CHANGES IN NARRAGANSETT BAY

Proceedings of the 2017 Ronald C. Baird Sea Grant Science Symposium

RHODE ISLAND SEA GRANT
COASTAL RESOURCES CENTER
GRADUATE SCHOOL OF OCEANOGRAPHY

UNIVERSITY OF RHODE ISLAND

ALL EYES ON THE BAY

LOBSTERS WITH SHELL DISEASE, FEWER CRABS, LESS KELP, A WATER COLUMN seemingly devoid of life. More productivity in the open ocean than in Narragansett Bay. A correlation of this decline with reductions to wastewater treatment plant effluent discharges.

Organisms growing prolifically on oyster cages in the bay. Better growth of oysters in the bay than offshore. A fear that warming waters would lead to more disease outbreaks.

The first set of observations and concerns was from fishermen who spoke at the 2017 Ronald C. Baird Sea Grant Science Symposium on changes in Narragansett Bay. The second set was from shellfish farmers. They came to the symposium seeking answers for the question of how to ensure optimal conditions for their industries to continue to operate in the bay for years to come. They wondered about what roles nutrient reductions, chemical inputs, and climate change play in the conditions they are seeing.

Scientists from the University of Rhode Island Graduate School of Oceanography, Boston University, the Rhode Island Department of Environmental Management, the Environmental Protection Agency, and the Narragansett Bay Commission, which operates two wastewater treatment facilities on the bay, talked about how climate and nutrients interact to create environments that are more or less hospitable to different species of plants and animals. They also discussed how wastewater is treated before being discharged into the bay, and how they test for the effects of chemicals in bay life.

While much is known, many questions remain. Temperatures continue to rise; further nutrient reductions are planned; and new chemicals are continually developed for uses such as firefighting foam, and they will make their way into bay waters. Even now, some changes, such as the increased residence time of summer flounder in the bay, defy what is thought to be understood about bay conditions and temperature rise. Calls for a return to using mesocosms—tanks that replicate bay conditions for testing various scenarios—and coupling those tests with computer modeling; researching why decapods, such as lobsters, are leaving the bay; and studying which sources of nutrients will be the most important for bay productivity now that sewage treatment plants are reducing discharges were some of the questions that emerged throughout the day.

We at Rhode Island Sea Grant will be returning to examine the contributions of all Baird Symposium participants to this discussion, and working with partners and stakeholders—"citizen scientists"—to invest in research to better understand the changes occurring in Narragansett Bay to improve management for all, in particular for those who make their living from its waters.

Dennis Nixon
Director, Rhode Island Sea Grant

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Changes in Narragansett Bay: Proceedings of the 2017 Ronald C. Baird Sea Grant Science Symposium was edited by Monica Allard Cox and produced by Rhode Island Sea Grant. The articles included are taken directly from the talks as presented at the symposium.

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A RESILIENT BAY

Stakeholder Perspectives

By **Hugh Markey**
Photos by **Melissa Devine**

Depending on the species they harvest, fishermen and aquaculturists report different perceptions of changes in Narragansett Bay.

If attendees at the Ronald C. Baird Sea Grant Science Symposium were united by a concern about the health of Narragansett Bay, some were divided about what exactly is happening and why. That was evident in the stakeholder segment of the program. The five-member panel of commercial fishermen in the lobster, crab, and shellfishing industries, as well as aquaculturists, boasted a range of experience from 10 to over 40 years on the water, and each held views of the bay that were as passionate as they were different. Most of the wild harvesters seemed to feel a reduction in nitrogen being released into the bay—due to wastewater treatment investments that reduced the amount of untreated sewage that overflows into the bay after storms—was at least partly to blame for perceived losses in their fisheries.

Some of the direst concerns were expressed by Al Eagles of the Rhode Island Lobstermen's Association. Unlike his fellow panelists who were University of Rhode Island graduates, "I got my education on Narragansett Bay," Eagles said of his career that has spanned 45 years. "We had a resilient Narragansett Bay back in the '90s," he said, even as water temperature was rising due to climate change. "Everything was flourishing, but today we as fishermen and observers of the bay do not see that same thing."

He cited the rise in lobster shell disease in the bay as a growing problem. He said that shell disease appeared in the late 1990s. "And it's getting worse by the year, believe it or not. I did a study last year, and there was a 67 percent incidence of shell disease in lobsters taken by the Newport Bridge, and when you go out front [closer to the mouth of the bay], there's very little shell disease, and the further offshore you go, there's no shell disease.

Lanny Dellinger, board member of the Rhode Island Lobstermen's Association, sees the absence of kelp in the bay as another indicator of trouble. "Ten or 15 years ago, we would have balls of kelp as big as a pickup truck along the shores. You just can't find that anymore. In the upper bay, you can't buy a piece of kelp."

Eagles agreed: "There used to be plenty of rockweed in Jamestown, off Rose Island, but that's gone. Yet if you go off Newport, the lobster is plentiful and so is the kelp. There is a disconnect between the bay and the open ocean."

How clean is too clean?

Mike McGiveney, President of the Rhode Island Shellfisherman's Association, traces his shellfishing heritage back 130 years, to the era of Scallop Town, a 19th-century nickname for a section of the East Greenwich waterfront that was a hub for scalloping. He too voiced concern about nitrogen reduction. "Are there enough nutrients to feed the shellfish? Is clean water healthy water? There are 5 tons less nitrogen going into the bay today. That has to have an impact."

Eagles pointed to what many would consider a positive indicator as a source of concern: the clarity of the bay's water. "If you go out there right now, as we did in the past couple of summers, and scoop up a bucket of water, there's nothing swimming in it. Narragansett Bay has turned into a swimming pool. If you look into a swimming pool, because of the chemicals you can see right to the bottom. If you go down to my dock right now or in the summer time, you can see the same thing.

"Everybody is saying what a great job they did in cleaning up Narragansett Bay, and the one thing everybody points to is how clear the water column is. To me, that's the worst thing anybody can say. If the water is that clear, it means it's dead; there's no life in it. It used to be that in the summer, if you scooped a bucket of water, the water would be brown. It would be full of life, full of zooplankton.

"As observers, as fishermen, we're not seeing the plankton, and that's why we're trying to bring this to the symposium today. The bay is swimmable, but not fishable. We have to ask ourselves, 'What has changed in the bay to turn it from a resilient bay to what I call a dead bay?'

"It really seems to have taken place in the last three years. Barnacles stopped growing on our traps in the bay. After a year, they still looked like they just came off the delivery trucks, whereas the ones in the open ocean had plenty of barnacles.

"A lot of our fishermen say, when they're going to fish in the bay, that they're going to fish in Chernobyl. That's a terrible thing to say."

Oysters in the bay

Mason Silkes, co-owner of Saltwater Farms, which operates farms in the bay and in Rhode Island Sound, offered a different perspective, saying that during the summer when he puts out his cages and lines, they're covered with growths of all kinds, and his oysters are thriving. "One of our main jobs in the middle of the summer is spending the better part of each day power washing the lines and cages. Everything grows like crazy. On the other hand, when we farm offshore, the growth rate of the oysters is not nearly as good."

Matt Griffin, researcher and shellfish farmer, says the oyster growth in the upper bay is actually better than in the lower. "I've personally not been concerned yet with the nitrogen inputs, but there may be a concern about a tipping point with multiple farms operating on top of each other. I am also concerned about possible increase in diseases that appear in warmer water. We must maintain a robust monitoring program to keep an eye on the pathways of these diseases to ensure that our product gets to market."

Griffin did express concern that reduction in winter phytoplankton blooms may reduce the nutrients available to immature shellfish that they need to survive the spring increases in predation and other stressors. He added that the closing of shellfishing that occurred last


Al Eagles

year as a result of a harmful algal bloom that shut down the sale of shellfish for both farmers and wild harvesters for a couple of weeks caused some economic loss, and may result in a negative public perception of unhealthy shellfish coming out of state waters.

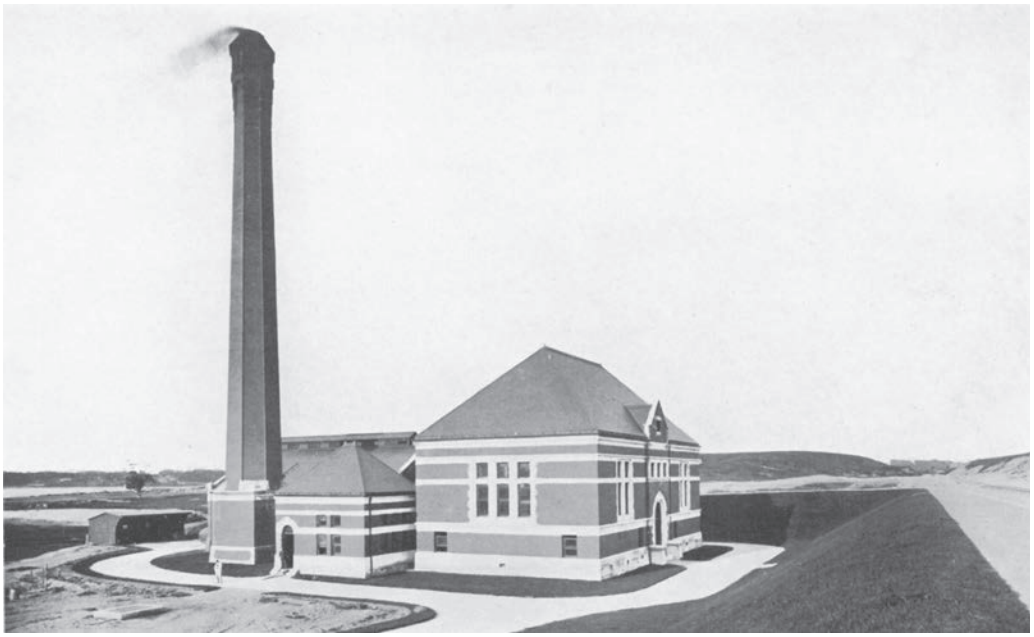
"How the reduction in nitrogen and climate change affect these things is a concern. I can't put my finger on one cause of the changes or one solution, and I'm not sure any of us can, but it's important that we're all sitting here with an open mind. It's important that we nail down the uses of the bay, both recreational and commercial. Hopefully the Bay SAMP (Special Area Management Plan) that's coming up provides the aquaculture industry an opportunity to grow, while giving the other industries a voice to be heard as well."

Dellinger worries that the traditions of Rhode Island itself may change. "I'm afraid we're going to lose our fishing heritage. A few years ago, there was probably around 1,000 people who made their living on Narragansett Bay, and if you look around now, the numbers are probably 10 percent of that. The fishing docks that the tourists like to come down and see, they're going to be gone in a few years."

NARRAGANSETT BAY

"Living and Dying by the Choices We've Made" - George Jones

By **Hugh Markey**



The Providence Sewage Pumping Station was part of a dramatic transformation to the city of Providence and Narragansett Bay that began in the late 19th century, when water began to be pumped through the city.

PRINT COURTESY OF THE RHODE ISLAND HISTORICAL SOCIETY, RHIX171900

When Italian explorer Giovanni de Verrazzano stood in what would become known as Narragansett Bay, could he see his toes?

Boston University associate professor Wally Fulweiler used that historical reference and others to illustrate the challenges involved in deciding what the bay "should" be like in her talk at the 2017 Ronald C. Baird Sea Grant Science Symposium.

"As late as 1865 there were beautiful and abundant … eelgrass beds in the Providence River estuary," Fulweiler said. "But then on Thanksgiving Day [in 1871], with a 13-gun salute and the ringing of bells, we began to pump water through the city of Providence." The waste from farm animals and horses that had until then stayed on the land began to be flushed into the bay. By 1901, there are records of damage being done to what had been pristine areas in the upper bay.

"The bay that we're discussing this morning is an artificial bay. The color that we see, the level of productivity, that's almost an artificial result, because it's coming from our fertilization," Fulweiler said. Because there was not the rapid influx of population experienced by bays in other parts of the country, Narragansett Bay, unlike the Cheasapeake Bay or Pamlico Sound, has had roughly the same amount of nitrogen entering the bay from the 1960s until recently, when major mitigation work began at the wastewater treatment facilities.

The mitigation work was undertaken, Fulweiler said, in large part because "the Providence River estuary and some of the more shallow embayments were experiencing hypoxia and anoxia."

"Bear in mind that hypoxia and anoxia can be normal occurrences in a normal estuary when you have lots of productivity, especially in the summertime." She cited warmer water as containing less gas (oxygen) and the naturally occurring stratification of the water column as normal conditions that could lead to low oxygen, exacerbated by the addition of nitrogen.

"Additionally, the fish kill in 2003 … acted as a very dramatic and public event" that galvanized people into taking action. The only other fish kill in the bay is on record as occurring in 1898 in the Providence River estuary and Greenwich Bay, Fulweiler said, while the 2003 event was confined to Greenwich Bay. It's important to note, she said,

"that it's not simply excess nitrogen … there were also physical conditions that helped make this happen.

"Even though we can dial back the nitrogen, we can still have low oxygen events because of the physics of the system, as well as any legacy impacts that Narragansett Bay is holding onto," she said.

In addition to understanding the impacts of nitrogen inputs and reduction to those inputs, Fulweiler said, "We cannot ignore this climate change signal."

"And I certainly understand this idea that climate change can't be blamed for everything, and I agree with that. I don't think there's a black and white answer for any of this. It is complex and confusing," she said.

She pointed to data that show that the total air temperature across the watershed has gone up between 1.3° to 1.7°C, and surface water temperatures have increased between 1.5° and 1.6°C from 1960 to 2010.

"How this impacts our ecosystem is not straightforward," she said. "It's not like we can just dial up the temperature and know what's going to happen.

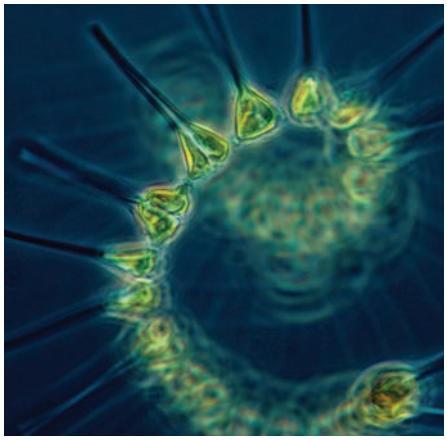
"On top of that, we have other changes. For example, there's been an increase in precipitation since the 1960s, [and] … the wind has been decreasing; this is actually a New England-wide phenomenon. Wind really matters, because if you want to get oxygen into your water column, you want to mix that water column, and a great way to do that is to blow wind on it. If you want to mix nutrients from the bottom into the surface waters to help grow phytoplankton, a great way to do that is with wind.

"Think about it: we're warming the waters, we've got increased precipitation coming in, we've got less wind available. That all will change the ecosystem."

Fulweiler said that data show a decrease in productivity "long before we changed the nitrogen coming into this bay." In fact, a long-term database shows there has been what Fulweiler characterized as a "really strong decline" in phytoplankton since the 1970s.

"How do we manage a bay that is so complex and diverse? In the upper Providence River estuary, there is no doubt that the area is heavily nitrogen influenced with lots of negative consequences like low oxygen conditions. Additionally, though, the lower and mid-lower parts of the bay were almost being fed by that Providence River estuary, and we see that primary productivity may have been decreasing long before nutrient mitigation.

"This may be happening for a combination of reasons. Climate change has played a part. Phytoplankton production is extremely light limited, and we also have seen that warmer winters have more cloudy days. Colder winters have more sunny days. If you're waiting for phytoplankton and you have more and more cloudy days, then you are waiting later and later for the phytoplankton to bloom. Additionally, changes in wind means you have less stirring of the water col-



A decline in phytoplankton—the basis of the marine food web—in Narragansett Bay may be partly due to an increase in the number of cloudy winter days.

PHOTO AT LEFT COURTESY OF NOAA; PHOTO BELOW BY ERIC GOULD

Greenwich Bay is a productive area for shellfish, but water quality issues have recurred over the years due to a legacy of pollution and the physics of the system, not only from excess nitrogen, Fulweiler said in her talk.

PHOTO BY MONICA ALLARD COX

umn, and, therefore, less opportunity for the phytoplankton to grab onto the nutrients. We also may have more zooplankton. Their metabolic rate could be increasing, they may be chewing down that phytoplankton more quickly, and there is less time for the phytoplankton to get itself into a bloom status."

Fulweiler said that the reduction of nitrogen inputs to the bay has been called "'a grand experiment,' but we might also call it a challenge and an opportunity."

"Narragansett Bay is a unique ecosystem," she said, "and we have a fantastic opportunity to study this change, to do so together, and to really be on the forefront of having stakeholders across the board and scientists come together and figure out how to manage this bay in the best possible way. Our grand challenge and opportunity is to try to quantify the impacts of changing climate and decreased nutrient loading, and I think there are some interesting opportunities ahead."

Following Fulweiler's presentation, rapporteur Candace Oviatt, University of Rhode Island oceanography professor, commented: "The loss of chlorophyll in the bay is a complex issue, and I've spent a lot of time trying to figure that out myself … Warmer winters mean that the grazing community stays active in the wintertime water column. So, a bloom will try to get started in the coldest part of the winter. But if it's not that cold, there will be a lot of grazers in the water column, a lot of zooplankton, and they'll graze that bloom down and that organic matter will never build up to a biomass that shows an increase in chlorophyll.

"So, from the 1970s to the 2000s we had lots of warm winters, and in those warm winters we had very diminished winter spring blooms, and we had a lot of zooplankton activity in the water column. The organic matter that was produced in the water column was consumed, and it didn't make it to the benthos. That meant a very diminished benthic community … It also meant a decreased level of chlorophyll in the water column.

"We have continued to experience warm winters, but occasionally we've gotten a cold winter along the way (2008 comes to mind). When we've had a cold winter, and we've still had plenty of nutrients in the water column, we've had a stronger winter-spring bloom, with that organic matter going to the benthos. So it's been a variable pattern … but the overall trend is that we're going to have a warmer bay, and there's not going to be a winter-spring bloom whether we have nutrients in the bay or not."

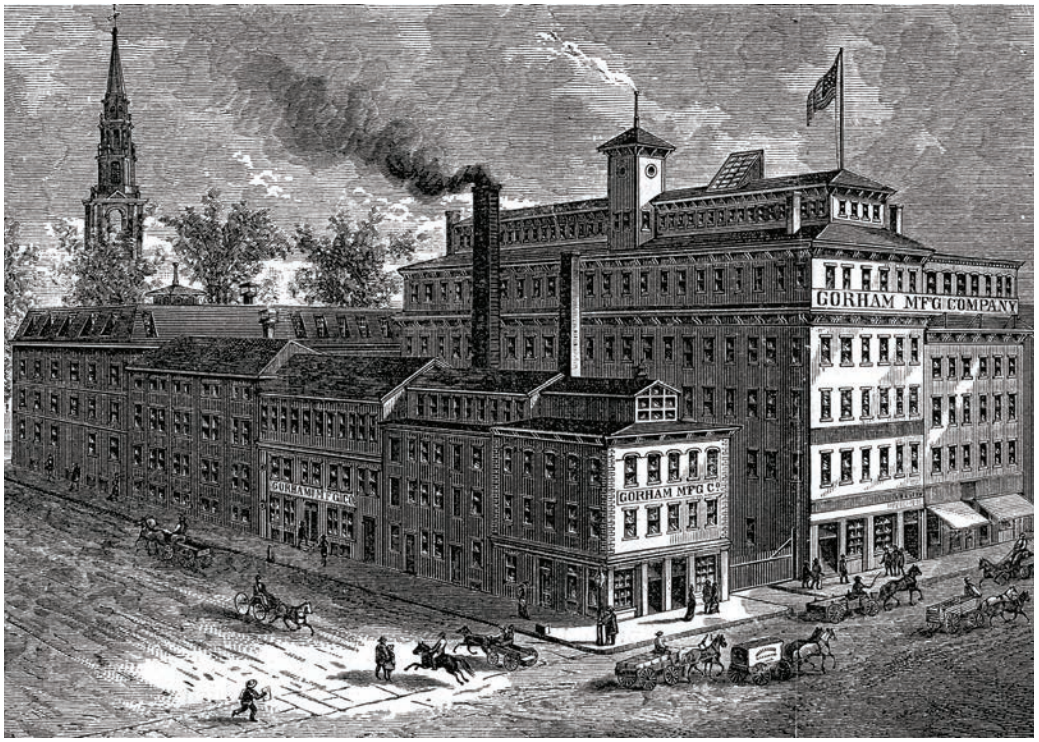
During the question and answer session, Janet Coit, director of the Rhode Island Department of Environmental Management, raised the following question: "What's our baseline? We're not looking to bring the bay back to pre-industrial times when we had the salt marshes … In conservation, we always ask the question, what are we trying to get to? What's the baseline we're comparing against and, given the complexity of everything that's going on right now, what are we trying to get to?"

Oviatt said, "I don't think it's up to the researchers to tell you what the bay should be like. I think it's the people who live here that should tell us what the bay should be like. We can try and figure out whether it's going in this direction or some other direction, but we're not here to tell you what the bay should be."

OUR CHANGING BAY

A Historical Perspective

By **Hugh Markey**



Gorham Manufacturing was one of the pioneers of Providence's fine jewelry industry, which has left a legacy of metals in bay sediment.

ILLUSTRATION COURTESY OF WIKIMEDIA

"I LIVE THE BAY."

Tom Uva, director of environmental science & compliance for the Narragansett Bay Commission, is not being hyperbolic. He discovered quahogging in his youth, spent at Oakland Beach in Warwick, and by the time he was a chemical engineering student at the University of Rhode Island, he was also a commercial shellfisherman. For 15 years, he lived on a boat, and today, he says, he still has four boats he likes to "fool around with."

His talk on "The Choices We Have Made" in Narragansett Bay, at the 2017 Ronald C. Baird Sea Grant Science Symposium, was just as wide ranging. While many of the questions raised at the symposium regarding bay water quality and the declining abundance of certain species focused on wastewater treatment plant discharges and warming waters, Uva recounted the many ways humans have altered the bay, and affected the species that inhabit it, for the past 400 years.

Uva said that as early as the 1660s, the area's beaver population was depleted by the fur trade, and the loss of beavers, and their dams, led to increased stream flow and sedimentation. In the 1700s, land began being cleared for farms. During this time, sewage flowed directly into rivers, where people believed it would be diluted into harmlessness.

Jewelry manufacturing began to blossom in Rhode Island in 1775. By the late 1800s, Rhode Island was the largest jewelry manufacturer in the country, producing 25 percent of the nation's jewelry. Rhode Island's reputation as a jewelry hub remained strong until it reached a high of 32,500 workers in the 1970s. During much of that time, toxins used in the manufacturing process were dumped directly into the bay. Heavy metals from textile dyeing were discharged into the bay as well, with remnants of this industrial heritage found in benthic sediments to this day.

In the 1870s, with the develop-

ment of early sewage systems, there were 65 direct outfalls to rivers, the beginning of the combined sewer overflow (CSO) problems that would challenge water quality into the 21st century. Also, animal waste, at that time, was hosed off the streets and into the rivers. Officials soon realized this was bad for shellfishing, and in 1901 the Providence Sewage Treatment Plant was built. It was not until 1912, after the human health consequences of polluted waters became apparent, that bleach was incorporated into sewage treatment, dramatically reducing health risks.

The Hurricane of '38 further altered the bay, wiping out eelgrass beds and transforming, through siltation, hard bottom habitat to soft bottom. The installation of the hurricane barrier in Providence in the 1960s changed flushing rates in the upper bay.

During that time, Uva said, fisheries were undergoing changes as well. Until the mid-1800s, both fish and shellfish species were abundant. From the 1870s forward, a series of problems began to surface, as eelgrass beds began to die from wasting disease, and scallop beds declined due to habitat loss. By the 1950s, advances in fishing technologies led to overfishing and declines in commercial stocks. More than 50 percent of the bay's salt marshes have been destroyed in the past 300 years, and winter flounder have declined by 90 percent since the 1980s. Uva noted that lobster has been in decline since 2001.

Providence's Fields Point, currently the site of the Narragansett Bay Commission's sewage treatment plant, the Harborside campus of Johnson & Wales University, and the headquarters of Save The Bay, was once known as a site for fishing and shellfishing, and for its waterfront picnic grounds. Boatloads of hungry visitors would pull right up to docks to enjoy clambakes on the shore. There were also major oystering businesses in the area near where Save The Bay is now located. In fact, the shells from the businesses actually changed the shoreline, according to Uva. "When we put in phase two of the CSO tunnel, the boring machine had no trouble penetrating rock; however, the machine would later hit tons of oyster shells deposited over the years. The result was that the blades of the machine were being destroyed."

Over the years, the area grew highly industrialized, and the Providence River became narrower with fill, but deeper with a dredged channel catering to significant shipping. Scrap metal operations dot the shoreline, processing Rhode Island's largest export. Providence Harbor is also the site of storage and distribution facilities for coal, fuel oil, salt, and cement. While the area is highly developed, environmental regulation—a relatively new phenomenon—followed the Clean Water Act in 1971 and has resulted in reductions in heavy metals and other toxins being discharged into the bay. Still, Uva questioned, where does the coal dust settle and the salt end up?

As for wastewater treatment, the Narragansett Bay Commission's $359 million Phase 1 CSO tunnel began operating in 2008, and the Phase 2 project was completed a few years later, at a cost of $270 million. Other upgrades ran into many millions of dollars, and the forthcoming Phase 3 CSO project is projected to cost $850 million. As Uva said, "Clean water is very expensive," but nitrogen pollution in the upper bay has now been reduced by 64 percent. However, many fishermen questioned whether this reduction in nitrogen discharge has reduced shellfish productivity, and, along with the chlorine used to disinfect the wastewater, has made the bay "too clean" to support life. Uva showed a slide indicating that chlorine discharges from Narragansett Bay Commission facilities have decreased since 1999, when dechlorination was added to the process. Total residual chlorine is now 96 percent below the Department of Environmental Management permitted limit, and meets Environmental Protection Agency criteria to prevent chronic, acute effects in marine organisms.

Uva said that how nitrogen reductions ultimately impact primary and secondary productivity of the bay is still a question, but as a result of wastewater treatment upgrades, people can now swim, fish, and shellfish in areas and during times that were previously closed to those activities.

One area that remains a challenge, Uva indicated, is a gyre that has formed in the upper bay, which has created an area of low dissolved oxygen levels. Uva recommended a holistic approach to watershed management there, using "smart engineering" techniques such as selective dredging to redirect flows to improve circulation.

A benthic monitoring video Uva showed reflected his optimism that the watershed was moving in the right direction. The film showed green crabs and spider crabs, mud anemones, whelks, and other creatures. "The bay is alive," he said. "We have all kinds of creatures there."

He also mentioned recent animal visitors such as beluga whales, dolphins, and seals as positive indicators about the health of the bay.

"The bay has been negatively impacted by us over the past 350 years, and we continue to impact it both negatively and positively," Uva said, but added, "The water is cleaner than it has been in a long time."

KILLING PATHOGENS, NOT AQUATIC LIFE

How Wastewater Treatment Facilities Disinfect Effluent

By **Meredith Haas**

The 1901 Field's Point Wastewater Treatment Facility Chemical Building is one of the oldest buildings at Providence's main sewage treatment facility. Dechlorination helps neutralize the chlorine used to kill pathogens in wastewater.

PHOTO COURTESY OF WIKIMEDIA COMMONS

That "pool" smell that may trigger fond memories for some while nauseating others isn't from chlorine. It's from chloramines, chemicals formed from chlorine reacting with other elements, such as ammonia—a component of sweat and urine. Bad news for avid pool-goers.

This brief chemistry lesson came courtesy of Art Spivack, University of Rhode Island oceanography professor, during the 2017 Ronald C. Baird Sea Grant Science Symposium, where participants came together to discuss ecological changes in Narragansett Bay and next steps forward to improve management.

Spivack, who specializes in biochemistry, was responding to perceptions that chlorine used by wastewater treatment facilities to kill pathogens from human and industrial sewage is being dumped into the bay along with the treated wastewater (effluent) and harming aquatic life—and leaving its tell-tale odor as evidence of its presence.

Since chlorine—a very reactive, naturally occurring chemical—is a powerful tool for killing pathogens, it is the most common form of treatment at wastewater facilities. Bleach was first introduced as a disinfectant in Rhode Island wastewater treatment in 1912, said Tom Uva, director of environmental science and compliance at the Narragansett Bay Commission, who discussed the history of human impacts to Narragansett Bay in his presentation at the symposium.

"There's a decline in fatal diseases once we started disinfecting water and wastewater," he said. "As a result, the upper bay can support beaches, and shellfishing has opened up."

All but three of the state's 19 wastewater treatment facilities, as well as those in Massachusetts that discharge into connecting watersheds, use chlorine in dealing with the 100 million gallons of human

Eastern oysters are one of the species DEM uses to test the quality of treated watewater.

PHOTO BY MELISSA DEVINE

and industrial sewage they receive daily. The other three facilities—located in East Greenwich, Narragansett Bay Commission's Bucklin Point, and West Warwick—switched to ultraviolet light to disinfect wastewater. This method obviates the potential toxic impacts of chlorine, but comes with added costs, which is why most facilities have continued using chlorine, said Angelo Liberti, chief of surface water protection at the Rhode Island Department of Environmental Management (DEM), who discussed the state's efforts to reduce pollution in the bay from wastewater discharge.

For example, in 2014, the city of Newport decided to upgrade existing chlorination/dechlorination systems after determining that construction and annual operation and maintenance costs for ultraviolet treatment would be between 24 and 35 percent greater.

Sulfites are added to wastewater to prevent chlorine-related toxins from entering the bay. These sulfites, the same chemicals that preserve freshness in baked goods, react with the chlorine that's left over after treatment to form sulfate and chloride—both of which are natural components of seawater, Spivack said.

"The relative amount of sulfate and chloride we're adding is at a level that's immeasurable compared to the background," he explained, "The chemicals that we're adding already exist [in Narragansett Bay] and add a tiny amount compared to the natural abundance."

The amount of sulfate naturally in seawater is 1,000 times higher than it is in dechlorinated water, according to DEM. Mitigation efforts have reduced the amount of chlorine entering the bay since the late 1990s by about 98 percent, Spivack said.

"In 2016, only 20 pounds of chlorine from all the wastewater treatment facilities combined was discharged into the bay," said Angelo Liberti, chief of surface water protection at DEM, who discussed the state's efforts to reduce pollution in the bay resulting from wastewater treatment facilities in his presentation at the symposium.

Twenty pounds, he added, is the equivalent of adding 80 gallons of household bleach to the total volume of the bay.

"That's the same as seven drops of chlorine in an Olympic-size pool," he noted. "The permit we set for the Fields Point treatment plant is 800,000 times less strong than household bleach. That's how protective we're being to aquatic life." The amount of chlorine that aquatic life can tolerate, Liberti said, is actually much higher.

To ensure that the effluent discharged into the bay will indeed not have any deleterious effects on aquatic life or, by extension, seafood consumers, the state conducts "bioassay," or toxicity, tests of effluent. These tests are based on Environmental Protection Agency (EPA) methods to determine the effects on an organism's ability to survive, grow, and reproduce. Rhode Island has been conducting these tests since 1990 at the EPA's Environmental Research Lab in Narragansett to determine acute or chronic effects of pollutants on aquatic life using the most sensitive species found in Narragansett Bay.

"Organisms are immersed in the effluent to see whether it causes toxicity. So, if there are particular pollutants that we're not monitoring for, this is a catch-all test to see if there are any lethal or reproductive effects," Liberti said. "It can account for chemicals interacting with one another that are more toxic than they would be individually or things we're not monitoring."

The species used in these tests are native to Rhode Island marine and estuarine waters (including mysid shrimp, Atlantic purple sea urchins, silversides, copepods, and Eastern oysters). They can be easily cultured in the lab, are sensitive to a variety of pollutants, and are generally available throughout the year from commercial sources.

"The reason we don't collect [species] from the wild is because you don't want some that might have a separate problem or unrelated stress," said Liberti, addressing concerns raised about the EPA lab tests. He explained that species taken from the wild may have other ailments, so it would be hard to isolate and determine the full effect of effluent toxicity, if there was any. "Species are carefully raised in the lab where there's quality control so it's a fair test."

"The toxicity tests, the bioassays ... done ... in the past after chlorination were highly toxic, which is what you'd expect," he said. "You want your chlorine to kill bacteria and viruses, but it also kills phytoplankton and zooplankton. But after dechlorination, there's virtually no toxicity detected in the effluent."

WHERE HAS ALL THE EELGRASS GONE?

By **Meredith Haas**

The health of eelgrass, like this example from Seattle, is tied to the health of marine ecosystems.

PHOTO BY J. BREW

A slide showing two different sets of eelgrass plants glowed on the screen. The set on the left seemed stunted and short. The set on the right had willowy, long shoots.

If you knew nothing about eelgrass, you might conclude that the plants on the right were the healthier of the two. In fact, however, the long seagrass blades indicate the plants were struggling to find light and put energy into growing taller, rather than sprouting new shoots every few days. The shorter plants with more shoots were actually hardier, had a more extensive root system, and would be better able to withstand a storm with wave action that could pull up the longer, "top-heavy" plants with less-developed root systems.

And the health of eelgrass is closely tied to the health of aquatic ecosystems. "Boaters hate it; it runs into their props, but we love it because it provides a protective habitat for juvenile finfish and food for waterfowl. It … increases the clarity [of water], and … it's a resource for food and habitat for a variety of different animals and some other plants, too," said Steve

Many species want to grow on eelgrass leaves. Healthy plants grow new shoots to keep ahead of fouling organisms, which, unlike parasites, do not take nutrients directly from their host.

PHOTO BY UPUPUA4ME VIA FLICKR

Granger, a researcher at the University of Rhode Island's Graduate School of Oceanography (GSO), who discussed the state of eelgrass beds in Rhode Island at the 2017 Ronald C. Baird Sea Grant Science Symposium.

Also known as seagrass, eelgrass used to thrive in extensive, thick green carpets in the Providence River estuary—giving 33-acre Green Jacket Shoal in the Providence River its name. One of the most productive ecosystems in the world, eelgrass also buffers coastlines from storm surge and waves, filters water, and removes carbon from the atmosphere. Only a fraction of Narragansett Bay's eelgrass beds remain, having been compromised by impacts of coastal development, nutrient loading from runoff and wastewater discharge, and climate change.

"[Eelgrass] can grow in a variety of sediments, but it doesn't like highly organic sediments," he said, because they can develop sulfides that are toxic to eelgrass, referring to the increase in nitrogen and other nutrients in the bay bottom.

"The bay is a continuum of water quality," he added, "The poorest is at its head because 60 percent of the nutrients entering the bay enter through the Providence River … This little portion of the bay is receiving an enormous amount of nutrients, translating it into primary production and pumping it down into the bay."

Even though the state has achieved a 55 percent reduction in nitrogen from wastewater treatment facilities, nitrogen levels are still three times higher than they have been historically, said Candace Oviatt, a professor at GSO specializing in biological oceanography. On top of that, water temperatures in the bay have risen nearly 2°C (3.6°F).

Eelgrass is "a cold-loving plant," Granger said, explaining that it migrated from the Arctic thousands of years ago to populate U.S. coastal waters as far south as North Carolina in the East and the Gulf of California in the West, where average summer temperatures reach 85°F. But, as a result of increasing nutrient inputs, the long continuous ribbon of eelgrass that once extended along the East and West coasts broke apart.

"The geographic distance between beds became so great that they can't exchange pollen between beds and …. They become genetically isolated in that particular area"—preventing the exchange of genetic material that might help plants in Narragansett Bay, for instance, adapt to conditions such as warming waters.

During experiments to better understand the relationship between nutrients and temperature on eelgrass, Granger found that colder temperatures could help offset some of the effects from increased nutrients, but once temperature was also increased it was all over.

"The combination of rising temperatures and nutrients is just lethal," he said. "It stresses the plant and stops it from producing new leaves, which get long and heavily fouled and die."

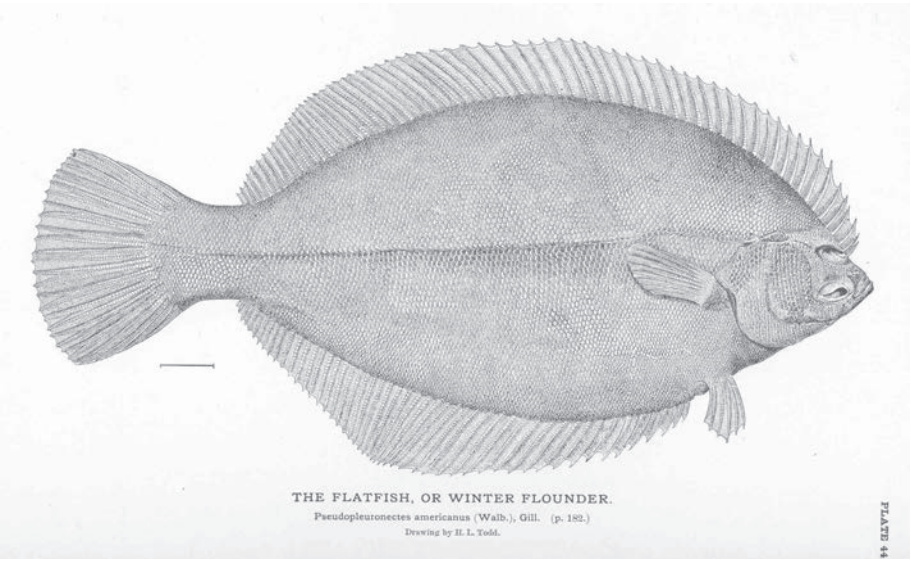
Despite this general downward trend for eelgrass beds in both the bay and the coastal ponds, there is some hopeful news. New eelgrass beds have formed in East Greenwich and in the Narrow River. Charlestown Pond is also looking good, said Granger, as shoots that were transplanted there have all taken to their new home. The future, however, is a warmer one that is compelling researchers like Granger to look at alternatives.

"Southern populations are more heat tolerant and developed that ability over time," he said. "Looking for genetically disposed plants that are better suited to heat, I think, is the future."

SHIFTING SPECIES

Ecological Changes in Narragansett Bay

By **Meredith Haas**



Decreasting numbers of winter flounder in Narragansett Bay are partly the result of warming waters, says oceanographer Jeremy Collie.

PHOTO COURTESY OF WIKIMEDIA COMMONS

Narragansett Bay today is not what it once was 100—or even 10—years ago. Coastal development and growing populations over time have meant changes to the bay's geography and a greater influx of nutrients, such as nitrogen, as well as hormone disruptors and other persistent organic pollutants. These human influences interplay with a host of complex natural systems, including climate, all of which are continuously changing the bay's ecology in unknown and unpredictable ways.

Over 50 percent of Rhode Island's salt marshes have disappeared, and the once vast green carpets of eelgrass are limited to remnant populations in lower Narragansett Bay due to the impacts of landfilling and dredging, stormwater runoff, wastewater discharge, and climate warming since the Industrial Revolution in the late 1800s. Nutrient reduction efforts are triggering further changes in the bay, and will continue to do so.

"As the Industrial Revolution progressed, benthic invertebrate biodiversity declined until the 1980s, then appeared to partially recover in the 1990s and following decades, but not up to the same level," said Stephen Hale, an ecologist at the Environmental Protection Agency (EPA), discussing changes in the benthic, or bottom-dwelling, communities of Narragansett Bay. The reason for the slight rebound, which needs more years of data to verify, he said, is still not fully known but is believed to be, in part, a result of reduced stressors entering the bay, such as nitrogen and metal inputs, thanks to legislation in the 1970s, including the Clean Water Act.

A Shift in the Benthos

Although the overall benthic diversity of the bay has declined, it is still relatively high, said Hale.

"The bay has a high benthic biodiversity because we have warm-temperate species from the south as well as cooler water species from the north. And since we have a deep East Passage, we also have species more common to the continental shelf. The bay also has rocky shores near the mouth that are not as common in other estuaries along the southern New England coast," he said, noting that about 21 phyla of invertebrates—mostly worms, crustaceans, and mollusks—have been found in Narragansett Bay. "That's about 60 percent of all the animal phyla on the planet."

About 1,214 species have been recorded with hundreds expected to still be unknown. The majority

Polychaete worms, top, are affected by low oxygen conditions, and American lobster, left, are affected by warming bay temperatures.

PHOTOS COURTESY OF NOAA

of these species live in the top 10 centimeters of the bay's sediment and support recreational and commercial fisheries, filter excess pollutants and nutrients from the water, store carbon, and help stabilize sediment against erosion. While one of the EPA's sample sites at the north end of Jamestown showed no real change in biodiversity since the 1990s, there was a decline near Spar Island in Mount Hope Bay—an area more vulnerable to human activity and impacted by wastewater discharge from the Taunton River and Brayton Point power plant. As a result, the biodiversity dropped there, leaving behind those species more tolerant of pollution.

Hypoxia (low oygen) resulting from excess organic material from algal blooms and increasing rainfall, which stratifies the water column and isolates the bottom water from re-aeration, is more common at these locations and is a primary reason for such a response. As oxygen was depleted from the sediments, there was a loss of deep, long-lived polychaete (marine worm) species.

"The prediction is that species will come back when you remove the low oxygen and high organic carbon conditions," said Hale, adding that while some stressors have declined recently (nitrogen from wastewater treatment facilities has been reduced) metal and toxin contamination of sediments lingers

from past industrial discharges, and new challenges have arisen in the form of invasive species and rising water temperatures.

"Temperature has a direct effect on the benthos. We're losing cold water species to the north and gaining warm water species from the south," he added.

One glaring knowledge gap, however, in understanding the change of the bay's benthic communities—how they will respond to future changes in climate and nutrient reductions, and what that implies for the rest of the ecosystem—is their biomass and secondary production.

"Other than the large animals that live on the sediment surface like crabs, we don't have the biomass data to calculate secondary production from benthic communities," said Hale, explaining that such production provides necessary food for shellfish and bottom fish. "We know almost nothing about this. It's hardly been measured."

Another knowledge gap concerns the loss of cancer crabs and lobsters in Narragansett Bay.

"We had a very dramatic decrease in the decapods; the cancer crabs, the lobsters; that started in the nineties," said Candace Oviatt, a professor at the University of Rhode Island's Graduate School of Oceanography (GSO) specializing in biological oceanography. "Decapods have basically left the bay and why that has happened, I think, is a huge research question. Some think it's temperature, others think it could also be predation."

A Shift in Fish

After noticing the decline in decapods, Oviatt and her team looked at fish biomass data in Narragansett Bay from DEM's trawl surveys after 2009 and found various responses to fish abundance.

"In many areas, the upper bay for example, at Ohio Ledge, it looked like fish have increased," she said. "In other areas like Hope Island, it doesn't look like they've changed at all, and in the lower bay there appears to be a slight decrease, about 10 percent. And it's in the lower bay where the nutrients haven't changed that much."

The more noticeable changes appear to be reflected in the species type as iconic cold-water species are vacating the bay and warm-water species are moving in.

"When you look at how the fish community has changed, it's basically shifted from resident species to summer visitors," said Jeremy Collie, a researcher at GSO specializing in fish population and dynamics. "From a conservation perspective, we should be concerned about the resident species because they've evolved here. From a productivity and a fisheries perspective, we also need to think about what the summer migrants are doing."

These migrants include black sea bass, scup, squid, summer flounder and butterfish. Those on the losing end of warming waters include silver hake, tautog, and winter flounder. Even though there is a lot of interannual variability with stocks rising and falling in any given year, there are very few species, said Collie, that aren't being impacted. The trend lines between increasing temperatures and increasing warm water species shows that the fish are responding to temperature.

"The preferred temperature of the fish community has increased to keep pace with water temperature," said Collie, adding that the total consumer biomass is increasingly concentrated in the summer months and declining in the winter. The timing of the migrations, he added, is shifting even more than temperature change would suggest. For example, summer flounder, a summer migrant, arrives earlier and stays later, occupying cooler temperatures than they did previously. It appears that the summer migrants may be moving into the bay earlier to take advantage of the prey species no longer being consumed by the decapods that have vacated the bay, Oviatt commented after the symposium.

Temperature can also have indirect effects on the bay's ecology. Warmer winters mean more cloudy days and less light to activate the winter-spring algal bloom, which ideally lasts for several weeks, raining down organic matter and feeding the benthos that support demersal (bottom-feeding) fish like winter flounder. In addition to changes in algal productivity levels, warmer temperatures mean zooplankton and other species that feed on phytoplankton are active and eating away the bloom.

"Without the strong winter-spring bloom, we have less production sinking to the bottom and feeding [demersal fish species]," said Collie. "We're seeing a shift from a benthic-dominated community to a pelagic-dominated community. It's a working hypothesis about how the changes in temperature are amplified in the food web."

But there isn't just one explanation. It's not all temperature, excess nutrients, or predators. It's a combination of all these factors.

"I think a lot of us are looking for a single explanation when there's multiple explanations," noted Collie, who is currently working on a Sea Grant-funded project to look at where winter flounder are vulnerable in their life cycle to better understand why this species has left Narragansett Bay. "Preliminary results suggest that the first and second winter of their life are a survival bottleneck. That should help identify the agents, causes, of mortality. It's likely to be more than one," Collie said.

CLIMATE CHANGE OR CLEAN WATER

What's to Blame for Decreased Productivity in Narragansett Bay?

By **Monica Allard Cox**

John King, professor of oceanography, University of Rhode Island

PHOTO COURTESY OF URI

In the talks at the 2017 Ronald C. Baird Sea Grant Science Symposium, two causes vied for recognition as the primary driver of changes to sea life—reductions in effluent discharges from wastewater treatment plants and climate change.

John King, University of Rhode Island geological oceanographer and climate change expert, was tasked with answering "How much of this change is climate change?"

"I was instructed that I was supposed to be 'hopeful' in my approach to this," King said early on in his remarks, "As many of you know, when I give talks on this, usually people leave the talks feeling like they've lived at Chernobyl for a number of years after it blew up."

While the line got a laugh, King went on to show a range of climate scenarios based on whether emissions remain at present levels, are curtailed, or increase, as indicated on his slide in gray.

"Here's me being hopeful," he said, "I hope like [heck] we don't end up in the gray area, because if we do, we're … just rearranging some deck chairs here today. If we end up in that area, it's ALL about climate change," which, he said, would "obliterate other signals."

Right now, he said, climate change and nutrient inputs "are both pretty important."

Other speakers pointed out that warming waters in recent years have contributed to increasing numbers of demersal species in the water column that eat phytoplankton from the winter-spring phytoplankton bloom before those nutrients have a chance to fall to the seafloor and feed bottom-dwelling species. King said that in sediment core samples taken from the Narrow River, the presence and abundance of certain bacteria demonstrate that warming waters do foster more growth than cooler waters. Slices of those sediment cores from, for instance, the Medieval Warm P eriod, showed more primary productivity than those from the subsequent Little Ice Age that spanned the early 14th century to the mid-19th century.

And, King said, "When you have a warm climate and a little bit of fertilizer added to the system, that's when the productivity seems to take off the most."

He warned, however, against viewing climate change temperature increases as having linear effects—thinking, for instance, that if two degrees of warming has one impact, that four degrees of warming will simply have twice that impact.

"There are thresholds in the climate system," he said, "and if you exceed the thresholds, big changes can happen with relatively small changes [in temperature]."

He pointed out that nutrient reductions would not have a linear effect either, as nutrients already present in the seafloor do cycle back into the system, so the impacts of further reducing effluent inputs to the bay would not be immediately obvious.

Sediment cores, however, serve as a predictive tool as well as provide historic insight—continuing to monitor them as temperature and nutrient conditions change, and comparing those changes to known circumstances going back hundreds of years, can help scientists and resources managers predict ecological changes in the bay.

As for making management decisions based on these data, he said, there is no straightforward answer. While environmentalists might seek to return to a more "pristine" system, those conditions might be "less desirable to fishermen." Still to be determined, he said, is "What do we want the bay to be?"

TESTING THE FUTURE

Monitoring, Experiments, and Modeling Key to Predicting Changes in Narragansett Bay

By **Monica Allard Cox**

Robinson "Wally" Fulweiler, associate professor of biology, Boston University

PHOTO COURTESY OF URI

Returning to an Eden of pristine water and optimal fish production is not a realistic expectation for what can be achieved in Narragansett Bay, warned Wally Fulweiler, associate professor of biology at Boston University, at the 2017 Ronald C. Baird Sea Grant Science Symposium.

Fulweiler, who has been studying nutrients and seafloor sediment in the bay for over a decade, was, however, optimistic about what researchers and stakeholders could learn about bay processes to make the best decisions possible.

"I think we have a chance to be one of the first estuaries in the nation to … work together to quantify the impacts of climate change and decreased nutrient loading, two major human interventions," she said in her second talk during the symposium.

Like John King, University of Rhode Island oceanographer, said in an earlier talk, Fulweiler stated that as nutrients from wastewater discharges decrease, the seafloor, or benthos, would be increasingly important as a source of nutrients that would feed both benthic species and be cycled into the water column to serve as food there. This happens in a process known as nitrogen fixation, in which bacteria—in this case in the benthos—metabolize nitrogen gas, deposited from the atmosphere or elsewhere, into biologically usable forms, such as ammonium. In addition, she said, nutrient-rich deep water comes into the bay from Rhode Island Sound; determining which source is more important will require study.

She also emphasized the value of continuing the long-standing monitoring of bay conditions. "Without this we could not have this workshop today to talk about changes or predict what's going to happen in the future," she said.

Fulweiler called for a return to the use of mesocosms, tanks at the URI Graduate School of Oceanography that were used to replicate bay ecosystems and determine how they would respond to varying conditions. With these mesocosms, she said, scientists could begin to "test the future"—for instance, to see "what happens when you add nutrients or change temperature."

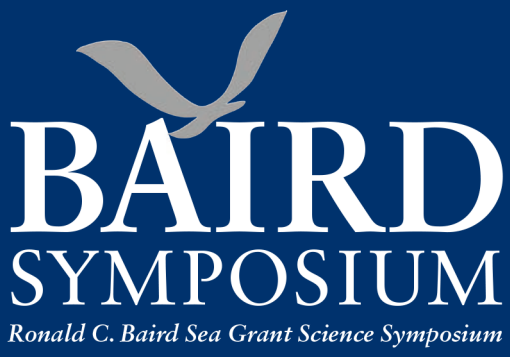
King later added his support for use of the tanks to help make decisions regarding future interventions. "You can't really start just messing with what the wastewater treatment plants are doing without understanding how the system works," he said. "You screw up something in the tank, you drain it and you try again. You trigger some sort of a threshold effect in the bay that is … unintended … that would really be significant."

Christopher Kincaid, URI professor of oceanography, commented that computer models can capture events that can't be replicated in the tanks. Fulweiler said that information from experiments in the tanks can feed into the models, and that the two "should work together" to provide a clearer picture of bay changes.

Fulweiler also emphasized the importance of the observations of the fishermen, aquaculturists, and others in the audience as providing crucial "eyes on the bay."

"You can provide information that we don't get," she said, "You have an intimate knowledge of the bay that we don't have.

As harmful algal blooms occur, new activities such as kelp farming emerge, and species changes take place in the bay, Fulweiler said, "citizen science" will become even more important to observing and understanding Narragansett Bay.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