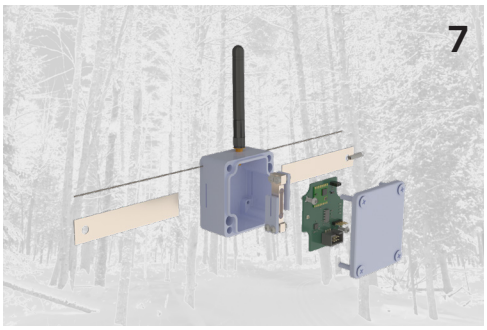
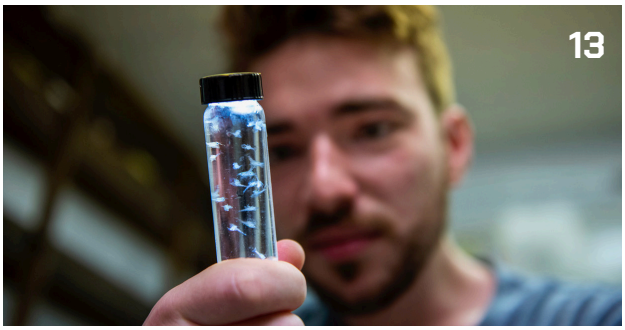

MAINE
EPSCoR
RESEARCH | EDUCATION | DEVELOPMENT





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What is Maine EPSCoR?

The Established Program to Stimulate Competitive Research (EPSCoR) was established by the National Science Board Resolution in 1978, and now encompasses EPSCoR programs at several other Federal agencies. EPSCoR is a program directed at states that have historically received lesser amounts of research and development (R&D) funding. Through this program, states develop partnerships between their higher education institutions, industry, government, and others to effect lasting improvements in their R&D infrastructure, capacity, and national competitiveness. Maine EPSCoR at the University of Maine oversees and implements the state's NSF EPSCoR programs.

EPSCoR funding opportunities are currently sponsored by the United States National Science Foundation, Department of Energy, National Aeronautics and Space Administration, United States Department of Agriculture and the Department of Defense.

Summary of programs

Maine is currently home to fourteen active EPSCoR projects. These projects represent nearly $27 million in funding from across the National Science Foundation (NSF), Department of Energy, and National Aeronautics and Space Administration.

Since the EPSCoR program's inception in 1980, Maine has engaged to advance EPSCoR's mission locally and build research capacity in the state. Maine was the first EPSCoR jurisdiction in the nation to earn two NSF EPSCoR Research Incubators for STEM Excellence (E-RISE) awards and a Collaborations for Optimizing Research Ecosystems (E-CORE) award, all part of the EPSCoR Research Infrastructure Improvement (RII) Program. This represents a $22 million investment in Maine over four years with an additional $17 million if the three awards are renewed. These programs connect Maine's leading institutions in research, education and development from across the state and unite them in the pursuit of improving Maine's research capacity and national competitiveness.

Maine's RII E-RISE and E-CORE programs collectively bring together 28 leading research, education, and economic development institutions from across Maine as formal partners.

Maine-FOREST

The $7 million RII E-RISE Maine-FOREST award, or Forest-based Opportunities for Resilient Economy, Sustainability and Technology, will expand the state's research and educational capacity to connect human and ecosystem focused innovations and services. Led by the University of Maine, the project takes an integrated thematic approach to fuel the state's forest-based economy and the rural communities it supports. Learn more at www.umaine.edu/maine-forest.

MARIA

Bigelow Laboratory for Ocean Sciences secured a $7 million E-RISE award for the Maine Algal Research Infrastructure and Accelerator (MARIA) project. MARIA will strengthen research infrastructure to serve as a nucleus of innovation potential for algae-based solutions in agriculture, aquaculture, energy, and pharmaceutical sectors. MARIA streamlines the process of exploring and harnessing algae's potential to help drive economic growth and workforce development in Maine's blue economy. Learn more at www.bigelow.org/services/maria.

Maine-SMART

The $8 million RII E-CORE Maine-SMART, a four-year initiative led by the University of Maine, is bolstering STEM research capacity and education and dismantle systemic barriers to innovation. Maine-SMART, or Strengthening Maine's Research Ecosystem and Pathways Through Strategic Capacity Building, will support more than 200 early career faculty and 2,500 undergraduate students at colleges across Maine, and an additional 120 educators and 9,000 K-12 students. Learn more at www.umaine.edu/maine-smart.

From Maine EPSCoR **Leadership**

Kody Varahramyan
Vice President for Research and Dean of the Graduate School

Shane Moeykens
Maine EPSCoR Director

As research projects in Maine conclude and new ones begin, the mission of federal EPSCoR programming remains our guiding star: building research capacity to strengthen Maine's communities, contribute to broader society, and advance the nation as a whole. With the launch of new initiatives—such as E-CORE RII and E-RISE RII from the U.S. National Science Foundation, Maine EPSCoR has embraced change and sought to determine how these opportunities can best be leveraged for local benefit.

In this issue, you will see how EPSCoR programming connects resources with researchers, educators, communities, and stakeholders. Federal EPSCoR funding enables scientists to ask big, consequential questions that shape our shared future, while also empowering educators to prepare the next generation of innovators who will strengthen Maine's workforce. This programming supports jobs, allowing Mainers to live and work in the communities they cherish. It sustains foresters who steward the vast forests once described by Henry David Thoreau and fishermen who continue to harvest the sweeping coastlines that inspired Winslow Homer. Together, these efforts build a stronger, more prosperous Maine and contribute to a brighter future for the nation and the world.

The stories highlighted in this issue represent only a glimpse of the many EPSCoR activities underway in Maine. We deeply appreciate the time, expertise, and energy that so many individuals contribute to these projects. It is with gratitude and enthusiasm that we share this newsletter with you, and we thank you for your continued support and interest in our work.

MAINE EPSCoR

Maine-SMART, nurturing a sustainable future and culture of innovation

An $8 million grant from the National Science Foundation is currently funding a four-year initiative led by the University of Maine to bolster STEM research capacity and education from Kittery to Fort Kent and dismantle systemic barriers to innovation.

Maine-SMART, or Strengthening Maine's Research Ecosystem and Pathways Through Strategic Capacity Building, will support more than 200 early career faculty and 2,500 undergraduate students at colleges across Maine, and an additional 120 educators and 9,000 K–12 students. The program seeks to foster collaboration between the state's leading voices and institutions through new K-12 and collegiate curricula, outreach, development and coordination efforts.

Maine faces a shortage of skilled workers in STEM sectors. The Maine Innovation Economy Action Plan notes that Maine's human capital in science, technology, engineering and math ranks 41 nationwide, down from 37 in 2018. Maine-SMART addresses the decline head-on by investing in educational STEM programming, including at key institutions in the state which are primarily focused on undergraduate programming.

Partner institutions for the initiative include the Maine Mathematics and Science Alliance (MMSA), the Gulf of Maine Research Institute (GMRI), the University of Maine at Fort Kent, the University of Southern Maine, and Southern Maine Community College (SMCC). The Maine Technology Institute is serving in an advisory capacity to the project.

"As part of Maine-SMART, MMSA will work to break down barriers to STEM education with and for our students and educators, especially underrepresented and underserved communities," said Ruth Kermish-Allen, executive director at MMSA and one of the lead investigators for the program. "By focusing on the assets and advantages these communities have related to STEM education content, instead of what is lacking, we uncover exciting opportunities for students to become involved in research on topics that matter to them and the people they care about, strengthening Maine's pathways into the STEM workforce."

Partnering teachers with researchers in Maine

Maine-SMART's Maine-BRIDGE program is matching middle and high school teachers in rural districts with STEM researchers to provide them with meaningful research experiences. Along with professional development retreats and other training opportunities, these teachers are equipped to better deliver the STEM education that their students deserve.

Maine has many rural communities, and STEM educators in the schools that serve them are often under equipped as they attempt to provide students with the STEM experiences that they deserve. Maine-BRIDGE provides research experiences catered to the interests of the teachers, and continued retreats and training help to integrate these experiences into lesson plans so the knowledge gained translates into the classroom. With new teachers entering the Maine-BRIDGE program each year, the program is helping establish a strong base of STEM education knowledge in the communities that need it most in Maine. This work will only continue to grow as more teachers and their classrooms engage with Maine-BRIDGE throughout the coming years.

Maine-SMART's workforce development objectives complement the project's economic development focus. Through strategic investments and support, the program helps Maine attract new federal research investments and sustain economic growth. Approaches include capitalizing on existing resources by nurturing broader understanding of Maine's existing but isolated or underutilized research assets. A more comprehensive approach to coordinating research across institutions will strengthen research and development capacity in Maine.

The new project also introduces new formal collaborations between the University of Maine System and the Maine Community College System, aiming to deepen the participation of community college students in research. Students at SMCC are kicking off this effort with hands-on experiential learning activities and workshops held in conjunction with institutional partners.

"The most exciting thing about this partnership for SMCC is the ability to not only put our students in the spaces where leading-edge technology is happening to build their skill sets, but that by being supported in these spaces, the students will build confidence in their capabilities and feel prepared for STEM career opportunities," said Erin Adams, a SMCC faculty member serving in the new program's executive leadership.

Another goal of Maine-SMART is to support strengthening statewide engagement with Wabanaki communities. In collaboration with the Wabanaki Youth in Science (WaYS) program, evidence-based initiatives are training faculty at colleges across the state in traditional science and methods that complement Western Science and will help generate new shared knowledge and collaborations. This program is open to all faculty at all academic institutions across the state, and thus far there has been strong demand to join this unique professional development program.

Developing new collaborations through Maine-SMART will provide opportunities to Mainers as the state develops its STEM workforce with a community-first approach.

"With Maine-SMART, we are establishing a geographically and institutionally diverse network, each part playing an important role in Maine's research and educational sectors," says Kody Varahramyan, UMaine's vice president of research and dean of the Graduate School. "Together we can streamline our efforts to provide more opportunities for Mainers by growing research and development in the state, by developing Maine's STEM workforce, and working toward a more prosperous future for the state."

Maine-SMART is part of the National Science Foundation's (NSF) new Established Program to Stimulate Competitive Research (EPSCoR) Collaborations for Optimizing Research Ecosystems Research Infrastructure Improvement Program (E-CORE RII), which promotes collaboration between academic institutions, government, industry and nonprofits to build the state's research and development capacity and infrastructure.

"Past NSF EPSCoR funding in Maine led to more than half a billion dollars in external federal investments in our state," said Shane Moeykens, Maine EPSCoR director at UMaine and the principal investigator of Maine-SMART. "It is both NSF's and our shared vision for Maine to leverage this new award to continue that momentum for the next 10–20 years."

Connecting classrooms to local environments

This spring, Maine-SMART is supporting a partnership between the Gulf of Maine Research Institute (GMRI) and Lewiston Middle School for field investigations of a local ecosystem. Seventh graders surveyed three vernal pools in the Thorncrag Bird Sanctuary in Lewiston, Maine documenting the presence or absence of different indicator species including caddisflies, fairy shrimp and amphibian egg masses.

Led by the GMRI through their Learning Sciences Lab with support from GMRI's long standing community science program, the Ecosystem Investigation Network. Connecting research and practice, GMRI's empirically tested community science curriculum engages students in investigations of authentic questions about local ecologies through a combination of field work and scientific modeling, and introduces students to critical ideas in science, including reasoning about variability and managing uncertainty.

Students carry lab materials to a vernal pool at Thorncrag Bird Sanctuary.

Vernal pools are an ephemeral environment.

Undergraduate students play a key role in developing forestry technology

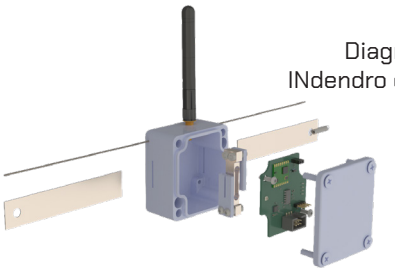


Diagram of INdendro device

It can be challenging for researchers and tree farmers to get their hands on the precise equipment they need to monitor their ecosystems. A dendrometer, an automated measurement device that wraps around a tree's trunk, can provide insights into growth and health. These measurements are critical to monitoring ecological resources, but dendrometers can be expensive to install and maintain. To help address this, researchers and students at the University of Maine's Center for Research in Sustainable Forests (CRSF) are developing their own cost-effective option for automated wireless tree measurement.

| John Hodson

| Josiah Bloom

The project sought to create a new kind of band dendrometer with funding from the NSF EPSCoR RII Track-2 project, "Leveraging Intelligent Informatics and Smart Data for Improved Understanding of Northern Forest Ecosystem Resilience" (INSPIRES; OIA-1920908) and E-RISE RII project, "Enhancing Maine Forest Economy, Sustainability, and Technology Ecosystem To Accelerate Innovation" (FOREST; OIA-2416915) grants. Leo Edmiston-Cyr, dendrometer project lead and technical computer programmer for CRSF, worked with two volunteer undergraduate engineering students, John Hodson (senior, electrical engineering) and Josiah Bloom (senior, mechanical engineering), whose contributions have been substantial.

CSRF's dendrometer, called the INdendro, can provide real-time tree growth data transmitted remotely with little manual labor. The INdendro is sensitive enough to measure tiny changes of about a micrometer in a tree's perimeter. These measurements have many direct applications, such as assessing growth and forecasting future changes. Constant automated data transcription also allows for dating weather events and growth periods. The INdendro seeks to make this information easy to access for landowners via a companion application that receives real-time data.

The work began out of necessity. No other dendrometers offered the combination of features that CSFR needs for their work. "The combination of a band dendrometer with a low-power, long-range wireless network is unique to INdendro," Edmiston-Cyr explained. "There aren't any truly comparable dendrometer systems." Most market dendrometers are point dendrometers, an alternative technology drilled into a tree and only measures growth in one spot. This limitation in resolution makes point dendrometers less reliable than band dendrometers. Additionally, no other dendrometers offer wireless data transmission at an affordable price. The INdendro promises to be competitively priced at approximately $100 a unit once final production begins. For comparison, that is roughly the price of the cheapest available point dendrometer, which does not offer wireless capability.

When Hodson and Bloom joined the project, the prototype INdendros still had to be assembled by hand in a time-consuming process. Hodson's job was to design a computer board and schematic that could be factory printed to speed up production, but he had to pivot before final production when the chosen computer chip became unavailable due to the COVID-19 chip shortage. To Hodson, this challenge was a test of flexibility and patience. "I had to take several steps back and redesign major portions of INdendro. In the process of these redesigns, I found several mistakes in my original design that I was able to fix accordingly. By working through these unexpected challenges, I developed a much better device."

Bloom, working on the body and tension mechanism of the device, reflected saying he hopes to see the final product mass-produced for research throughout New England and beyond. His design prioritizes simple assembly while remaining durable enough to spend years in the elements. The current working designs, deployed in Pinkham Notch, New Hampshire and Nutting Preserve, Maine, have already been operating for the past two years. "For w this project, I became the person my teammates relied on for mechanical design decisions," remarked Bloom. "I learned to trust my expertise while making critical engineering choices."

The INdendro pushes past the capabilities of market dendrometers by utilizing LoRa radio transceivers which can afford long range with low power requirements and operate in the 915MHz ISM band. The maximum range is about 600 meters – depending on conditions – and allows for many dendrometers over a wide area to connect to a single base station. Edmiston-Cyr summarized the project's importance not just to researchers, but also to resource managers. "The entry cost is extremely low. The installation is extremely simple. It grants the ability to instrument your asset and know how it's performing for you."

The effort is reaching its final stages of development. Once the test batch is finished, Edmiston-Cyr and his team can produce the units at scale. The CRSF, through the Cooperative Forestry Research Unit, cooperates with many landowners who will be among the first offered to use the tool. Thanks to its innovation, affordability and ease of use, the INdendro will be a powerful tool for tree monitoring.

Safety researchers develop systems to make advanced manufacturing in New England safer

A coalition of experts and institutions from across New England have been working for two years to expand the use of intelligent manufacturing. The Northeast Integrated Intelligent Manufacturing Lab (NIIM) was established through a collaborative NSF EPSCoR Research Infrastructure Improvement Program: Focused EPSCoR Collaborations (formerly known as Track-2) Program award in 2022.

The NIIM lab, based at the University of Maine, is focused on intelligent manufacturing, which is becoming increasingly embraced. "Modern manufacturing is moving a lot towards 3D printing and human collaborative robotics," remarked Vikas Dhiman, an assistant professor of computer engineering working on the NIIM project. Robots already work in close proximity to humans in this modern age of manufacturing, which provides huge benefits to productivity. The NIIM project envisions advancements in robotics and manufacturing that would benefit the Northeast, especially through the addition of artificial intelligence (AI) and machine learning.

In manufacturing, the use of robots has been limited to precise and highly specific tasks, such as "drill a 2mm hole at a 2cm location in this plate." Recent advancements in AI have changed the scope of tasks, and created the possibility of robots working on loosely defined tasks, such as "sorting out defective parts." Moreover, AI allows the robots to work in the same physical space as humans, instead of being confined to a cage. However, collaboration between humans and machines creates new safety concerns. The NIIM project has made safety a top priority. Researchers are studying how AI integration can help improve human safety when working in close proximity with robots. For instance, robots need to use cameras and sensory equipment to detect humans and operate around them.

Safety researchers using AI are presented with a dilemma. A robot needs to track a person at all times to prevent a collision and worse. In this field, accuracy is critical. "AI is very good at improving accuracy, but it also brings uncertainty because all AI algorithms are interpolation algorithms," said Dhiman. "One can think of interpolation algorithms as connecting dots. Any given set of dots can be connected in multiple ways. This choice leads to uncertainty which is inherent in all AI algorithms." Currently, the open research questions focus on estimating and reducing uncertainty, as well as making decisions that are aware of this uncertainty. The safety application of AI has become a broader discussion in the robotics field.

Dhiman is studying this uncertainty in AI predictions. There are several sources of uncertainty, which are often organized into two categories: aleatoric and epistemic. Aleatoric uncertainty, from the Latin alea for die, concerns random chance. Epistemic uncertainty, from the Greek episteme for knowledge, concerns uncertainty that comes from the lack of data. Dhiman noted that the NIIM team would have to estimate both. "It is important to account for both kinds of uncertainty, even if it requires separate algorithms." To quantify these sources of uncertainties, the NIIM team has been using a multitude of methods, including developing Bayesian neural networks. Bayesian algorithms start with assumptions and collect data to update those assumptions, not unlike how humans make predictions. More importantly, Bayesian algorithms are uncertainty-aware; they know what they do not know. These algorithms will help robots dynamically identify key parts of their environment and adapt accordingly.

In its first two years, the NIIM lab has made an impact on manufacturing research. The project has emphasized the potential uses of AI algorithms and the ways that manufacturing can benefit from embracing robotics. Dhiman hopes to develop AI algorithms that enable robots to work in close proximity with humans while probably guaranteeing everyone's safety.

Strengthening Maine's forests, communities and economies

A $7 million grant from the National Science Foundation will fund a four-year statewide collaborative project led by the University of Maine to foster resilient forest communities in Maine.

Maine-FOREST, or Forest-based Opportunities for Resilient Economy, Sustainability and Technology, expands the state's research and educational capacity to connect human and ecosystem focused innovations and services. The project takes an integrated thematic approach to fuel the state's forest-based economy and the rural communities it supports. Key foci of the project include artificial intelligence and informatics; wood-derived alternatives to plastic, concrete and more called cellulosic nanofiber bioproducts (CNF); rural and Wabanaki resilience; and economically diverse rural development.

Maine-FOREST will ultimately nurture adaptive community resilience and strengthen the capacity of rural communities and the Wabanaki Nations to respond to current and future socio-ecological threats and opportunities.

The grant provides $4.5 million for scholarly activities at UMaine as well as $2.5 million for collaborative activities led by project partners across the state that include nonprofits, private colleges and three additional University of Maine System campuses. The award also includes an opportunity to secure an additional $4.5 million to extend Maine-FOREST for three additional years.

"Maine-FOREST is a multiyear, statewide effort that is helping to transform the state's forest-based economy by leveraging new innovations and knowledge that link to other ongoing efforts like the state's ambitious Climate Action Plan or Forest Opportunity Roadmap, as well as prior NSF investments. Integrating new knowledge on the forest with emerging products and rural communities is essential for future climate-smart progress in Maine," said Aaron Weiskittel, professor of forest biometrics and modeling, director of the Center for Research on Sustainable Forests and the project's lead investigator.

The incubator teams created through Maine-FOREST will close key strategic gaps in the state's ability to capitalize on pioneering technology in the forest products sector and forge culturally inclusive approaches to collaboration across partner networks.

A key deliverable for the project is a forest economy and workforce dashboard updated in near real-time to help Maine's forest products sector make data-driven decisions. It will also help support the Maine Economic Development Administration University Center, led by UMaine Economist Andrew Crawley, a co-principal investigator on the grant, to steward the dashboard and guide future efforts.

Maine-FOREST is helping create a new forest sector business development position. Through this effort, a statewide Maine-FOREST Institute will be created to help sustain collaborative partnerships and ensure the successful translation of innovation into economic impacts.

"Maine-FOREST strategically aligns well with Maine's recent EDA Forest Bioproducts Advanced Manufacturing Tech Hub effort, which aims to establish Maine as a global leader in forest-based biomaterial production and manufacturing by innovating the process of extracting biological building blocks to manufacture

UMaine students walk through Demeritt Forest

environmentally sustainable products," said Brian Whitney, president of the Maine Technology Institute, which is partnering on the project. "Given Maine-FOREST's research emphasis on CNF and other emerging technologies like AI, as well as the creation of a statewide research institute, the proposed project will help advance our EDA Tech Hub and support the development of Phase II proposals in the coming years."

The rural and Wabanaki resilience and smart rural development themes under Maine-FOREST will also directly impact 10 diverse, rural and economically distressed Maine communities and Wabanaki Nations. The Maine-FOREST team will use community-driven approaches to problem and solution identification to help envision alternative future trajectories for residents. A key focus is to help rural students see potential future educational and career pathways for success in these local communities, rather than pursuing opportunities elsewhere.

Maine-FOREST also includes plans to engage and collaborate with K-12 schools in Maine's forest communities.

"Through Maine-FOREST, Maine Mathematics and Science Alliance (MMSA) is partnering with Maine TREE and Rural Aspirations to expand interdisciplinary leadership, place-based learning and entrepreneurial opportunities for rural schools. We are honored to be a part of this collaboration and highlight the critical skill of codesigning evaluations of educational project outcomes in environmental education," said Ruth Kermish-Allen, executive director of the MMSA who is also a principal investigator of the project.

"Investments through Maine-FOREST will eventually double the size of the Maine TREE Forest Ecology Research Network and help Rural Aspirations disseminate its stability model, an inside-out design process where teachers, administrators and select community representatives codesign school and community systems that incorporate social and economic development challenges into learning experiences. MMSA is helping our partners evaluate the impact of their educational programs, ultimately improving the learning experience in 15 K-12 schools for 200 educators and nearly 2,000 students."

The project taps into the Pine Tree State's rich network of nonprofits and universities. In addition to UMaine, Maine-FOREST includes the University of Southern Maine, an emerging research institution; the University of Maine Fort Kent and the University of Maine at Presque Isle. Other partners include Colby College, Bates College and the Maine Development Foundation. The grant will directly support more than 45 faculty, 85 undergraduate students, 10 graduate students and four postdoctoral researchers over its first four years. The project is helping to strengthen connections between the state's universities and nonprofit organizations through direct collaboration and partnerships.

"This investment from NSF's E-RISE RII program powers scientific progress through broad networks of researchers, institutions and organizations that will significantly enhance STEM research capacity in our EPSCoR jurisdictions," said NSF Director Sethuraman Panchanathan. "We are investing in a future where EPSCoR jurisdictions are even more competitive in the scientific enterprise, both nationally and internationally."

Maine-FOREST was awarded through the NSF's new Established Program to Stimulate Competitive Research (EPSCoR) Research Incubators for STEM Excellence Research Infrastructure Improvement (E-RISE RII) program that aims to create and cultivate sustainable networks of diverse research teams to collaborate on locally relevant research critical jurisdictional research priorities.

Establishing Maine as a leader in environmental genetics

Awarded in 2019, the NSF EPSCoR RII Track-1 Maine-eDNA project has reached the conclusion of its NSF funding. The program, which investigated Maine's coast, inland lakes and the waterways in between, championed environmental DNA (eDNA) as a powerful and cost-effective approach to monitoring an environment as small as a stream to as large as Maine's coastline. Maine-eDNA Co-PI Michael Kinnison, University of Maine professor of evolutionary applications remarked, "The real power that we were seeing for eDNA is being able to look at the biology of the Maine coast at not just local but by very large scales that span habitats. That sort of snapshot of the coastal system is broadly something that's really hard to get a handle on with other approaches."

Bigelow Laboratory for Ocean Sciences Senior Research Scientist and Geomicrobiologist David Emerson served as a Co-PI for Maine-eDNA and authored the white paper that developed into the project's proposal. "There are three things that really excite me about eDNA. Scientifically, it is the opportunity to study all organisms, from microbes to whales, within an ecosystem to see how they interconnect; collaboratively, it is the opportunity to work together with researchers from many different disciplines using a common language, DNA, and practically, it is the opportunity to develop an important new tool for ecosystem management and sustainability," explained Emerson.

This genetic tool leverages the DNA shed by organisms in their environment. Researchers take a sample from the environment, in the case of Maine-eDNA as little as a liter of water, and, depending on method, identify the likely presence of a specific species or range of species in the vicinity. While like any technology there are tradeoffs, this allows researchers to accurately detect species presence in a relatively unobtrusive manner that does not rely on visual identification.

Researchers across Maine saw potential in the technology. "We saw an opportunity to push an emerging technology forward, become a leader in the field and benefit the lives of Mainers," explained Kody Varahramyan, Maine-eDNA PI and UMaine Vice President for Research and Graduate Studies. "Maine-eDNA's achievements exemplify the power of partnership and collaboration."

eDNA technology has developed quickly over the past decade. When the original proposal for Maine-eDNA was in its infancy, researchers were exploring the capabilities of eDNA and interested in finding more applications, but the depth of real-world applications was limited. Fast-forward to 2024 and the President's Office of Science and Technology Policy released their National Aquatic Environmental DNA Strategy which directs government offices to invest resources in the technology. During the interim years it was projects like Maine-eDNA that pushed the technology forward by improving methodologies, standardizing approaches, making data accessible to others, and pushing the scope of application into new areas.

Maine in many ways was a perfect testing ground as the technology offered a way for researchers to survey the vast expanse of Maine's waters over the course of several years at a fraction of the price presented by other approaches. A survey of this size also demands the standardization and ground truthing the technology needed. Maybe most importantly, the project put eDNA technology in the hands of students, researchers, resource managers, businesses and other stakeholders through outreach and collaboration.

While the COVID-19 pandemic created new barriers to performing research, it likely increased adoption of eDNA. On mass, people were seeing the proliferation of DNA testing and learning what the technology was capable of as it became the gold-standard for COVID detection. Suddenly, people were familiar with the notion that PCR testing could detect small amounts of DNA from organisms we couldn't directly see, which made adoption of the technology easier.

One avenue of uptake was through community groups concerned with harmful algae blooms (HABs). Many Maine communities have lakes that serve as water supplies or centers for recreation. When an algae bloom appears it can be hard for these small community groups to identify the bloom and determine if it is a HAB and if so what type in order to react to it. Working with Maine-eDNA researchers at the Bigelow Laboratory for Ocean Sciences, groups such as Wolfeboro Waters were able to purchase and use eDNA testing equipment to monitor blooms in their communities.

Mentorship was a feature of the Maine-eDNA program. With over 30 graduate students, primarily seeking Ph.D.s, their research enriched nearly every aspect of the project. Graduate students conducted their own research, drove Maine-eDNA's vast coastal sample collection efforts, and helped guide the project's undergraduate interns as they entered the world of eDNA for the first time. These students' research was helping define eDNA's strengths and weaknesses through trial, error and innovation. Kinnison reflected, "You don't always learn what you set out to learn, but you learn something." While this can be frustrating, it is a crucial element to developing as a researcher and pushing an emerging technology forward.

Recognizing that powerful new technologies can come with unintended consequences, Maine-eDNA researchers found common interest in advocating for ethical principles in this emerging field. Anticipating the possible ethical pitfalls presented by a transformative technology is critical to utilizing it equitably. While it is a time consuming pursuit to look at such potential problems from multiple angles, it is also an essential one, especially given the historic misuse of genetics in ways that sometimes harmed marginalized peoples. This work took the form of classes, working groups and investment in data sovereignty principles in collaboration with international programs like Local Contexts.

In addition to developing new eDNA tools and insights into the Maine's coast that will be used for many years to come, one of the greatest achievements of Maine-eDNA was to set a genetic sample and data baseline for Maine's coast.. Maine-eDNA's Index Site samples and data of lake, estuary, and coastal environments across Maine will be the genetic reference point to which Maine's changing coastal systems will be compared for the foreseeable future.

This work will be continued by the Maine Center for Genetics in the Environment (MCGE), one of Maine-eDNA's primary outcomes. Kinnison, MCGE's director, explained, "MCGE marries Maine's long term, well-established natural resource industries to modern data, technology, genetic technology, biotechnology, type tools." The center serves as a steward of the technology and a place people know they can turn to when they seek insights from eDNA.

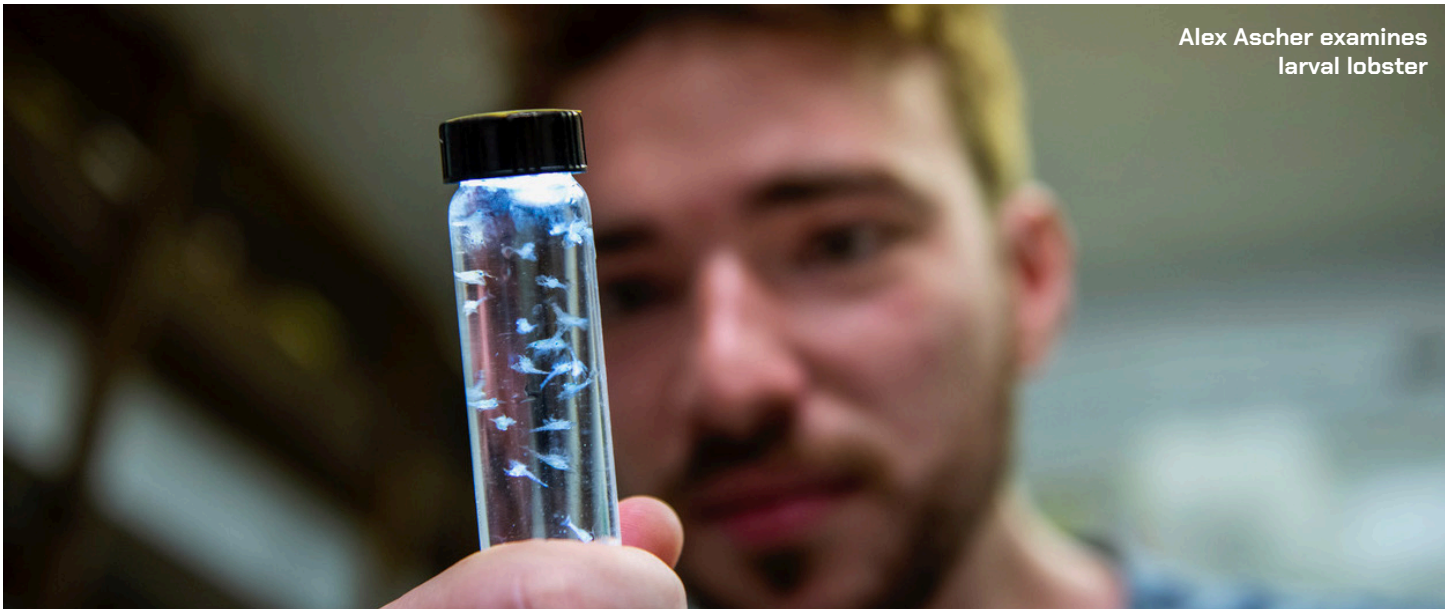
The Maine-eDNA project in some ways only scratched the surface of what eDNA can do. Focusing on aquatic environments leaves the vast terrestrial world to explore through the lens of countless disciplines where eDNA is also emerging. MCGE hopes to bridge that gap. "The center is something that could bring people from all across the UMaine campus and across institutions in Maine together," remarked Kinnison. "We are building and nurturing a community of people who see these opportunities."

So while Maine-eDNA has completed its work, there is so much more to do. The program established eDNA as a powerful tool for understanding Maine's aquatic ecosystems. These new insights are helping resource managers, communities and other stakeholders make informed decisions about the environments they work with. The MCGE will continue to be a resource for partner organizations like the Gulf of Maine Research Institute who were able to stand up their own molecular lab by drawing on the expertise within the larger Mainee-eDNA program. "The community of practitioners that has arisen as a result of Me-eDNA will continue to be a force multiplier for propelling the technique into the future of coastal and fisheries management in the Gulf of Maine," said Graham Sherwood, a senior scientist at the Gulf of Maine Research Institute], Maine-eDNA's work will carry forward through the work of MCGE and everyone involved with Maine-eDNA throughout its length.

If you are interested in potential applications of eDNA for your business, community, or education, please reach out to the Maine Center for Genetics in the Environment at MCGE@maine.edu.

MAINE eDNA

MAINE CENTER FOR GENETICS IN THE ENVIRONMENT



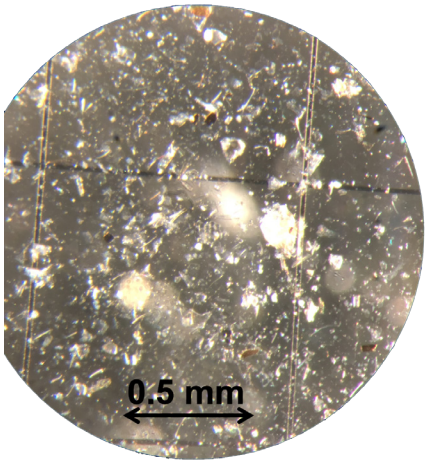
Alex Ascher examines larval lobster

New methods complement old in revealing diet of larval lobsters

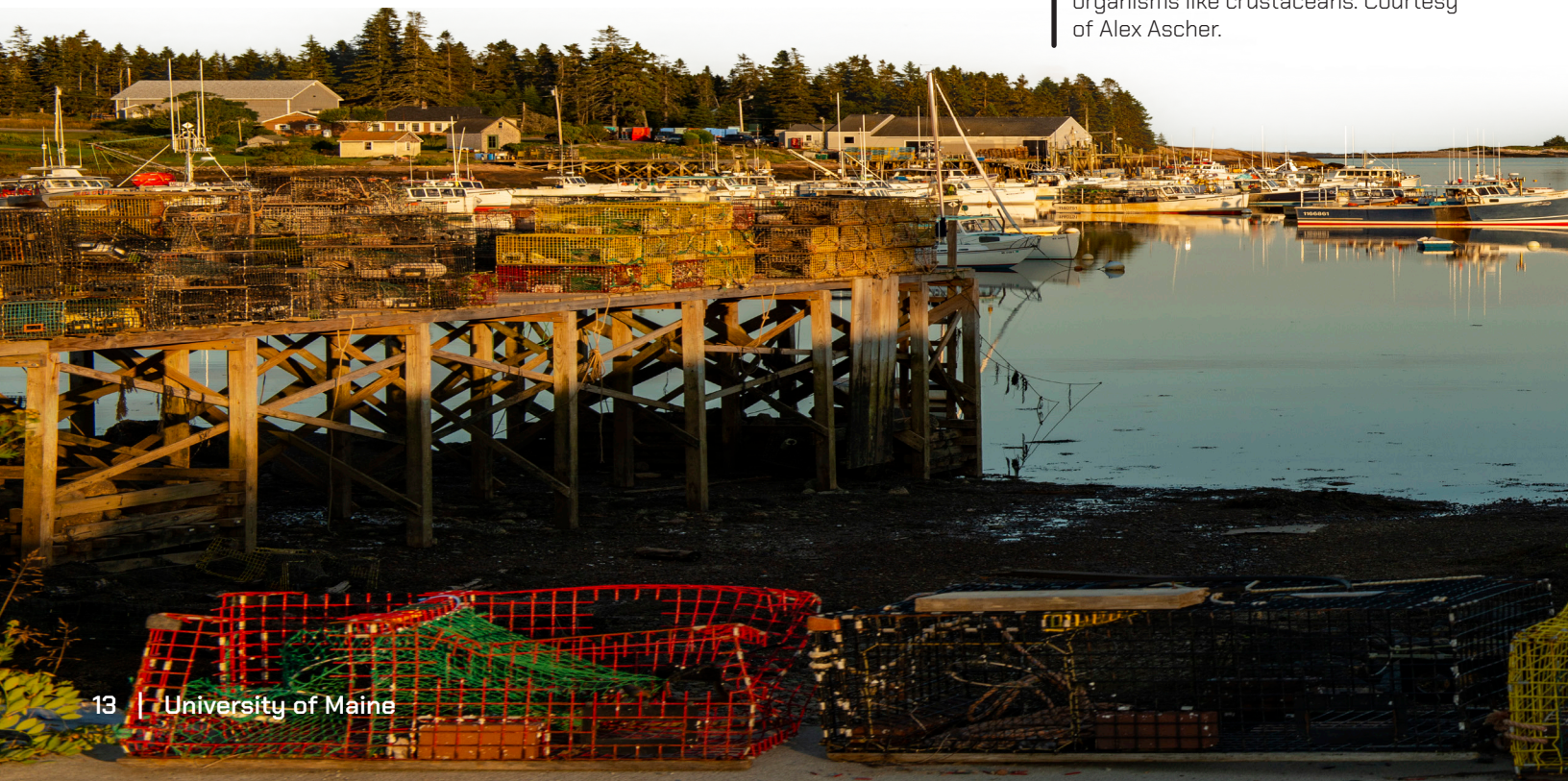
Scientists know little about what larval lobsters eat and how their diet benefits their survival. That's primarily because these crustaceans are only about a quarter of an inch in length and their stomachs are about the size of a pinhead. That makes them no small challenge to examine under a microscope, the traditional method for conducting this type of research.

In a new study titled "Contemporary eDNA methods complement conventional microscopy in zooplankton diet studies: Case study with American lobster postlarvae," published in the journal PLOS One, the team of scientists show how new techniques that leverage trace prey DNA along with traditional microscopy can lend greater insight into larval lobsters' feeding habits, helping researchers determine whether the changing supply of planktonic prey in a warming ocean will hinder larval lobster's ability to survive.

"Lobsters are an important economic and cultural resource. They're also important ecologically as a large-bodied



Even a skilled researcher will miss things during microscopy. Soft bodied organisms will not leave the same identifiable remains as hard bodied organisms like crustaceans. Courtesy of Alex Ascher.



crustacean scavenger spending most of its life on the bottom of the Gulf of Maine," said Alex Ascher, the publication's lead author, a former UMaine Ph.D. student and a pa former UMaine Ph.D. student engaged in the NSF EPSCoR RII Track-1 Maine-eDNA project and now a postdoctoral researcher at Quahog Bay Conservancy and Woods Hole Oceanographic Institution. "This means they are well studied, but there are still gaps when it comes to their early life history."

To overcome the limitation in lobster diet research, the team used two molecular approaches to examine specimens.

The first is metabarcoding, an approach that uses a "universal" genetic marker to broadly identify prey present in the larval lobsters' stomachs. It is also widely used in the study of environmental DNA. In this first-ever probe of newly-hatched lobster using metabarcoding, Ascher and the research team not only confirmed some of the common broad prey categories observed by microscopy, most prominently crustaceans, but they also detected a strong signal from other prey that have soft body parts in their own early life stages, such as worms and fish eggs. They also found a wide diversity of single cell organisms in the diet such as microalgae and fungi, most of which were likely foods consumed by the animal prey.

But one of the challenges with this approach is that the lobster larva's own DNA can overwhelm the signal from closely related prey in the diet, such as other species of crustacean. To counter this, the team developed a specialized blocker that was able to mask much of the lobster genetic material, revealing a diversity of organisms that could not be identified visually.

The next approach introduced was a primer-probe based Polymerase Chain Reaction (PCR) designed to target a particular prey species of interest with high-fidelity. In this case, the researchers were interested in knowing whether Calanus finmarchicus, a foundational crustacean prey species in zooplankton residing in northern waters, was consumed by larval lobsters. If a lobster has eaten Calanus, the primer and probe attach to the prey's DNA and light up with fluorescence, just as in a PCR-based COVID-19 test. Based on early estimates, the team can now demonstrate for the first time that newly-hatched lobsters consume Calanus at a rate higher than would be expected, given the availability of other zooplankton prey in the wild.

"Now we have a bigger tool kit to understand the larval diet that not only takes advantage of visible evidence from traditional microscopy, but also capitalizes on two new molecular approaches that open a window on the invisible," said Richard Wahle, a co-author of the study who previously directed UMaine's Lobster Institute and was a professor with the School of Marine Sciences. "It will help us answer long standing questions about how larval lobsters interact with the planktonic food web."

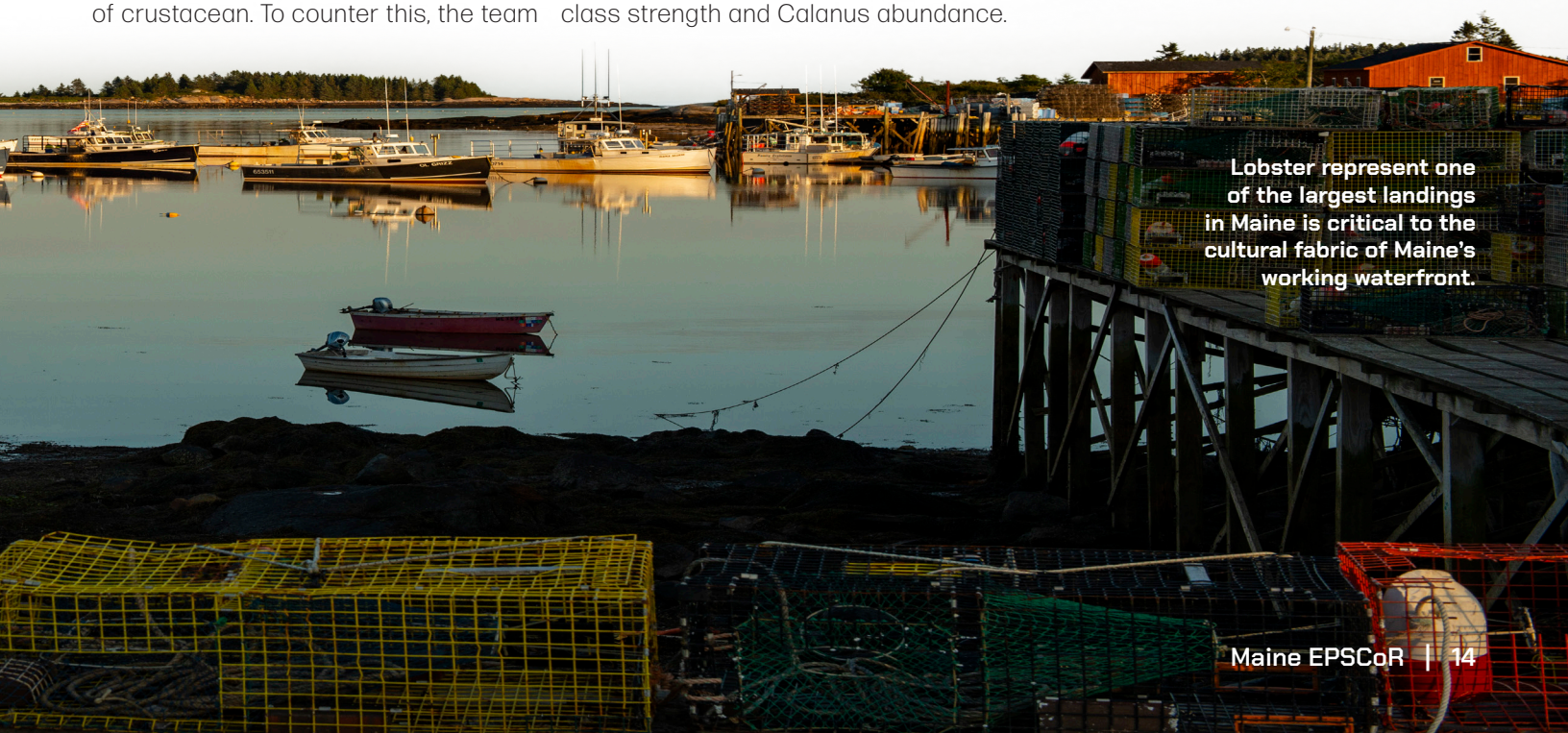
This work also serves as an important step in understanding a previously reported strong correlation between lobster year class strength and Calanus abundance. As a result, researchers suspect that the lobster population in the Gulf of Maine could be dependent on available prey during their critical early stages in the plankton.

"What are the important components of the larval lobster diet?" Ascher asked. "What are the prey that really sustain them, and are those prey likely to be more or less available to them in the future?"

The answers to these questions have real implications for Maine's lobster industry, the ecosystems they inhabit and the coastal communities that rely on them.

Using these methods, the research team is preparing an upcoming publication more fully revealing the diet of early and late-stage larval lobsters in two locations of the Gulf of Maine.

This study was part of Ascher's Ph.D. dissertation in collaboration with Bigelow Laboratory researchers Peter Countway, Robin Sleith and David Fields. Their work is a component of a larger multi-investigator effort to understand the feeding ecology of larval lobster in the planktonic food web through retrospective time series analysis, larval feeding studies and new environmental DNA approaches to diet analysis. The project is supported by Maine Department of Marine Resources, Maine Sea Grant and the National Science Foundation EPSCoR Track-1 Maine-eDNA research program.



Lobster represent one of the largest landings in Maine is critical to the cultural fabric of Maine's working waterfront.

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