 2002, is famous for its very rich and extremely hard water. This is owed to high levels of calcium and magnesium sulfates, which come from the gypsum-rich geology below. Hard water is often desired in brewing, so much so that the term "Burtonization" was coined to refer to adding calcium sulfate to improve water's suitability for brewing. Calcium and magnesium sulfates are among the most desirable minerals in brewing, providing essential nutrients for yeast, increasing hop utilization rate, and assisting in the removal of unwanted proteins from the grain. Burtonization is a common process in the making of the now popular and ubiquitous pale ale and IPA styles, which are brewed around the world from water sources quite divergent from those of Burton-on-Trent. With plenty of sulphates in the water, both hop bitterness and aroma are made assertive and drying, exemplary of these styles of beer.

THE RIGHT
WATER
CAN BE
THE DIFFERENCE



Eric Heupel takes a scientific approach to home brewing.

DEAD LEAVES IN THE RESERVOIR WILL CHANGE THE OUTPUT

If our next stop on our brewing liquor tour was Dublin, we have the ideal contrast to Pilsen water. Famous for Guinness, the world's most widely known dry Irish stout, Dublin's water is known for its high bicarbonate levels. The malts of a stout are more acidic, and the high bicarbonate levels lower the mash pH by acting as a buffer, preventing the natural acidity of the dark malts from becoming overbearing. Assuming the water used has not been adjusted artificially by the brewer, Pilsen water makes an undesirable stout, and likewise Dublin water does not make an enjoyable pilsner.

In modern times, traditional styles of beer such as those mentioned are brewed around the world, owing

to water treatment methods that allow the mineral content of water to be altered to suit the needs of the style. If a water source requires additional minerals, the necessary additives can be dissolved into the brew easily enough, though this convenience is not necessarily a brewer's panacea. Often the addition of one mineral necessitates that another be removed, so technologies such as reverse osmosis, which strips almost all ions from water, are employed to create a blank canvas from which to develop a brewing composition from scratch.

At Beer'd Brewing Company, located in Stonington, Connecticut, Aaren Simoncini, brewmaster and co-owner, keeps tabs on seasonal fluctuations that occur from his water source, which is a reservoir in Mystic, Connecticut, maintained by Aquarion Water Company. "I'm in touch with them on a quarterly basis at this point, because I know that there's a seasonal swing," Simoncini says, IPA in hand. Some of the most common causes of these swings include spring rains and melting snow, which dilute mineral concentrations in the reservoir. Since reservoirs are a surface water source, such seasonal shifts occur more drastically than with underground sources such as aquifers and wells. If the mineral content is diluted, more will have to be added by the brewers to stay precise with a particular beer's water profile. Water during dry summer months or drought is the opposite, resulting in less required adjustment of the brewing liquor.

In the autumn, leaves falling and finding their way into the water are also a concern. As Simoncini says, "dead leaves or debris in the reservoir will change the output." The influx of decaying vegetation typically increases the acidity of the water in the Aquarion reservoir, and therefore during this period more minerals that act as pH buffers, such as bicarbonates, are required to prevent the mash pH from dropping too low. Utility companies like Aquarion mainly concern themselves with the public safety of the water they manage, including microbial contamination and toxic compounds, such as lead or nitrates. The treatments they make to their water generally cover these necessities only, meaning it's up to the savvy brewer to keep tabs on such seasonal fluctuations to ensure a stable product.

IPAs and double IPAs are the forte of Beer'd, with a majority of their nearly 60 beer recipes being innovative variations and explorations of the style. For each beer that is brewed, the water build is catered specifically to that recipe. As Simoncini explains, "Sometimes I want to accentuate some maltiness, sometimes I want to accentuate a bright, bitter beer. Or with hops, I really need to build up the sulphates. When developing a recipe, you're not finishing the paragraph if you don't go ahead and build a water profile for that particular beer."

Luckily both for Simoncini and talented home brewer Eric Heupel, the water provided by Aquarion is very soft, so brewers can simply add chemicals rather than undergoing the extra step of reverse osmosis. Brewing in Mystic, Heupel, a Ph.D. candidate in oceanography at University of Connecticut's Avery Point campus, uses the same water source as Beer'd Brewing Company. Though the two brewers have never collaborated, their general ideas on brewing water for IPAs are strikingly similar. "I add a lot of calcium chloride—I really like calcium chloride versus gypsum [calcium sulphate] to get that calcium content," says Simoncini, "I add Epsom salt [magnesium sulphate] very lightly to get the sulphates up, but keep them less than 100 [parts per million] so the bitterness doesn't become cloying or metallic."

For Heupel, the balance of ions in his IPAs is of equal concern, as he notes that "chloride generally accentuates maltiness, and sulphates bitterness." For an IPA that he wants to have more balance between the hop and malt flavors, he says he prefers "chlorides and sulphates in the 1:1 to 1:1.5 range." However, Heupel also likes to make a "hop monster of a beer." For this double IPA he has a different ratio for these ions in mind, changing the chloride-sulphate balance to 1:4. "This seriously accentuates hop bitterness and dries the beer out as well," he says.

This look at the importance of water to the brewing of beer is truly only a taste. Many more minerals and ions can be found in water as it moves through the hydrologic cycle at various scales, from global processes to the specific localities known for unique water compositions. Many brewers today, especially those in the craft beer movement, are hybridizing existing beer styles, or creating unique brews whose styles are inchoate and yet to be officially defined. With such nuance brings water builds that are unique to the brewer instead of a particular region. Conceivable is the notion that in contemporary brewing, the water composition in a boundary-pushing ale or lager might not naturally exist anywhere on the planet. Furthermore, environmental changes, whether caused by human activity or otherwise, eventually alter the chemical composition of a water source over time. Such changes must be taken into account, or suddenly a subsequent batch of the same beer will not be consistent with prior times it was brewed.

As chemically complex as brewing liquor can seem, it is far outweighed by the innumerable organic and inorganic compounds from which grains, hops, and yeast are respectively made. When it comes down to it, in terms of chemistry, water is the most malleable of beer's four main ingredients. With the right research, keen application of the other three brewing elements, and a bit of math, the right water can be the difference between an acceptable beer and one of world class.



TASTE OF A PLACE: WATER GIVES OYSTERS UNIQUE “MEROIR”

This story is excerpted from the forthcoming *Rhode Island Shellfish: An Ecological History*.
Contact rhodeislandseagrant@gmail.com to be alerted when it is available.

by **Sarah Schumann** Photographs by **Angel Tucker**

“More than any other food, oysters taste like the place they come from,” writes author Rowan Jacobson in his connoisseur’s guide *Geography of Oysters*. “While they are creatures of the sea, they draw their unique characteristics from the land and how it affects their home waters ... Think of an oyster as a lens, its concave shell focusing everything that is unique about a particular body of water into a morsel of flesh.”

The unique taste of an oyster is called its “meroir.” A takeoff on the viticulturist’s “terroir”—the characteristic taste of a wine imparted by the soil, climate, and topography in which its grapes are grown—the meroir of an oyster derives from the sediments, algae, and salinity of the location in pond or bay where an oyster is raised.

Rhode Island’s oyster meroirs are considered among the best: According to *Geography of Oysters*, “Some of the most savory oysters in the world come from a geographical arc running from the eastern end of Long Island, along the ragged Rhode Island coast, to Block Island, Cuttyhunk, and Martha’s Vineyard: the line marking the terminal moraine of the most recent glacier. Along that arc, mineral-rich waters produce salty oysters with unparalleled stone and iron flavors.”

MATUNUCK OYSTER FARM

Farmer: Perry Raso

Location: Potter Pond

Meroir: Crisp, briny, with a sweet finish

The 7-acre Matunuck Oyster Farm, with its associated Matunuck Oyster Bar restaurant, has played a big role in putting Rhode Island oysters on the map. Owner Perry Raso not only produces a very popular oyster, he has also made his farm a center for education and ecotourism, inviting the public to see, touch, and taste his oysters while taking in the experience of Potter Pond.

Like many oyster growers, Raso got his start in wild-harvest shellfisheries, diving for steamers and littlenecks in Point Judith Pond. But after completing a degree in aquaculture and fisheries at URI, he decided to try something new, and he leased a 1-acre aquaculture site in Potter Pond. That small beginning didn't last long.

"The 1-acre farm that I started in 2002 expanded to 3 acres and then to 7 acres," Raso recalls. "In 2006, the farm was producing a lot of oysters and I was selling them to Boston and New York, and I wanted to ensure a future for the farm. I was running the business out of a section of a rental house in a nice neighborhood. I had a couple of employees and a lot of gear. It wasn't a sustainable way of continuing my business.

"So I purchased a run-down restaurant that was shut down for a couple of years, because it was the only commercial dock on the pond. I figured I'd open the restaurant with the farm-to-plate theme ... From that 1-acre farm with one student employee, now 11 years later, there are 12 people on the oyster farm, the vegetable farm has six employees, and depending on the time of year, the restaurant has between 150 and 250 employees."

In addition to greeting guests at the restaurant, Raso connects with the public through farmers' markets, events, and educational workshops at the farm.

"Open air markets like farmers markets have been a great way to connect with the customers. Community events are a great way to get our name out there, and a great way to keep it out there. We also sell juvenile oyster seed and take part in restoration projects. And agritourism ... It's a way to foster acceptance of the business. It's also a way to create revenue and spread the good word about shellfish."



Perry Raso displays some of the oysters he grows in Potter Pond.

© Photo by Acacia Johnson

RHODE ISLAND'S
OYSTER MEROIRS
ARE AMONG
THE BEST

ROME POINT OYSTER FARM

Farmer: Billy and Russell Blank

Location: West Passage, Narragansett Bay

Meroir: Saltier than the ones grown in Salt Pond

Billy and Russell Blank have spent their whole lives on the water, starting with quahog diving and lobstering. In the early 2000s, they were facing some tough choices. While they loved quahogging, the price for quahogs was sluggish—and meanwhile, their lobster catch was declining.

“We needed to do something,” says Billy Blank. “And then aquaculture came along. We watched [quahogger and early aquaculturist] Lou Ricciarelli. For about three or four years we watched him. And it looked promising.”

Ricciarelli was an early pioneer in growing oysters using modern methods, and is widely considered to have been ahead of the curve. His untimely death in a diving accident in 2009 was keenly felt throughout both the wild-harvest and aquaculture industries.

“Unfortunately, he didn’t get to see the whole thing turn into what it’s starting to turn into,” laments Blank.

By that time, the Blank brothers had already followed in Ricciarelli’s footsteps, setting up an oyster lease off Rome Point, in North Kingstown.

“We started with \$10,000 between us,” remembers Billy Blank. “We sold our lobster gear, most of it. Ten years ago, 10 grand. And without the boats and the trucks, I’m gonna say we’re probably now sitting on close to half a million in total equity. We probably have over a thousand cages.”

Although the brothers continue to harvest wild quahogs in their spare time, aquaculture has proven to be the right decision for them, Billy Blank says.

“The quahogging industry as a whole hasn’t progressed with the times. We do it because it’s a beautiful job out there. It keeps you in shape. The freedom. But you still got to pay the bills at the end of the day. If you want to have a house, if you want to have a retirement, if you want to have a truck, you have to keep money coming in. I think this [aquaculture] is the wave of the future, because we’re the middleman ... We harvest them and sell them directly to the co-op. So we get to decide how much we’re going to get for them.”

EAST BEACH OYSTER COMPANY

Farmer: Nick Papa

Location: Ninigret Pond

Meroir: Freshwater springs in the pond add a sweetness to the flavor

Nick Papa grew up in the Warwick quahogging community, but he found his own destiny in oyster growing.

“My dad was a shellfisherman for his profession,” says Papa. “I started going with him, and he would pay me a couple bucks to sort and count all of his clams. Being out there so regularly, I always wanted to see if I could do it myself. Finally I talked my dad into letting me take his boat out, and the experience when I did was pretty special, being out there and being in charge of myself and working. The bay is just so special, I almost got addicted to being out on the bay ... I couldn’t imagine being away from it. But I could see the ups and downs of the quahogging industry itself.

“Somehow I ended up moving my boat from Warwick to Wickford, and I met the Blank brothers and Lou Ricciarelli. They always offered to show me what they were doing with the oysters. It was pretty different from quahogging, where no one will tell you anything about what they’re doing. So I decided to try it out. I figured it would be more consistent, that you wouldn’t have to sell them if the price was low. And since it’s so sustainable, and it’s good for the environment, I couldn’t help but to give it a shot.”

Papa eventually took out a lease in Ninigret Pond and started the East Beach Oyster Company. The location was close enough to his grandparents’ house on the pond to feel familiar, yet far enough away from Warwick and Wickford to escape the skeptical glances of Papa’s quahogger friends.

“There were some heated debates about aquaculture when I was younger, so I kind of kept it to myself that I was even trying it,” Papa admits. “Because it’s still kind of a bad word to a lot of the quahoggers.” His quahogger father was not opposed to the project on ideological grounds, Papa notes. “He just thought it would be a lot of work. And since I didn’t know much about it, I wasn’t doing it efficiently at the time, so at the beginning it was quite a struggle. So my dad was on the fence for quite a while.”

Since then, Papa’s father has started working side by side with him on the 3-acre oyster farm. In fact, Papa says, “Most

of the quahoggers were pretty positive about it after they found out what I was doing.” Ultimately, Papa finds he can satisfy his addiction to being on the water just as well on the oyster farm as on his old quahog boat.

“It is special for the obvious facts of the beauty of your surroundings. Sometimes you might work right through a sunset, you might see the most beautiful sunset of the year. It’s part of my lifelong goal of just trying to spend time outdoors. I enjoy all of the weather types. There’s something special about all of those conditions: the rainy windy days, or when it’s snowing, or when it’s springtime and you can hear the thunder. There’s a fondness to the memory, I guess.”

ISLAND PARK OYSTERS

Farmer: Dave McGhie

Location: The Cove, Portsmouth

Meroir: It reminds people of that taste you get in your mouth when you’re swimming

Dave McGhie started oyster farming after being inspired by Roger Williams University associate professor Dale Leavitt’s community class in practical shellfish farming. He was contemplating applying for a lease site at some point in the future, when all of a sudden, opportunity knocked.

“I heard about a lease that was up for sale because a fellow had passed away, unfortunately,” says McGhie. “But we ended up helping the widow out by buying the lease. That happened in May 2013. So we bought the lease with some oysters there at the farm, not knowing how many, and we bought some gear.”

McGhie has worked on boats his whole life, including a stint as a quahogger in the early 1990s. But oyster biology was entirely new to him.

“The oysters were a learning curve,” he admits. “I’m sure we’ve killed some oysters ... They grow way faster than you think, and you never have enough gear.”

Having worked previously in wild-harvest fisheries, McGhie was initially surprised at the level of cooperation among growers throughout Rhode Island.

“Commercial fishermen, they don’t help you much,” McGhie explains. “And aquaculturists will go out of their way to help you. Guys have invited me to their sites, and I’ve visited their farms, and done some upweller work with other guys. I think they realize, if someone gets sick from an oyster in



Oysters from East Beach Oyster Company

Rhode Island, they’re not getting sick from an oyster from Dave McGhie’s farm, they’re getting sick from a Rhode Island oyster. There’s no distinction between my farm and anyone else’s farm. I think they realize that the industry is only as strong as the weakest guy. And there’s enough market share right now that you don’t have to cut each other’s throats.”

Island Park Oysters are grown in a 2.4-acre lease in the water body known as “The Cove” at the northern tip of Portsmouth. The farm is in shallow water, accessible by walking in waders at low tide. The location is part of the draw for McGhie.

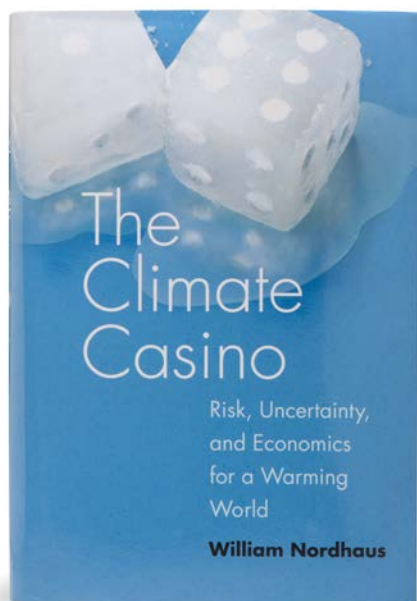
“There’s been days when I’ve been out there and the horseflies are the size of helicopters, and the sun was beating down, and there was no wind, and you’re sweating. It is a farm, and that’s a four-letter word. And sometimes it really is farm work. And there’s been other days, when you go out in October, and it’s just beautiful, and the ospreys are hunting around, and it’s just the greatest thing. The air has that smell of marsh and salt air, and it’s just perfect. There’s probably more of the horsefly-biting days than those other days! But there’s enough of those nice days to keep you going back.”

The Climate Casino

RISK, UNCERTAINTY, AND ECONOMICS FOR A WARMING WORLD

By William Nordhaus

Reviewed by **Emi Uchida**



The year 2015 is a critical year for climate change policy. Leaders, negotiators, nonprofits, and other stakeholders from most nations in the world will gather in Paris for the United Nations Climate Change Conference (COP21) to establish a binding and universal agreement on climate—a post-Kyoto Protocol agreement. The nations are charged with a decision so important that what will be agreed upon will have implications for generations to come. What makes it difficult to agree on climate change policy are the vast uncertainties: How fast will the world economy grow? What technologies

will be available to reduce greenhouse gases? These questions are difficult for any economist or energy technology expert to forecast. Perspectives on these questions are largely what drive the divergent estimates of CO₂ emissions across simulation models from scientists all over the world, leading to a wide range in the predicted increase in the planet's temperature. The decisions this year by global leaders need to be made in a world of deep uncertainty. Can society wait to revolve the uncertainties before we act?

William Nordhaus, in his most recent book on climate change, brings together the best available scientific and economic evidence to answer the fundamental questions about climate change policy and concludes that global society needs to take immediate actions based on the best science and choose cost-effective policies. While there have been several books on the science behind climate change, this book fills in a significant gap dealing with the societal aspects of climate change—why climate change is an economic problem, the economic costs and damage, comparison of policies to slow change, and international spillovers and bargaining.

Nordhaus, a professor of economics at Yale University, is arguably the most well-known economist working on climate change and has made significant

contributions. He is a pioneer in the development of integrated economic and scientific models to determine the most efficient (least costly) ways for coping with climate change, known as the DICE and RICE models. These models have been used in cost-benefit analyses of climate mitigation strategies in prestigious reports such as that of the United Nations. Interestingly, Nordhaus has been critical of the well-known Stern Review, which called for immediate, bold actions on climate change. In this book, he attempts to offer scientific and economic arguments in detail for why, when, and how of climate change policy.

Nordhaus's logic and policy conclusions are clear and persuasive. The book starts by surveying the current science of global warming and concludes that the planet will experience warming greater than it has seen for more than a half-million years. It then analyzes the potential impacts from climate change on different sectors of the economy and concludes that the impact will be costly and grave for human and natural systems that are “unmanaged” in low-income and tropical regions, including rain-fed agriculture, seasonal snow packs, coastal communities, river runoff, and natural ecosystems. In contrast, “highly managed” sectors in developed economies, including irrigated and modernized agriculture, are likely to adapt to climate change at low



cost. These macro-level conclusions are courageous since there will be winners and losers even within the highly managed sectors and firms. However, it offers a broad-brush rule of thumb when societies need to prioritize in allocating limited resources for adaptation. Nordhaus alerts the readers to “tipping points,” which can lead to sudden or irreversible changes at a large scale that humans cannot manage with existing technologies. Nothing novel here.

The highlight of the book is in much of its second half, when Nordhaus digs deeply into the essential questions of climate policy—how much, how fast, and how costly. Nordhaus argues, and concludes convincingly, that we need to adopt policies targeting around +2 degrees Celsius. More importantly, to do so, we must raise the price of carbon and other greenhouse gas emissions. Higher prices become an incentive for

consumers to prefer low-carbon goods, for producers to curb emissions, and for entrepreneurs to develop low-carbon technologies—leading to a low-carbon economy. Nordhaus compares carbon tax and cap-and-trade to other existing and more politically palatable programs—including a gas tax, tighter auto standards, and weatherization tax credits—and shows that raising the price of carbon through a carbon tax and cap-and-trade are by far the most cost-effective among those policies.

The last few chapters discuss climate politics: denial of science among U.S. leaders and ignorance of the public, society’s sensitivity to any taxes, nationalism, and free-riding—whereby some countries benefit from others’ mitigation efforts but don’t do their perceived fair share—being the obstacles to international agreement. He emphasizes that most nations must be

Damage is viewed in the Rockaway neighborhood, Queens, where the historic boardwalk was washed away during Superstorm Sandy on October 31, 2012.

© Photo by Spencer Platt, Getty Images.

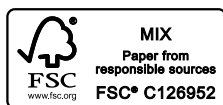
part of the agreement for it to succeed. While this has been said by others before, Nordhaus’s suggestion of using trade sanctions as penalty for free-riding or neglecting climate agreements is interesting.

In this critical year for international climate policy, this book may be worthwhile for anyone who desires a practical and in-depth understanding of the economics of climate change. Nordhaus covers the key concepts of economics related to climate change and policy, and does so in language clear enough for non-economists but also with enough details to give a wide range of readers food for thought.

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This photo, taken by John Supancic,
shows one of the pumping stations,
known as “the gatehouse,” on the
Scituate Reservoir.

