Summer 2020

Maine EPSCoR Summer 2020 Newsletter

Maine EPSCoR

Aquaculture | Community | Action | Engagement | Economic Development

SUMMER 2020 NEWSLETTER

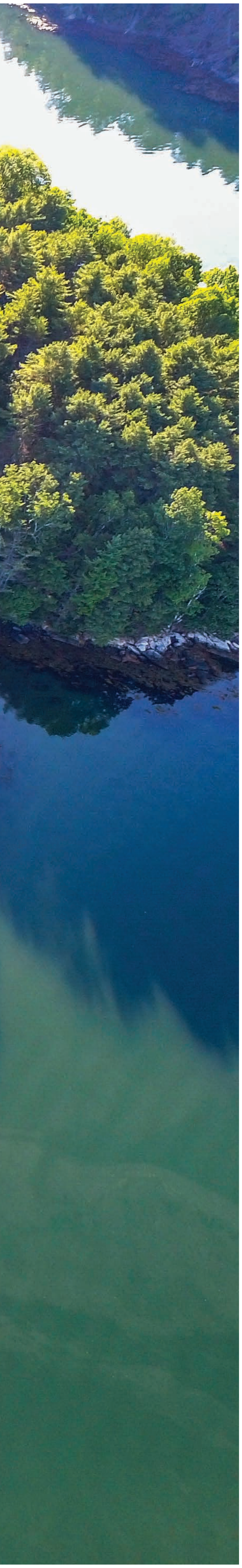
MAINE EPSCoR

Maine EPSCoR

An ‘Inspiring’ Future

Utilizing science and technology to solve some of Maine’s most complex issues

1865 THE UNIVERSITY OF MAINE



From Maine EPSCoR Leadership

NSF EPSCOR-FUNDED RESEARCH AND ACTIVITIES ACROSS THE STATE have proven themselves to be resilient and impactful amidst challenges associated with the COVID-19 pandemic and its subsequent restrictions.

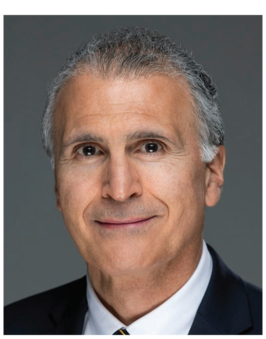
Since our last published update, Maine EPSCoR successfully completed the Year 5 No Cost Extension (NCE) report for the previous Track-1 award, the Sustainable Ecological Aquaculture Network (SEANET), thus closing out the research grant that has acted as a catalyst for cutting-edge sustainable aquaculture research in the state of Maine. During the NCE, SEANET supported 12 faculty participants, 23 graduate students, and 50 undergraduate students, created 27 publications, and saw $10,699,228 in awarded follow-on grant proposals.

Understanding the influence of climate change on the Gulf of Maine was an important focus for the work conducted during the No Cost Extension. Researchers examined the role of the Western Maine Coastal Current subduction under the Eastern Maine Coastal Current in creating an acidified zone at the mouths of estuaries along the state's mid-coast. Maine's marine resource economy depends on shell-forming organisms for over 90% of its revenue, so the identification of susceptible areas along the coast is an important first step in preparing for a more acidic Gulf of Maine.

SEANET personnel also investigated how oysters respond to stressors such as higher temperature and ocean acidification (OA). The results indicate that these animals are more susceptible to disease when exposed to higher rates of OA and higher water temperatures. Thanks to the identification of these types of emerging threats, researchers and farmers are working together to develop solutions that will help protect the livelihoods of many Mainers.

The Year 1 Annual Report for Maine EPSCoR's current Track-1 award, Molecule to Ecosystem: Environmental DNA as a Nexus of Coastal Ecosystem Sustainability for Maine (or Maine-eDNA) was approved by NSF on July 28th. The Maine-eDNA project completed important first steps in establishing protocols and baseline data in Year 1, and although COVID-19 has brought extensive challenges to conducting field research and in-person educational outreach in Summer 2020, the project has safely moved forward. Examples of the project's resilience include conducting essential virtual training sessions for researchers, and the recruitment of graduate student assistants. As of July 31st, 17 graduate students have joined the project, and field research and sample collection have commenced.

EPSCoR-supported faculty, students, and staff have exhibited perseverance through this year's challenges, and deserve our recognition. We are also thankful for those who have showcased their continued support and interest in our work. We hope this newsletter showcases our enthusiasm for the future, and provides you with a firsthand look at some of the most exciting research taking place in the beautiful state of Maine. Thank you.



KODY VARAHRAMYAN, PH.D.
Vice President for Research and Dean of the Graduate School

SHANE MOEYKENS, PH.D.
Director of Maine EPSCoR

MAINE EPSCoR

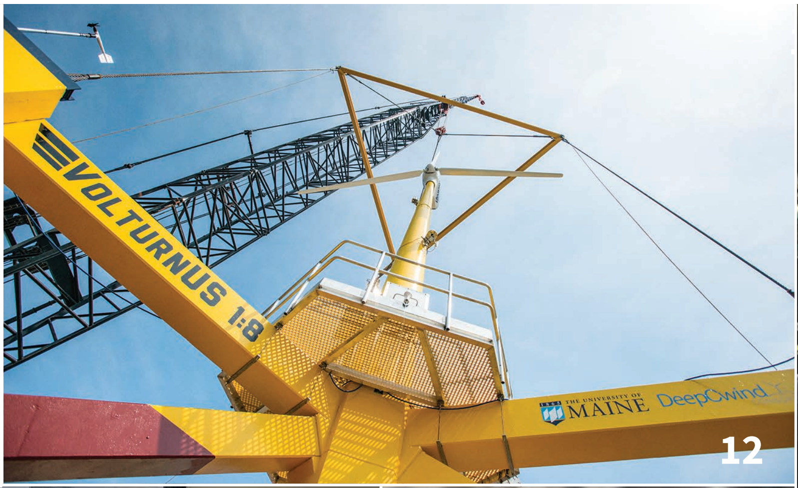
What is Maine EPSCoR?

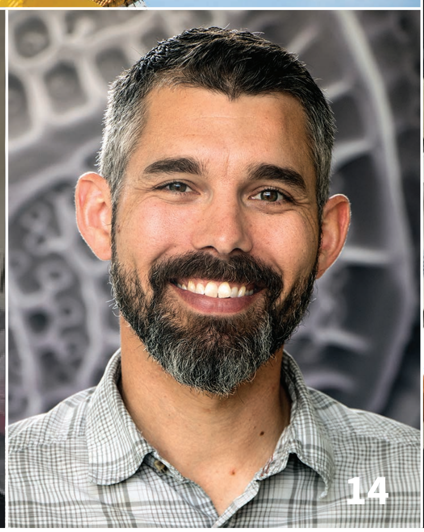
Maine EPSCoR (Established Program to Stimulate Competitive Research) at the University of Maine seeks to expand opportunities for more diverse faculty, staff and student populations. Diversity brings different perspectives and skill sets, and helps broaden our vision. We recognize that geographic and societal challenges exist that require pragmatic solutions with achievable and measurable goals. Maine EPSCoR strives to enhance diversity in all elements of EPSCoR programs while increasing participation of underrepresented minorities in science, technology, engineering and mathematics (STEM) disciplines.

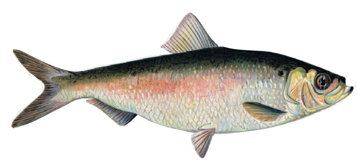
ON THE COVER:

Maine depends on its forests for cultural, environmental, and industrial purposes. The INSPIRES project (page 2) aims to help us better understand these forests, and how we can continue to treasure them for many generations to come.

Cover Photo by by Laurie Bragg





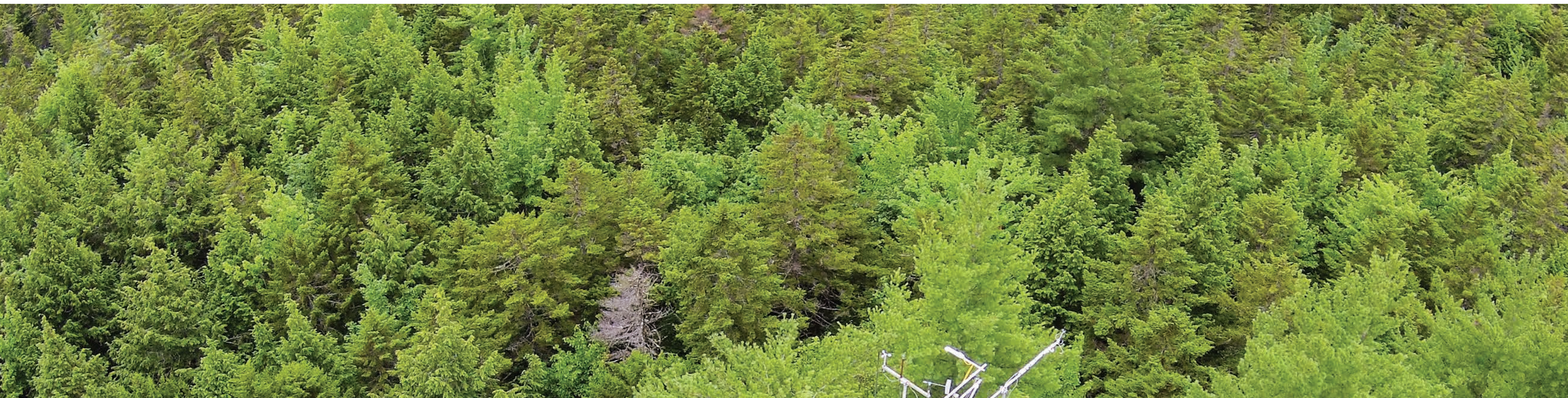


Contents

Maine's Acadian Forest:

The potential frontline of climate change in the age of vulnerability and big data

BY STEFANIA IRENE MARTHAKIS



IN THE NORTHERN REGION OF MAINE LIES THE SOUTHERN EXTENT OF BOREAL FORESTS, which are slower growing because of longer winters. Picture softwood or conifer trees (e.g., spruce, fir). As you head south, a more temperate climate is found with faster growing hardwoods like maple, oak, and birch. These two types of forests intersect in central Maine, where the University of Maine is located. In this transitional zone, Aaron Weiskittel, Professor of Forest Biometrics and Modeling and the Irving Chair of Forest Ecosystems Management at the University of Maine, heads the INSPIRES project, which officially began in August of 2019.

Leveraging Intelligent Informatics and Smart Data for Improved Understanding of Northern Forest Ecosystem Resiliency (INSPIRES) is possible through a four-year, $6 million (RII Track-2 FEC) grant from the National Science Foundation (NSF). Weiskittel, who is also the director of NSF's Center for Advanced Forestry Systems and UMaine's Center for Research on Sustainable Forests, is hoping to answer a critical question: "How do New England's diverse and working forests respond to emerging and novel future stressors like changing winters, invasive pests, and greater seasonal variability?"

Aaron Weiskittel, one of the Principal Investigators on the INSPIRES project, is also the Director of the Center for Advanced Forestry Systems and the Center for Research on Sustainable Forests at the University of Maine.

Working with nearly 28 million acres of forests across three states (Vermont, New Hampshire, and mostly Maine), Weiskittel and his team (Co-PIs: Kate Beard & Ali Abedi, UMaine; Scott Ollinger, UNH; and Anthony D'Amato, UVM) aim to develop comprehensive monitoring and harness the big data revolution. The INSPIRES project focuses on three areas: developing ecological sensors, working with K-12 educators (like those in highly forested rural Maine), and leveraging new technology, statistical methods, and computer science with an ever-changing and highly dynamic ecosystem like forests.

The forest is one of Maine's most important economic resources. The forest industry directly adds ~5% to the state's GDP; one of the highest contributions of any state in the U.S. With the addition of tourism and hunting, Maine quickly becomes one of the most forest-reliant states. In addition, many Mainers view the forest as a vital piece of their heritage. However, the forest, inherently dynamic and visible, poses many challenges for modern foresters.

Forestry, itself, is in a state of transition due to expanding global markets, changing workforce development, ongoing mill closures, past/pending pest outbreaks (e.g., spruce budworm), technological advancements, and a younger generation of foresters. Maine may be well positioned as the new generation becomes interested in the forest, green collar jobs, and an emerging carbon economy. Governor Janet Mills has proposed that the state of Maine will be carbon neutral by 2045. This positions Maine as a potential leader in this industry, sustaining the heritage of its citizens within a future circular economy reliant on the sustainable management of extensive, yet dynamic natural resources.

INSPIRES proposes to address these multi-dimensional challenges by balancing Maine's most important resources, landowners, workforce, and heritage on the frontlines of climate change. Researchers will use advanced technologies like wireless sensors and remote sensing to better monitor the forest, while researchers back in the lab develop new methods to handle this big data. In other words, the former provides the necessary data and the latter turns this data into readable information through interpretation and identifying key cycles that can help improve the ecological models used to forecast future conditions.

"Sensors are often hardwired to take data at regular and fixed intervals," said Weiskittel. "Can we develop smarter technology that learns from itself and tells the sensor when to collect data at ecologically important intervals?"

To help answer this question, Sonia Naderi, Ph.D. candidate, is leading a team of two undergraduate students in the Electrical and Computer Engineering department, Victoria Nicholas and Thayer Whitney, to build a low-cost and low-power sensor suite.

"These low-cost sensors enable large scale deployment, providing much needed data points in places that no data has been collected in the past," said Co-PI Ali Abedi.

The data collected by these sensors are then processed using artificial intelligence and machine learning methods developed by researcher Kenneth Bundy. With new areas of machine learning to explore, Bundy's objective is to find optimum operating patterns that make sure the wireless sensors scattered throughout the forest are measuring parameters such as soil moisture, pH, and carbon in a way that allows them to effectively communicate with one another, and efficiently send information to a base station that allows remote online access to the data.

"Machine learning methods developed in this project not only process data, but also provide us new data on quality of wireless communication channels helping the researchers to design a network that can last a long time in the forest without the need for daily change of batteries," said Abedi.

INSPIRES then goes a step further with ecological modeling, forecasting, and projecting a future forest under alternative scenarios. With so many different types of data, it is essential to come up with a common platform to understand key metrics. Weiskittel and his team have been working on these metrics within a broader vision akin to a real-time dashboard for the forest with a prototype version released in spring 2020: https://forestapp.acg.maine.edu/.

But what would a Digital Forest look like? Weiskittel describes his vision as an online interface (or "Digital Forest Big Data" framework) that anyone can log in to. This application would look and behave similarly to Google Earth, but the information would pertain specifically to Maine's forested regions, which take up

The forest is one of Maine's most important economic resources. The forest directly adds ~5% to the states GDP; one of the highest contributions of any state in the U.S.

Researchers are using advanced technologies like wireless sensors and remote sensing to better monitor the forest, while researchers back in the lab are developing new methods to handle this big data.

approximately 90% of the state's entire land area.

With Weiskittel and his team spending a lot of time looking at vulnerability, one of the uses of this future forest app would allow a landowner to zoom in on a specific location in order to monitor spruce budworm defoliation or vulnerability. Landowners and researchers could also monitor for Canadian lynx or carbon. Thanks to the application, new possibilities for identifying "hot spots" of vulnerability may arise. Through spatial and ground data, the landowner would also be able to see a forty-year history of Maine's forest, look at drivers, balance trade-offs, and address emerging trends.

The INSPIRES project also aims to extend its reach with an educational component. The goal is to develop better curriculum materials and course content for middle school and high school students that teach how to interpret graphs, take measurements, and build other skills such as quantitative reasoning.

Along with education comes sustainability and legacy. To continue the work of INSPIRES, a Complex Systems Research Consortium will be developed. Through this institute, the University of Maine, the University of New Hampshire, and the University of Vermont will exchange information, leverage prior knowledge, and create a common framework to apply to difficult issues, particularly for natural ecosystems.

The University of Maine has a long history of bringing various people from different fields of research together to face issues that are relevant to Maine and beyond. With Governor Mills' statement of carbon neutrality, INSPIRES plans to help achieve this goal by changing forest management and developing new relevant technology to help managers.

"That's what excites me—bringing people together to work on something that can help the entire state," Weiskittel said. "Moving this forward is critical, given the importance of our region's forests. It's particularly important that we do so with the goal of a low-carbon economy." ■

Expanding Research Capacity in the State of Maine

LIZ THERIAULT, MAINE EPSCOR STUDENT WRITER

Photo by Jennifer Smith-Mayo

MAINE EPSCOR'S NEWEST TRACK-1 GRANT, titled *Molecule to Ecosystem: Environmental DNA as a Nexus for Coastal Ecosystem Sustainability for Maine* (Maine-eDNA), is bringing environmental DNA research to the Pine Tree State, and positioning Maine as a national leader for understanding eDNA.

As a part of the program's funding, the University of Maine's new eDNA core facility (managed by Maine-eDNA participant Geneva York) received two new pieces of technology in the spring to advance eDNA research. The new machines specialize in analyzing larger than normal samples of water and identifying hundreds or even thousands of different species by sequencing their DNA. One of the machines, a Digital Droplet PCR, allows researchers to test for specific DNA strands and produce extremely accurate counts of a target species within a body of water.

"We are on target for substantial research expansion with the new equipment we purchased through the Maine-eDNA grant, as well as leveraging funds from the grant to increase expertise and capacity for eDNA research in the state of Maine," said York.

The core facility is key for eDNA research, but also provides a public service accessible to NGOs, conservation organizations, or even concerned citizens. Organizations send water samples to the lab, where the new technologies, combined with York's expertise, provide key understandings. York is currently working on 11 different collaborations with organizations around the state and across the nation.

For example, the Maine Department of Transportation (DOT) asked York and the core facility to use eDNA to identify key passages for Atlantic salmon, so they can make informed decisions about where they can build roads and culverts and avoid damaging migration routes of the salmon.

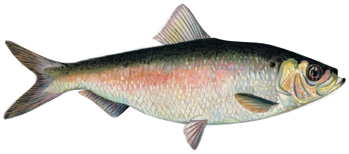
"We work with a lot of groups that are concerned with the conservation of rare species or the detection of invasive species," said York. "The eDNA techniques we utilize are not invasive, so we can detect animals without actually interfering with their normal activity and without damaging them."

The new eDNA core facility at UMaine positions the university and the state to become national leaders in eDNA technology. The collaborations that York has fostered in such a short period of time point to the rapidly expanding needs for eDNA services in conservation and development efforts.

"If we can become a leader in this technology, that will bring in a lot more research to the state and move a lot of conservation forward," said York. "We want to make [the eDNA technology] more accessible so that more people will understand its utility and trust its results." ■

Maine-eDNA:

Looking backward to move Maine forward



LIZ THERIAULT, MAINE EPSCOR STUDENT WRITER

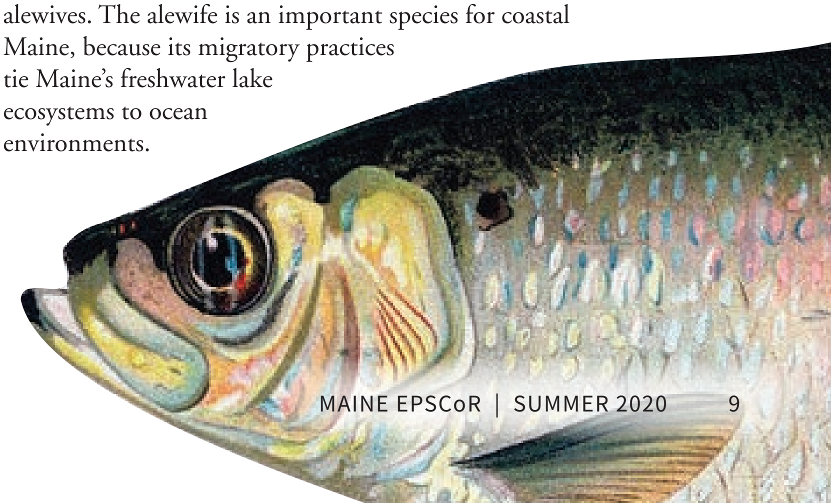
The alewife is a species of herring found in North America.

WHAT DO YOU SEE WHEN YOU PICTURE A TIME MACHINE? Maybe it's the car from the popular 1980s film *Back to the Future.* Or perhaps you picture a metal box decorated with flashing lights and mysterious levers. But for Michael Kinnison, he pictures environmental DNA (eDNA).

Kinnison is a co-PI on Maine EPSCoR's newest National Science Foundation Track-1 grant, *Molecule to Ecosystem: Environmental DNA as a Nexus for Coastal Ecosystem Sustainability for Maine* (Maine-eDNA). Beginning in 2018, Kinnison worked with Maine EPSCoR to develop, pitch, and secure the Maine-eDNA grant. After the grant was awarded, he spearheaded numerous projects using eDNA.

eDNA is the genetic material left behind by organisms in their natural environments. Depending on the organism's size, eDNA can be composed of an entire living organism, shed skin cells, gametes or waste products. For EPSCoR's Track-1 grant, eDNA is collected from water or sediment samples to learn more about Maine's aquatic species.

Kinnison uses this left-behind genetic material to look into the past of Maine's aquatic species; more specifically, alewives. The alewife is an important species for coastal Maine, because its migratory practices tie Maine's freshwater lake ecosystems to ocean environments.



"Alewives are migratory fish, who hatch from their eggs in freshwater lakes and then migrate to the ocean where they grow for a number of years, before coming back to the lakes to reproduce," explained Kinnison. "They bring nutrients and other materials from the ocean to help lake systems, and they become food for a lot of organisms when they go out to the ocean."

But this important link has been weakened. Historical practices of building dams on lake and river outlets have stopped the migrations of alewife and many other species, which has drastically changed the ecosystems of Maine's freshwater lakes. Currently, many of these dams are now being taken down around the state. And recent knowledge produced by environmentalists has stressed the importance of alewives, not only for ecosystems, but as an important resource for Maine's indigenous populations. This has sparked large restoration efforts by conservationists and citizen scientists.

Researchers are still primarily unsure of the location, population size, or environmental impact of alewives before the dams interrupted their migration process. Kinnison and his research hope to fix that.

"The question we are presented with is, when you restore something, are you really getting the same thing you had before you lost it?" asked Kinnson. "We can use eDNA to collect the DNA left by alewife that has collected in sediments, to know where they were and how many of them existed before Europeans colonized the area, put up dams and harvested."

This is where the time machine comes in. The eDNA nestled into the sediments lining the bottoms of lakes and oceans is composed of genetic material of species from hundreds and thousands of years ago. By collecting and analyzing this data, researchers like Kinnison are able to deduce species' locations, population density and migration patterns of aquatic creatures that haven't lived in that ecosystem for hundreds of years.

And the accessible information doesn't just stop at one species. By using the combined eDNA of multiple species, Kinnison is able to see the ways a species like alewife impacts an entire ecosystem.

"We can look at the food they ate, which is zooplankton, to see how they shaped the zooplankton communities, and those zooplankton eat algae, so we can look at how alewives can have effects all the way to the basic food web of microscopic diatoms," said Kinnison. "This is how we are trying to use eDNA as a time machine."

Being able to understand how, when, and where the alewife population existed in Maine's past ecosystems will strengthen future restoration and conservation efforts. One of Kinnison's end goals with Maine-eDNA is to aid in restoration efforts of alewives: "Part of the goal is to do a better job at where and how we reintroduce them into lakes, and also improve how we manage or work with them in marine environments," said Kinnison.

But at this beginning stage of Maine-eDNA, Kinnison has other goals in mind for the project as well.

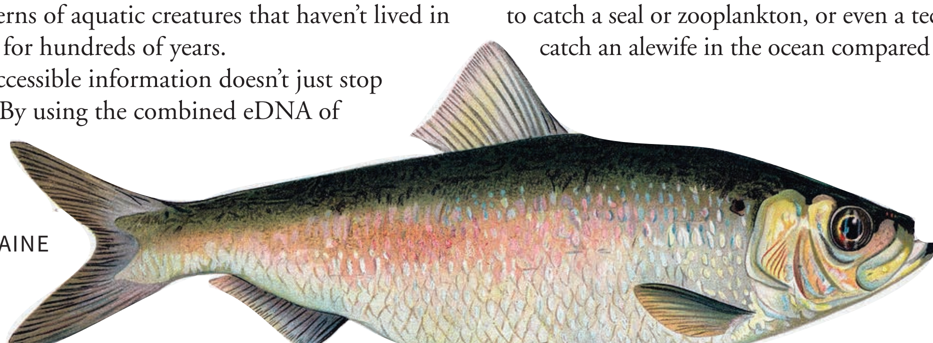
"What we are trying to do is build a capacity, an ability, a new tool or a way to use eDNA to bigger ecological questions," said Kinnison.

If Kinnison's research is able to examine alewives and improve restoration efforts, then his practices have potential to be applied to other organisms, like salmon, eel, lobster or other species that are important to Maine. This practice of considering multiple species and their interactions is often performed in assessing sustainable fisheries. But creating effective resource management decisions on entire ecosystems can be difficult and time consuming.

"To understand how we interact [with aquatic species] and how they respond to human effects in the environment takes a lot of data collection, a lot of people, a lot of time, and a lot of different equipment," said Kinnison. "And it's all made more challenging by the fact that techniques people use to catch an alewife are different than the techniques used to catch a seal or zooplankton, or even a technique used to catch an alewife in the ocean compared to a lake or river."

"The question we are presented with is, when you restore something, are you really getting the same thing you had before you lost it?"

—Michael Kinnison



A variety of finfish and shellfish species are important to Maine's economy. The questions Kinnison and his team are trying to answer using eDNA are important to help make the fisheries more robust.

Different techniques for data collection make it almost impossible for researchers to compare data sets with current tools. But through eDNA, researchers are able to consistently collect comparable data across all types of organisms—because all organisms are composed of DNA.

"One of the real problems with natural resource management and even in ecology as a field is we often have to reduce things down to a small scale, like a single pond or lake studied intensively, or even just experiments in a lab, because that is the scale where we can manipulate, study things and get enough data to ask a question," said Kinnison. "But we always know in the back of our minds that one lake isn't the same as all lakes. But eDNA allows us to get samples relatively easily through water collection, and we can start to ask real questions that link lakes to other lakes, the ocean, or the whole coast. It's scaling up to ask questions that we couldn't do before."

New eDNA research also has practical benefits beyond improving research capacity. Maine's economy is heavily reliant on coastal and natural resources. And changes to Maine's fisheries, drinking water, coastlines and other areas impact the livelihoods of Mainers. Using eDNA helps researchers expand and deepen the understanding of these changes, which creates better resource management practices and protects Maine's way of life.

But the potential to expand Maine's economy beyond natural resources does exist. One of Maine EPSCoR's primary goals is expanding workforce development within the state by funding training, education and technology development.

"More types of technology can help expand the job options for people in the state and the types of businesses that can be here. But moving a state from mostly natural resources to technology means a lot of training," explained Kinnison. "And the trick is making that training accessible without disrupting the current system while building a future for Maine. I like to think of eDNA as a bridge that brings high-tech genetic tools and capabilities to our natural resource economy while building a workforce skill set that can be adapted to other types of biotechnology, new business, and innovations."

Moving forward, the new Maine-eDNA grant will ensure that Maine's capacity for new technologies expands, while training its workforce for new economic opportunities. The grant will open the doors to new collaborations between researches and with large partners, such as the Darling Marine Center and the National Ocean and Atmospheric Administration. In the coming years, Kinnison and other Maine-eDNA researchers will use eDNA as a time machine to look backwards, and to make sure Maine's future is sustainable and efficient. ■

Faculty Spotlight:

Andrew Goupee

LIZ THERIAULT, MAINE EPSCOR STUDENT WRITER

Assistant Professor of Mechanical Engineering

Ph.D., Mechanical Engineering, University of Maine, 2010

M.S., Mechanical Engineering, University of Maine, 2005

B.S., Mechanical Engineering, University of Maine, 2003

Dr. Andrew Goupee came to the University of Maine for his undergraduate career in the fall of 1999, and due to the various academic and professional opportunities UMaine presented, remained to complete the entirety of his academic career. Currently, Dr. Goupee teaches Strength of Materials; Dynamics; Mechanical Vibrations; Wind Energy Engineering; and Capstone Design in UMaine's Mechanical Engineering department.

Dr. Goupee's research aims to develop a more resilient and effective control strategy for offshore wind turbines that would enable higher energy captures and reduce fatigue loads. In the fall of 2018, Dr. Goupee was awarded an RII Track-4 award, which provides opportunities for non-tenured investigators to further develop their individual research potential through extended collaborative visits to the nation's premier private, governmental, or academic research centers. In the summer of 2019, Dr. Goupee traveled with his graduate student, Eban Lenfest, to the National Wind and Technology Center in Boulder, Colorado. There, Dr. Goupee and Lenfest collaborated with experts in wind turbine technology to expand their knowledge and secure additional awards from the U.S. Department of Energy, NASA, and the Advanced Research Projects Agency-Energy (APRA-E), totaling over $1.5 million in external funding to progress his research through these new grants.

Andrew Goupee (right) and his graduate student researcher, Eben Lenfest, (left) pictured outside the National Renewable Energy Laboratory's (NREL) National Wind Technology Center (NWTC) in Boulder, Colorado.

EVERYONE KNOWS THE WORLD IS POWERED THROUGH ENERGY. Around the globe, different energy sources are harvested to power everything from kitchen appliances to skyscrapers. But as the world moves forward, the need for cleaner energy capture is pressing, and inspiring innovative energy capture solutions. Dr. Andrew Goupee, assistant professor of Mechanical Engineering at the University of Maine, is contributing to that innovative energy capture through his research with offshore wind turbines.

Wind energy is one of the fastest-growing technical industries in the United States. Across the nation, wind turbines are being installed to harness natural resources and create clean energy. But researchers like Goupee are working to expand those capacities even more, by turning to a mostly untapped source of wind.

Offshore wind turbines currently exist in mostly shallow areas of water where traditional fixed-bottom technologies can be employed. But for the state of Maine, coastal waters are often too deep for conventional technologies. Offshore wind is Maine's largest untapped natural energy source, with more than 156 gigawatts of potential energy. To ensure that Maine does not miss out on capturing this powerful natural resource, Goupee is assisting in the development of floating offshore wind turbines. This new practice would allow for even higher levels of energy capture; however, it also presents new challenges in terms of unpredictable motion instabilities that could potentially harm the turbine.

To combat this, Goupee's research focuses on developing a new control strategy to increase the resiliency and effectiveness of floating offshore wind turbines. Beyond his work as an Assistant Professor of Mechanical Engineering, Goupee is also a Cooperating Faculty member at the University of Maine's Advanced Structures and Composites Center (ASCC), where he has worked for 10 years. At the ASCC, Goupee has been an integral part in the center's VolturnUS project, which resulted in patented floating concrete hull technologies that support wind turbines in water depths of 150 feet or more. This new technology has the potential to drastically reduce the cost of offshore wind, and incentivize investments in Maine's natural resources.

Floating offshore wind turbines are in need of precise control systems to ensure high-energy capture and reduce fatigue loads. Other floating technologies that do not require sophisticated control systems are often significantly more expensive, as they require an abundance of anchoring systems.

"Semi-submersible systems like VulternUS are the ones that are commercially going to be viable," explained Goupee. "And if we want offshore wind to grow, we need to take advantage of every technological trick that is available, to create a control system that keeps energy capture high in these windy environments, and more or less makes these devices more profitable."

To help his research, Goupee applied for an RII Track-4 Grant through Maine EPSCoR that provided funding to send to send Goupee and his graduate assistant researcher, Eben Lenfest, to the National Wind and Technology Center (NWTC) in Boulder, Colorado. There, Goupee and Lenfest collaborated with experts to advance their research. Goupee also was able to secure external grants through the Advanced Research Projects Agency-Energy (APRA-E), totalling $1.5 million.

Moving forward, Goupee expects the knowledge and tools he acquired at NWTC to extend through all his future work. ■

Faculty Spotlight: Doug Rasher

LIZ THERIAULT, MAINE EPSCOR STUDENT WRITER

Senior Research Scientist, Bigelow Laboratory for Ocean Sciences

Ph.D., Biology, Georgia Institute of Technology, 2012

B.S., Zoology, Michigan State University, 2005

With the new EPSCoR RII Track-1 Grant, *Molecule to Ecosystem: Environmental DNA as a Nexus of Convergent Research for Maine's Coastal Ecosystems (Maine-eDNA),* comes new faculty members and principle investigators to lead interdisciplinary groups of researchers. For Maine-eDNA, Dr. Doug Rasher has taken on the role of Project Lead for a research goal: Species on the Move: Patterns and Determinants of Range Shifts, where he and his team are investigating the ways in which Maine's coastal kelp forests are changing in the face of climate change.

The Gulf of Maine (GoM) is one of the most rapidly warming bodies of water on Earth. That means that the species living in those waters are being affected by this changing environment.

"We are losing some of the species that have historically been here, and we are gaining new species that traditionally were not found here. As the region becomes warmer and more hospitable to warm-water species, they are moving into the region," said Rasher. "We want to understand how this reshuffling of species is reshaping our coastal ecosystem."

The GoM is also unique to Rasher's research, as it contains some of the southernmost Atlantic kelp forests, which span from Rhode Island to Baffin Island, Canada. Rasher uses eDNA to investigate how warming water and invading species will affect these kelp forests. Unlike more traditional investigation methods such as scuba-diving surveys, eDNA does not rely on sight detection of an animal or plant. Instead, eDNA is able to detect the arrival or presence of a species through its genetic signature in the water, even when there's a very low abundance.

"Environmental DNA as a tool will allow us to see these species shifts as they are unfolding, rather than only noticing them after they've happened," explained Rasher. "This will allow us to make observations and conduct experiments that tell us why and how [the changing environment] is altering the ecology of the system."

The use of eDNA technologies is also aiding Rasher and his team in developing forecasting models that can predict shifts in the distribution of fish and algae before they even happen. An "early warning" system such as that would be extremely advantageous for regulatory agencies, as well as aquaculture and wild-capture fishery industries, who could then make decisions about how they are going to embrace or mitigate any impending changes.

As Rasher moves forward in the grant's five-year life span, he is optimistic and excited to work with such an interdisciplinary team. Rasher's team includes ecologists who collect observations and eDNA samples through scuba diving, molecular biologists who are developing the tools needed to answer the team's questions, and oceanographers and computational biologists who are developing models to understand how changing temperatures and currents might impact the arrival of new species.

"This project is very interdisciplinary, which is what is really exciting about Maine-eDNA. It brings together a really diverse group of people to ask pressing questions," said Rasher. "Generally speaking, interesting questions in science tend not to fall neatly within a single discipline; they tend to span the boundaries between disciplines. So you need scientific collaboration to answer those questions."

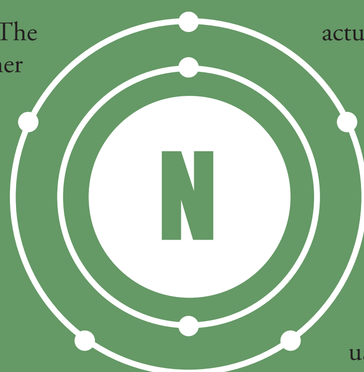
Rasher also uses those collaborations in the classroom. He is teaching classes at Colby College, including "Seafood Forensics: Uncovering Fraud in Ocean Food Systems," and "Coral Reef Ecosystems." His class "Coral Reef Ecosystems" is co-taught with Ben Neal of Colby College and Nichole Price, another Bigelow Laboratory researcher and senior personnel on Maine-eDNA. Students go to Bermuda during their winter break to gain hands-on experience collecting field data and conducting laboratory research. His other class, "Seafood Forensics," teaches students about the unfortunate and common practice of mislabeling seafood.

One of the only ways to identify mislabeled seafood is DNA forensics (in other words, DNA metabarcoding of fish tissue samples), which is the same molecular approach used in many projects within Maine-eDNA. One of Rasher's frequent guest speakers in his class is Peter Countway, a molecular biologist at Bigelow Laboratory and Co-Lead of Theme 2. Countway provides the class with an in-person demonstration of how eDNA tests can be used to correctly identify the fish sample in question.

Moving forward in the near-term, Rasher is kick-starting his field work this summer, along with continuing to develop specialized eDNAtools that will allow him and his team to detect kelp forest organisms—from kelp to large fishes—with just a small water sample. ■

How One Maine-eDNA Graduate Student is Using eDNA to Better Understand the Nitrogen Cycle

LIZ THERIAULT, MAINE EPSCOR STUDENT WRITER



WHAT MAKES UP THE AIR WE BREATHE? The first answer that comes to mind may be, rather obviously, oxygen. Yet oxygen isn't the only molecule surrounding us in our atmosphere, and it isn't even the most abundant. In fact, air is made of 78% nitrogen. For researchers like Rachel Presley at the University of Maine Darling Marine Center, this makes nitrogen an incredible research topic.

Presley came to UMaine to pursue a Ph.D. in Oceanography after obtaining her undergraduate degree in freshwater sciences from the University of Texas at Austin and her master's degree in biology at the University of Florida. She received funding from Maine EPSCoR's previous Track-1 award, the Sustainable Ecological Aquaculture Network (SEANET) to do research on the nitrogen cycle, and is going to conduct additional research as part of Maine EPSCoR's current Track-1, Maine-eDNA, with her advisor, Dr. Jeremy Rich, an assistant professor in UMaine's School of Marine Sciences. Throughout her academic career, Presley has always been fascinated by the nitrogen cycle and its impacts on marine life.

"Nitrogen is a really important element; it is in almost every living thing," explained Presley. "DNA, protein, things like that all have nitrogen in them. It's a really important element for life in general, but what's really cool about it is that you have all these different chemical forms of nitrogen, such as ammonium, or organic molecules."

These different nitrogen forms are created from different nitrogen compounds, which occur when one nitrogen molecule combines with a molecule of the same or different element. The change from one compound to another is actually caused by microbes and bacteria.

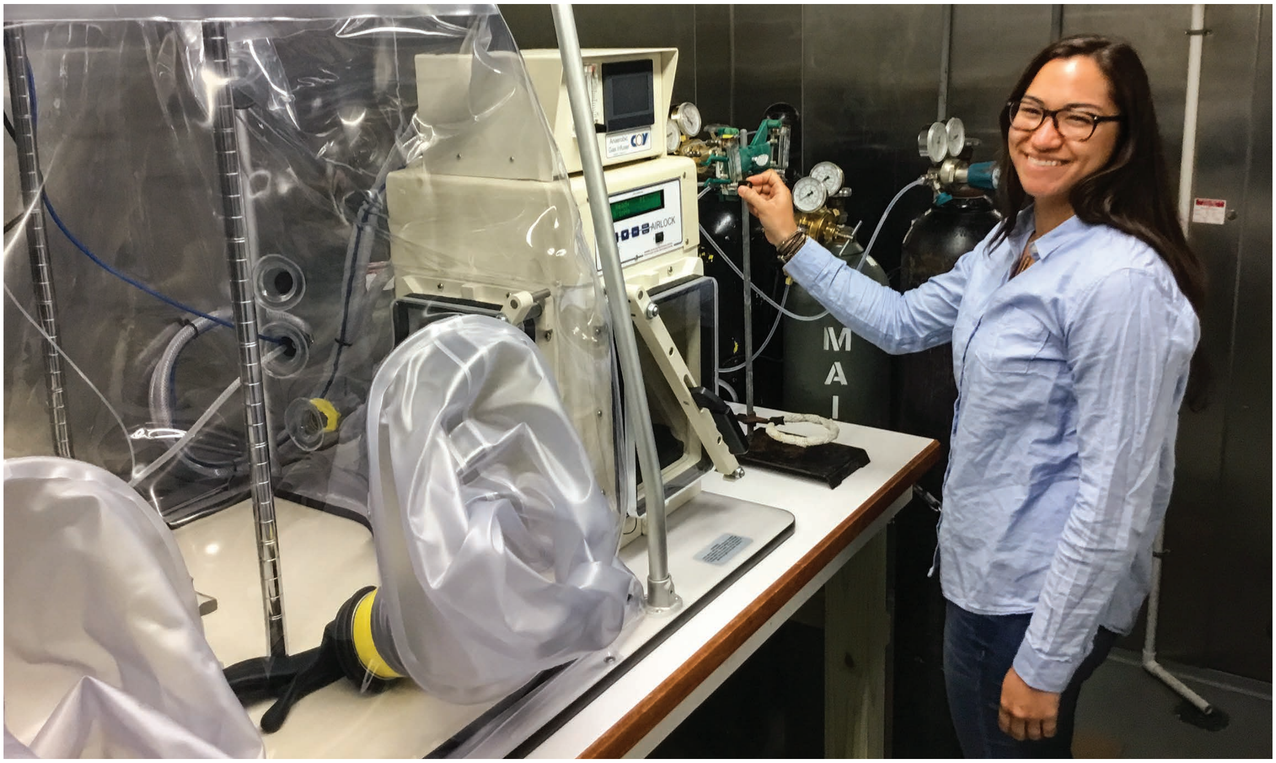
These bacteria and microbes are different in every living organism. And different microbes mean different nitrogen compound changes.

"There are organisms that can retain nitrogen in an ecosystem, but there are also organisms that result in a nitrogen loss," said Presley. "There are forms of nitrogen that organisms cannot use. Like the nitrogen available in the air you're breathing right now. You're breathing it in, but you're not able to take it in as a source of nitrogen for your body."

The nitrogen we breathe but cannot use is a form of unavailable nitrogen. Presley explained that this form of nitrogen is able to pass through organisms without undergoing a change, and is redistributed back into the ecosystem. But what about the compounds of nitrogen that are transformable?

"Whenever an organism converts a bioavailable form, such as nitrate, and transforms it into what we call an unavailable form like dinitrogen, that's essentially a loss," explained Presley. "They convert it into an unusable form that can't be used by any other organism in the ecosystem. On the other hand, if the organism transforms it into a different bioavailable form, such as ammonium, it can still be used by other organisms in the ecosystem."

This creates a competing process. Some organisms contain microbes or bacteria that transform nitrogen into another available form, while others turn the nitrogen into something unusable. Essentially, the microbes that transform nitrogen compounds could be



Presley hopes her research will help further the understanding of what factors lead to the dominance of one nitrogen transformation process over the other.

compared to humans' use of renewable or nonrenewable resources for powering our society; certain microbes produce renewable nitrogen sources, while others do not.

Much of Presley's research is work that has not been done before. For Presley, that means much of her time is spent prioritizing the gathering of baseline information that can be used by future researchers for comparisons. That means collecting information on the compositions of different bodies of water.

"The majority of what I do is looking at marine or lake sediments, and we often go diving to collect the cores ourselves, or we will send down cores that are deployable off of ships," said Presley.

From there, her research continues in the lab, where they place sediment samples in environmental chambers to simulate certain temperatures or sunlight exposure before adding stable isotopes that allow Presley and her team to track what is happening to a nitrogen atom as it goes through changes in the nitrogen cycle.

"If you want to think about it in terms of real-world application: Say you have a beach, and there's a big spill from a wastewater treatment plant nearby, that has dumped all these excess nutrients into the water," said Presley. "You want to be able to say that based on these factors, we know the nutrient loss pathway is going to dominate, which means that the bay will be able to heal itself by using the excess nitrogen once and then ridding itself of any excess nitrogen."

"On the other hand, if we knew that the bay was not going to recover on its own because the recycling pathway would dominate, and organisms would continue to cycle the same amount of nitrogen without expending the excess, we could use things like bioremediation, or other efforts to recover the ecosystem," she explained.

Presley hopes her research will help further the understanding of what factors lead to the dominance of one nitrogen transformation process over the other. Doing so will help researchers, industry members, and conservationists mitigate and combat potentially harmful additions to our water. This means healthier ecosystems and preserved bodies of water. ■

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Photo by Laurie Bragg

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