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S1E1: What is eDNA and how will it change Maine's coastal communities?

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The Maine Question podcast transcript

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[*Repetitive, pulsing background music*]

00:04 Ron Lisnet

Hello, and welcome to The Maine Question, the official podcast of the University of Maine where we sit down with researchers, innovators and changemakers to answer some of today's biggest questions. My name is Ron Lisnet and I'll be your host for this exploration.

[*Repetitive, pulsing background music*]

00:20 Ron Lisnet

You know there's so many topics, challenges, and questions that UMaine research is looking into that's it's, it's really hard to know where to begin. But we need to start somewhere for this, our very first episode, So, we thought to begin with one of the defining characteristics of the state of Maine, and that is the coast and actually, any body of water in general.

Coastal communities and the Gulf of Maine define the state in so many ways: livelihoods depend on it; people recreate in and on the water. Most of Maine's population is near the coast. We all depend on these waters. Whether it's the ocean or freshwater. But there is a lot happening to this environment and the plants and animals that live there.

01:01

From plankton all the way up to the North Atlantic Right Whale. The established methods for monitoring these populations of critters are pretty low-tech and basically involve capture with Nets or containers of some sort and counting a particular species. That method, which is thousands of years old, is time consuming and can cause significant collateral damage. But now a new high-tech tool is come along that has the potential to revolutionize how this work is done. A $20,000,000 grant from the National Science Foundation EPSCoR program will fund five years of research into the development of this tool.

01:39

The Maine Environmental DNA, or eDNA for short, initiative will be led by UMaine and its partner, the Bigelow Laboratory for Ocean Sciences. We're going to talk more about this with Mike Kenison, Professor of evolutionary applications at UMaine and one of the lead researchers on this project on what The Maine Question is.

02:01 Mike Kenison

So, what is eDNA and how will it change Maine's coastal communities?

02:06 Ron Lisnet

Welcome, thanks for joining us. Appreciate it.

[*Background music fades and ends.*]

02:09 Mike Kenison

Oh, happy to be here.

02:10 Ron Lisnet

So, I guess the obvious first question is, eDNA is a bunch of letters thrown together. What exactly is it?

02:16 Mike Kenison

Right, so the eDNA is the short terminology; short, quick version of Environmental DNA. That's what the E stands for, and environmental DNA is DNA that we can collect and somehow analyze out of environmental samples. Environmental samples include water, air, soil, sediments, snow. The list keeps growing, but basically any material from the environment where organisms might inhabit, we can potentially draw DNA from that. And this environmental DNA is generally speaking, a leftover a waste product of those animals' lives. It's shed skin cells. It can be for larger animals. It can be the sum of their waste products. And for some smaller organisms that can actually be the whole organism; some plankton or bacteria.

03:14 Ron Lisnet

I've heard you describe this before as; you know, fishermen have used nets for thousands of years. This is a new kind of net? Can you elaborate on that?

03:22 Mike Kenison

Yeah, so a lot of environmental monitoring—our understanding of systems—involves some need to capture organisms and has for as long as we've been trying to somehow assess the environments around us. Somehow understand those organisms and use them in some way. You know about 6000 years ago somebody came up with the brilliant idea of using nets to pull fish and other organisms out of aquatic environments. And over the last, you know, century or more, a lot of management of fisheries and other fields have used those nets to catch the organisms account 'em and identify them. With Environmental DNA, we've just in a way, scaled these Nets down really small.

Our new nets for environmental DNA, could fit in the palm of your hand. They're a filter, and the net size—instead of being inches of mesh to catch some big organism—now the mesh size is microns or way smaller than microns. And at those scales we can actually catch fragments of DNA. And with those fragments of DNA, well, we might not be too interested in eating those directly, we can analyze those fragments of DNA to understand what organisms were in that environment recently and use that information...is now really an independent way—a new way to know about systems. It's not too often that suddenly we have a different lens or view into the environments that we're interested in.

04:55

And so having something as independent as this means, not only can we use this tool where maybe nets aren't ideal for a number of reasons—maybe they could harm an organism that we don't want to harm, or we can't maybe readily apply the net because of the type of environment, a big net—we can still use these DNA Nets and these DNA nets catch everything. So, that's really transformative. You know there's no other nets out there that you could put out there and catch everything from microbes to whales, but these DNA ads can.

05:25 Ron Lisnet

So, what is the process? How does it work exactly? Is it just a matter of scooping up a pail of water out of a particular body of water you want to study and and then analyzing the DNA in that water?

05:36 Mike Kenison

You're not far off, there. I mean, it really at its base level, once you take these nets, these filters being the most common way to collect this DNA. Once we've got that DNA by collecting, say, a water sample, the water samples don't need to be big. Many cases water samples are no bigger than a common bottle of drinking water. That sort of size you know, a few 100 milliliters. With that volume of water, we filter it through our new nets to catch the DNA on the filter.

We then use modern genetic approaches, which essentially are fancy photocopiers. They take a small number of copies of DNA that are in these samples and they multiply them. They copy and copy and copy. And by copying those small number of DNA fragments that are left behind—this this trace DNA that might be relatively dilute in these systems—by copying it, we bring it up to a level where there's a detectable signal and it's enough DNA also that we can now using again modern genetic tools not only just make more DNA, but we can read the DNA. We can tell the sequence of that DNA, and map that to an organism that carries that DNA originally, that shed that DNA.

06:51 Ron Lisnet

So, for fans of the TV show CSI or people that are into forensic sciences, is that a reasonable thing to equate this to?

07:01 Mike Kenison

Very much so in terms of the the sensitivity and sophistication of the technology. Really, the tools we are using are forensic level. They detect such low levels of DNA that they can be in many ways equivalent to a DNA sample that maybe somebody left behind when they touched a gun or table or something at a crime scene to, really, an organism swam through an area of water or stepped on a piece of ground. They would leave behind some DNA. With that level of sensitivity comes all the same sort of need for rigor.

So, in almost all cases we—our labs to run environmental DNA samples—look a lot like forensics labs. They have a lot of clean environments. They have a lot of care to make sure that we're not accidentally detecting contamination, because again, where we're really going after this small, small amounts of material in the environment.

08:00 Ron Lisnet

How do you know it works? And how far along are the techniques and the accuracy? Are those things about this still being developed?

08:07 Mike Kenison

We know it works on a lot of different levels now, but the like many cases where science the first step was probably—from what we know from people who were really getting going with this work early on—it was just the idea to look. So, the first step was somebody went to a site where one of the better known early examples had to do with bullfrogs introduced in France. They took some water samples out of a pond and said, you know, why we don't give it a try. Let's see if there's some DNA there. And they found the DNA. And from a few of those early examples—then that really changed perspective of what we thought we could detect.

I think, up to those examples, a lot of people would have suggested the DNA was just too scarce to find, but those gave the impetus—the inertia—to move forward, and since then the refinements to keep building while people do more and more sophisticated experiments and analysis. So, a lot of times now studies are conducted where we can say, place an organism or a sample of its tissue in an environment and verify that we can detect it experimentally, which leaves very little error that the technique works. And then in other cases, when it rolls out to being more large scale real world, what we're seeing is good correspondence between the DNA data and the data that people collect with other methods.

09:27

We're seeing that, if they go out and net fish with the big nets, our little nets are also catching the DNA of those organisms. They're comparative, right? And so all of these things are kind of pushing us in the direction that the technique is now actually grounded to the point that real world applications are happening.

I've given the analogy before that, it's sort of like early version smartphones. And the early smartphones, you know, they gave you some basic rudimentary abilities. You could not just call somebody, but you could do some email. You could do some texting. You could do it, maybe get a little Internet access and it wasn't perfect, but it was workable and working at a high enough level that from that point on that got the ball rolling and the momentum going. And eDNA is there, now. We're now seeing applications of eDNA in real environments, for real management detection purposes, detecting invasive species, detecting endangered species, and so on.

And while we recognize it's got a ways to go for some...for...to reach its full capacity, its full potential, it's definitely in use and workable now all the way to the level that some eDNA has now been used in, you know, major policy and court-related cases showing that you know, it stands up to the rigor needed for major, you know, federal-level policies.

10:49 Ron Lisnet

So, I know there's two major areas that this work is focusing on. One is sustainable fisheries and the other you sort of alluded to is harmful species or invasive species. Those are...that's sort of a dual track. That work is going to be done in both of those areas?

11:06 Mike Kenison

Right. So, kind of the area where a lot of our work is happening around this Maine Environmental DNA-type project we wanted to start with some areas that are very pragmatic, practical needs for the state of Maine. You could develop technology of all sorts of level of interesting refinement and do sort of one-off studies and that would be academically interesting, but we wanted to ground this in something that in the near term, in the next few years, we can produce usable tools that will that will change the sustainability for coastal systems.

Sustainable fisheries in it of themselves...you know, Maine has a really long fisheries history. Some of that fisheries history has shown, you know, remarkably sustainable use of resources and great outcomes, like lobster. And other cases, everybody is aware of situations where the fisheries haven't turned out so well.

12:00 Mike Kenison

You know, the collapse of Cod in the Gulf of Maine or the real declines in a lot of sea run fish is due to dams and things like that. Where environmental DNA can come into this now is now, there's a lot of interest in how do we kind of monitor at the scales needed to achieve recovery in these organisms. Or to anticipate how some of those fisheries might change or improve our targeting for some types of fisheries.

So, in the restoration standpoint, you've got all these sea run fish that are...that a lot of effort is going into restoring. How do we know that's working? How? Where? How do we get information on a scale as big as the Gulf of Maine? When these fish go out into that ocean, how do we know they're doing their jobs out there? Environmental DNA can be a solution for it. If you're working with shellfish or the like, you know, you're an aquaculture grower? Environmental DNA can potentially improve when you put your shellfish out to grow elements like that. Real practical immediate uses.

13:05 Mike Kenison

In the flip side, to harmful species is, overtime, you know, the Gulf of Maine is a rapidly changing environment. Temperature-wise, climate-wise it's one of the most rapidly changing coastal bodies of water in the world. So, we are anticipating that a lot of change is going to happen to the organisms that use that environment and our ability to make use of them.

That starts to get into this realm of some of the harmful species scenarios that we're already starting to see emerge and are causing tides. Toxic harmful blooms of organisms, harmful algal blooms in both freshwater and marine environments. In marine environments they affect shellfish, closures, freshwater environments, they impact drinking water, too. Being toxic to dogs, you know, something that showed up in the news recently — and what's challenging with that is we're seeing new organisms showing up in these harmful blooms and their frequency of these blooms is not always easy to predict when and where and how that's going to happen. So environmental DNA gives an opportunity to get out, potentially test water in more places, less cost, and potentially avoid some of the costs of those blooms.

14:15 Ron Lisnet

And you may know earlier that it’s coming.

14:16 Mike Kenison

Know...and early warning. Get your get your product out of the water if you're an aquaculturist or, you know, warn people earlier. Allow the water system to improve its, you know, change over their treatment process.

All of these could benefit from something like helping to manage around those harmful blooms. Early, you know, forecasting. And then the other big challenges as the Gulf of Maine changes, the organisms that are there and where they live in the Gulf of Maine is inevitably going to change. We're already seeing some of this happening. Lobsters moving North and so on.

Lobsters aren't themselves harmful but losing lobsters could be potentially a harmful species type scenario. But in other cases, these are organisms that are moving into our system, some of them are introduced by humans, some of them are just spreading from what was normally warmer water environments further South and those organisms can harm or change some of our coastal communities, change kelp beds, or areas—like that green crab, you know, is to compare against lobster is an organism that is, you know, potentially having devastating effects in some areas. eDNA can be an early warning system to understand not only where they are now, but we combine that with enough survey of environmental DNA along the coast and with environmental data, maybe we can start to again forecast where they will be.

15:41 Ron Lisnet

Another interesting aspect to this is it could be done by—at least collecting the samples—could be done by anybody. How can crowdsourcing or citizen science...uh...is that part of this?

15:52 Mike Kenison

I would actually lump a lot of the challenges that we have in the Gulf of Maine and other places under sort of a monitoring crisis in a way. And we know there's these changes in the environment, you know that are going on. We, we know that there are changes in fisheries that are happening, but in many ways the biggest problem that we're up against—while we know these things are happening—is knowing how they're happening, where they're happening and at what rates. And there's—if you were to kind of survey the state of Maine right now for the number of biologists that we say have to cover all the different lakes in Maine to know where a new invasive species shows up, we're not even close, right? Try to cover the miles and miles and miles—thousands of miles of coastline of Maine in and out all over the place.

16:40 Mike Kenison

How do you cover that with a couple dozen biologists? You can't. So, the challenge in many ways is sort of we're increasingly getting into a monitoring crisis. We have more organisms that we care about. We know in some way or another they're either increasing or decreasing at abundance in ways that it can impact us in good or bad ways but we just can't get the data. And so, environmental DNA because it can be as simple as collecting a bottle of water and delivering that to a lab to analyze to give data back, means we have the capacity now to really bring in a much bigger workforce. A really, in many ways, a volunteer workforce.

The opportunity to engage citizen scientists, school groups, NGOs—nongovernmental organizations—and others that have maybe had limited capacity before to do these sort of surveys using physical nets or gear, can very readily get out and take water samples.

And so, I've sort of likened it in some ways to like democratizing an environmental monitoring. It means now people who are living and interacting in places with this environment, the environment that means the most to them, they can now contribute meaningfully, potentially to this monitoring. And if enough people are doing this in enough places, then now we have a lot more data coming in to tell us about these challenges or opportunities in the growth in the Gulf of Maine than we ever could have.

18:13 Ron Lisnet

So, instead of dozens of sample sites you're talking thousands or tens of thousands. You mentioned, you mentioned STEM — or school groups — and is STEM education and making a more scientifically literate workforce is that part of this equation as well.

18:28 Mike Kenison

Absolutely. So, STEM stands for, you know, science, technology, engineering, math. Kind of the cornerstones of a lot of educational investment right now. The beautiful thing about environmental DNA is a way to help move forward STEM-type education is it hits on each one of those elements. It has the science of DNA, the technology and engineering around, collecting and amplifying that DNA. And the mathematics around analyzing the results from it. And so, if you're an educator from kindergarten to college and your goal is to make for engaging opportunities for people to learn those STEM skills, environmental DNA can be used in almost anywhere in the discipline.

19:15 Ron Lisnet

It checks all the boxes.

19:17 Mike Kenison

Anywhere in the curriculum, right? You can plop it into the curriculum and one of the beautiful things about it is it's long been shown and known that educational outcomes, the ability for people to learn STEM concepts is greatly improved by their ability to do some work, do some activity that is directly impactful to them. And so, environmental DNA, being a technology where you can collect samples in your your backyard or pond or the ocean nearby or the stream that runs by your school means almost...it can be broadly used for this place-based type of STEM education. And in the process of doing that, not only can those school groups get valuable information and education around that they can use to learn about science, technology, engineering and math, but the samples they collect can be brought into this bigger data stream. They're just as valuable is all the data collected potentially by the scientists. So again, it gives an opportunity to that people know that the work that they're doing in STEM is collecting something that's not just a one-off lab exercise, but they are actually collecting something that's going to be part of a bigger picture to help their state and their town, what have you. That's powerful.

20:34 Ron Lisnet

Maine, obviously, with its very long coastline its fisheries tied to the water, both fresh and saltwater, in many ways Maine is—is Maine an ideal place to develop this technology? This eDNA?

20:47 Mike Kenison

Right so, environmental DNA, you know, intersects nicely with Maine. Just because Maine has this diversity of systems to work on. So, when we're targeting, say coastal systems to look at with environmental DNA—in Maine that gives us everything from lakes, to rivers, to estuaries, to the ocean. A fairly diverse gradient of ocean and coastal marine habitats from the South end of Maine to the North, and so it's just a wonderful resource there from the environmental standpoint. It gives us a lot of places where we can test ground truth, develop these tools.

But I think the other reason that Maine is really a great place to roll out environmental DNA is because it's also a state where people do have these strong connections to their environments, you know. Historically, Maine has this natural resource-based economy. It's part of our culture and we see it broadly across Maine—many, many groups of citizens that are, again, very committed to natural resources. Whether that's a Lake Association in the care for the Lake that they live on, or a coastal Co-op of lobster fishermen who care about the sustainability of that resource. Maine has a long history of innovative, citizen activity in the management and investment in those resource.

So, if you want to realize this kind of dream for environmental DNA to become out there for everybody, a democratized resource or toolkit for monitoring. You've already got an engaged population who is keen to make that happen. And we're already seeing that we're seeing some of the first really big growing interest around environmental DNA in Maine is by these citizen groups and others who say this is a chance for us to step up and be part of the equation.

22:36 Ron Lisnet

How do you think this project will intersect with the research in science education here at UMaine? Will this filter into the curriculum?

22:42 Mike Kenison

From a research standpoint—starting with that element, there's kind of two prongs on that one. One is we'll certainly see quite a few investigators trying to drive forward to technology and science of eDNA itself. How do we make eDNA a better inferential tool in general, but the other area where we hope it will intersect with research, and we're already starting to see this is because it can address some fairly fundamental questions that many types of scientists need. In general, they need to know what organisms are in the environment and where. If you're if you're working in, you know fisheries, or if you're working in Forestry. If you're working and almost any of these areas knowing where the organisms are and what they're doing is pretty important.

So, we also see this second prong of being eDNA becoming accessible, and a tool used by people who are not geneticists—really seeing increased capacity of it playing out in a whole broad-based range of environmental research as well as the capacity for people working in engineering, chemistry, and other areas, to drive forward the technology.

23:51 Ron Lisnet

Applications.

23:52 Mike Kenison

Applications are so diverse.

From an educational standpoint, yeah, we anticipate that environmental DNA can, you know, certainly come broadly into some of our core curricula around Biological Sciences, genetics and so on. Kind of a fundamental level, that that makes sense. But it also has the capacity here to roll out in other areas. If you're in environmental Sciences, classically, a lot of people being educated in those areas wouldn't have had a lot of time invested in understanding these genetic tools, but these genetic tools are now coming along so quickly and developing to such an effective level, that we need to see that roll out. So, the opportunity for environmental genetics training in the whole kind of sector of our science education here is that there's an untapped resource, and those people can bring these genetic tools forward in the long term.

24:49 Ron Lisnet

So, this is really jumped up to another level with the recent awarding from the EPSCoR Office of a $20,000,000 grant to fund this work, here at the University of Maine, and with Bigelow Lab. And there's a lot of partners involved with this, so can you speak to that? And where do you think this is going to develop? Big picture over the next decade, what, what might we say?

25:08 Mike Kenison

So, this funding from NSF EPSCoR being, uh, research infrastructure investment track one-type grant is really intended to build this capacity statewide, not just here at the University of Maine or Bigelow. And NSF really views that investment as an investment, not just in the nitty gritty nuts and bolts of doing the research, they link it very strongly to workforce development, educational component.

So, this this grant is really—I just wanted to make it clear—is funding across the board. It will drive forward new eDNA research, but it will drive forward educational elements. It'll drive forward new training for people who are already in the workforce. Potentially, people who are in currently working in environmental fields who could benefit by understanding how to interpret and apply the DNA data, will hopefully get the training in these sorts of areas.

So, it has that that intersection with workforce broadly, and then I think a really interesting element for environmental DNA...Maine has, you know, a need like many other states in the nation to complement its current natural resource-based economy with growth in technology-based areas. Economically speaking, this is a formula that is generally recognized as is probably going to be essential for the future economic growth of Maine and most of the nation.

One of the tricks to getting to that end point is, how do you train the existing workforce or workforce that is classically been in that less technology driven sector? I like to think of eDNA is kind of the gateway of that training or a bridge type of technology because it applies to our natural resource needs immediately. It can address questions that we have around forestry and fisheries. These things that are that are centered to Maine's economy and culture now. But in the process, while learning these tools for environmental DNA, people are learning genetics skills. They're learning data skills. They're learning to apply technologies and they're building these skills that are immediately transferable if they were to go to forensics, if they were to go into biomedical area. You know, the genetic tools that we're using for environmental DNA overlap a lot with the tools that are currently moving forward biotechnology, other types of value technology. So, in this sense, we have the opportunity to start now with something that shores up and helps our current economy and workforce while at the same time building the familiarity and toolsets that can help people become innovators in related fields and hopefully grow those areas for Maine.

28:00 Ron Lisnet

And we mentioned Bigelow Labs. Let's make sure we acknowledge everybody that's involved. The major players are University Maine, Bigelow—who else is?

28:08 Mike Kenison

In addition, the University of Southern Maine, University of Maine, Machias, Southern Maine Community College, Eastern Maine Community College. We have some private, Liberal Arts colleges. University of New England, Colby College, Maine Maritime Academy. And then we have a series of other independent research labs like Bigelow Labs, you know, which is world renowned for their work in understanding ocean systems, particularly microbial ecology. You know, like Gulf of Maine Research Institute, which again has a long history of driving innovation in, kind of our marine economy.

So, it's a large set of players and that again really gets into just the group that's core to developing some of the research and infrastructure and education material initially. But again, the hope is this spreads out fairly quickly and broadly to a large set of partners and that partner group, you know, ranges from federal and state agencies. Tribal governments are interested in this as well. Through the intention again of at NSF EPSCoR, we...this has been designed as a program to try to be as comprehensive in who we reach in Maine and who we involve in this eDNA growth as possible.

29:25 Ron Lisnet

I imagine as a scientist you're asking or...and always will ask the same set of questions or look, investigate the same sorts of questions, but is this a game changer for scientists such as yourself, in terms of how you do your job?

29:40 Mike Kenison

This is very personal to me. I mean in the sense of a game changer. For somebody who's worked in and around fish ecology and biology for, you know, decades, for me that has literally been physical nets, surveys, historicals, getting into the water, which I'll never want to give up...which I love, I love dearly.

29:59 Ron Lisnet

It’s the fun part of your job.

29:59 Mike Kenison

But for many of us, the questions that we could ask were often very limited in scale or scope. Just trying to ask fundamental questions about the biology, ecology, evolution of organisms, and natural environment, we've long been constrained to limit it to a stream or two, a lake or two, or field or two plots, buckets, labs, and so on. Environmental DNA can be a game changer in the sense of being able to collect data at relatively low cost and relatively wide expanse. And so now the opportunity to ask really large-scale questions, really talking even through the ambition of this main eDNA grant, get to the point of asking questions really about what drives the stability and resilience of the whole coast of Maine. Top to bottom, lakes to the ocean. Those are questions that we couldn't grapple with with classic ecology/biology tools in the past.

Environmental DNA is getting us to that point, and in part I'm really optimistic that it's going to move to that level even more and more because it has a power to it that we've just not really had with so many other ecology-type data science tools, and that is, it brings the power of combining datasets like almost nothing else. We've seen this in the bio medical realm, right? The ability human genome project. Now there's where all these labs can access common information about a human genome, and they can contribute new data about genes and so on, and that's really driven forward our understanding of human biology, medicine, and so on.

Environmental DNA, because it relies on this same genetic code which is universal to all these organisms, means we can collect...a sample that's collected in Machias to understand about Alewife; we could draw data from that and combine that with a sample from Casco Bay on lobsters, and a study about harmful algal blooms in Sebago Lake, and pull these datasets together with hundreds and hundreds of other samples collected by Citizen Sciences, school groups, and others, and through that address questions that no single scientist could ever address on their own. The data just was never there to do it. So, we are really moving this up to a big data field and the sort of datasets that could allow us to mine and re-mine these data and understand coastal systems for generations to come.

[*Background music starts*]

32:28 Ron Lisnet

Well, we're eager to see where it's all going to go. I appreciate you taking the time to talk to us.

32:31 Mike Kenison

Oh, thank you. It was a pleasure.

32:33 Ron Lisnet

Thanks for joining us. You can find this in all our podcast in most of the places that podcasts are available: iTunes Podcast, SoundCloud, Stitcher, Google Play.

We welcome your feedback on this show as it develops. Drop us a line at Maine Question at maine dot edu.

This is Ron Lisnet. We’ll see you next time on The Maine Question.