Sarah M.: Here are the steps to eating a raw oyster. One, use one of those tiny oyster forks to make sure the meat is totally separated from the shell. Two, optional, squeeze a bit of fresh lemon or tap a dash of sauce into the shell. Three, open wide and slurp it down. Easy as one, two, three but in earlier times there would've been an added step or two because Virginia oysters were giant.

Rowan Lockwood: Oysters that were almost a foot long, we're talking oysters that you'd have to cut into several pieces before you could eat them.

Sarah M.: From Virginia Humanities, this is With Good Reason, I'm Sarah McConnell. Today, how ancient oyster fossils can help us preserve oysters of the future. Later in the show, when you want to catch a tiger, there's some key things to look for, paw prints, scratches on trees, but definitely the most interesting way to find a tiger is to ... if there's a scratch mark, they'll often pee on that tree or on the sand around it and if you smell their pee, it smells like popcorn. But first, fossils give away the secrets of the past and researchers say they can also help predict the future. Rowan Lockwood has been studying the fossil record in the Chesapeake Bay and she says a lot has changed in just a few hundred years.

Sarah M.: Rowan Lockwood is a professor of geology at William and Mary, she was named a 2019 Virginia Outstanding Faculty Award recipient. Rowan, you are at the forefront of a field called conservation paleobiology, what is that?

Rowan Lockwood: Well, it starts really all with anchovies. Back in the '60s, a scientist out in California noticed that the anchovy and the herring, basically the small fish harvest, was way down. A lot of people blamed pollution, they blamed the beginnings of climate change and he thought, “Maybe I could use the fossil record to figure out what's actually driving it.” He punched a bunch of holes all over the sea floor off the coast of California and what he found, looking at these fossil scales, is that anchovies and herrings just do this. They have basically a boom and a bust history where they get really common and then they're really rare, and then they're really common and then they're really rare, and it's a natural cycle.

Sarah M.: It seems scary though because you could look at the fossil record and say, “Don't worry about die-offs, they've always happened.” And yet, they could be cataclysmic now.

Rowan Lockwood: Sure. In the case of anchovies, we discovered that they naturally come and go, but in the case of a lot of other species, whether it's caribou or wolves or small mammals or oysters, that's not the case. Josh Miller, who's at Cincinnati, he has done a phenomenal job looking at where caribou used to migrate in the past, and we're talking going all the way back to the last ice age, where they used to migrate, but then also where they used to calve, where they used to have their babies. From the record he can help us see how that's changed over time and he can help people in the Arctic National Wildlife Refuge predict where they should or shouldn't build roads, where they could develop, all that sort of thing.

Sarah M.: Give me an example of how he is looking at the fossil record to tell us where caribou calved or roamed.

Rowan Lockwood: For him, it's all about the antlers. Great thing about caribou, both the males and females have antlers, they shed them, the females shed them soon after they give birth. As far as I can tell, Josh spends almost every summer up there walking, walking, walking miles and miles and tracking where all of those antlers are preserved.

Sarah M.: He is looking for fossilized antlers?

Rowan Lockwood: Yup.

Sarah M.: Where does he find those?

Rowan Lockwood: They're all over the countrysides. If you go up to the Arctic National Wildlife Refuge, you find a lot of antlers on the ground. He then has to date them and figure out are they 100 years old, 1,000 years old, 10,000 years old.

Sarah M.: That amazes me. You mean they're not 30 feet down?

Rowan Lockwood: No, no. It's all about getting buried, so in that particular area, there's not a lot of sand or sediment that's burying these things. At the bottom of the Chesapeake Bay where I work, there is a lot of sand bearing things, so in his case, his fossil record is just right out there in the open.

Sarah M.: You in particular in your research, have been looking at ancient oyster shells, why?

Rowan Lockwood: I'm fascinated in the fossil record of oysters mainly because I want to see what they looked like before humans came along. If you look at the Chesapeake Bay today, we have information going back about 50 years on what size the oysters were, where they lived, how they grew, but that's not very much time if you think about oyster history. In fact, we started dredging and we started fishing those oyster populations down over 100 years ago.

Sarah M.: How many oysters do we have now compared to, let's just start with maybe 50 years ago. In the '50s and '60s, what do the oyster population of the vast Chesapeake Bay look like?

Rowan Lockwood: Not great. By the 1950s and '60s, the oyster population was already probably at three or 4% of its historic abundance, we had already really decimated those populations.

Sarah M.: But now?

Rowan Lockwood: Now we're down to one or 2%.

Sarah M.: Is there a way you can help me envision how much of the Chesapeake Bay was once covered by oyster reefs?

Rowan Lockwood: Sure. It's estimated today, if you think about oysters sitting in the bottom of the bay, they're all filtering water, that's one of the reasons we care about our oysters in the bay. They're filtering water and people estimate it takes them over a year, for the living oysters in the bay today, to filter the whole volume, that whole bathtub, that whole bay of water. If you go back to the mid 1800s, it probably took about a week for those oysters to filter the entire bay. If you go back to the fossil record, the oysters that I'm studying, and they're about 200,000 years old, you go back that long, it took them about a day. We're talking about massive oyster reefs, some of them presumably reaching the surface, some of them with oysters that were almost a foot long. We're talking oysters that you'd have to cut into several pieces before you could eat them.

Sarah M.: If you are swimming in the bay back then and you gulped a mouthful of water, it had probably been filtered by an oyster?

Rowan Lockwood: Yes, and it would be much cleaner as a result. One thing to think about, if folks had been swimming in the bay today, it's pretty hard to see anything, if you do open your eyes the visibility's really low. Back then, it would have been crystal clear because of all the work of those oysters.

Sarah M.: What do you think decimated the oyster populations? Was it pollution, disease or overharvesting?

Rowan Lockwood: In my personal opinion, and this is based on some work I'm trying to do with ancient DNA, in my personal opinion, it's really overharvesting, those oysters will be just fine. They've lived with those diseases for a very long time and diseases don't tend to kill off shellfish, unfortunately humans do.

Sarah M.: You live near the Chesapeake Bay and you know how strong the fishing interests are for continuing to dredge what few oysters are left.

Rowan Lockwood: It's a really difficult balance, I think we have to keep in mind this socio-cultural side of the waterman's culture. At the same time, if there's no bay or the bay is super unhealthy, that culture isn't going to be allowed to continue. I think it's a difficult balance, but just as we've done with striped bass, with blue crab, we really need to think about the longterm sustainability, the longterm future of the bay and the oysters.

Sarah M.: What have you learned from journals of the early explorers and settlers as to what they actually wrote about seeing when it came to oysters and how they harvested them themselves?

Rowan Lockwood: There aren't that many historical records out there, but we know, for example, that Captain John Smith wrote in his journal that the oyster reefs were so large they were a navigational hazard. They actually had trouble coming up the bay into the James River, they had trouble not hitting or wrecking against those oyster reefs. He tells stories of oysters that were, quote unquote, "as big as paving stones."

Sarah M.: Tell me about the fossilized oysters that you've found. Where do you find them, how old are they and what are they revealing to you?

Rowan Lockwood: I'm really working with oysters from Delaware all the way down to South Carolina, a lot of the work I do is around the Chesapeake Bay so anyone who has ... thinks they have fossil oysters in their backyard, please give me a call. What I do is I slice them in half with a tile saw and when do that, and you look at the top of the shell, you can see that the shell has growth lines in it. There these really cool gray and white alternating stripes and I can count those gray lines and those gray lines represent winter, they represent when that shell was growing in the winter. I can measure the size of these oysters, I can count those gray bands and I can tell you how long they lived and I can start to get at things like population size, I can start to get at things like growth rates, that let me compare oysters today from oysters in the past.

Sarah M.: Are you finding that oysters from millions of years ago grew larger than they're allowed to grow now?

Rowan Lockwood: Yeah. Part of what we find is that, you know, the average oyster in an oyster survey today is maybe five inches long, it lives a maximum of five years. When I go in the fossil record, I'm finding oysters as long as 12 inches, I'm finding oysters that lived up to 25 years. This is a much longer lived animal than what we previously realized and it changes how we could approach restoration, it changes how we could think about bringing them back in the bay.

Sarah M.: Same species of oyster?

Rowan Lockwood: Exact same species of oyster, it's called Crassostrea virginica.

Sarah M.: How long ago did the oysters you're talking about live?

Rowan Lockwood: I'm working here with oysters that are anywhere from 80,000 to about 500,000 years old and they're all growing in the same temperature and the same salinity as the oysters today. The big difference is they're not experiencing overharvesting. When we harvest oysters today, we preferentially harvest the big ones. It's the big ones that are female and it's the big ones that have the most babies, so when we harvest oysters, if we're harvesting everything that's say maybe over three or four inches long, you are preferentially harvesting those really big females that have lots of babies. The way we harvest most oysters is by dredge and dredge pulls everything up so even if you were to dump

the oysters back down again, it's unlikely that they would survive. We need to get creative, we need to think about other ways or maybe even go back to historical ways of harvesting these oysters to make it more sustainable.

Sarah M.: Is this true not just for the Chesapeake Bay, but up and down the East Coast, along the Gulf Coast and out along the West Coast?

Rowan Lockwood: As I said, I've been studying oysters from Delaware down to South Carolina and what I'm finding is that it depends on the location. If you look in North Carolina, there's no real difference between the fossil and the modern oysters, they're generally the same size, they live for about the same length of time, they grow at the same rate. But if you look at the Chesapeake Bay or you look at Delaware Bay, today's ones are shrimps, they're really stunted in growth and they're not living very long.

Sarah M.: North Carolina has huge oysters or small now and small in ancient times?

Rowan Lockwood: Small now and small in ancient times.

Sarah M.: Why would there never have been giant oysters off the coast of Carolina?

Rowan Lockwood: Great question, one of my students and I are trying to figure that out. If you go far enough back in time, we're talking like millions of years, 20 million years, we had incredibly big oysters, two or three feet long, oysters. These were the ancestors of the modern oysters and they lived off of North Carolina. Why they existed then and not now, we think that it's related to plankton, the amount of food that they have to eat, but it's very difficult to test that.

Sarah M.: What to do to restore the oyster beds of your line?

Rowan Lockwood: Right now, most of the money that we spend on Chesapeake Bay restoration, most of that money that goes towards oysters really concentrates on baby oysters, are they raising them in the lab and releasing them or maybe laying down dead shell on the bay for oysters to land on? I would argue we need to spend a lot of time and energy, we need to spend much more of our focus on these really big adult oysters. Each adult oyster can produce over a thousand offspring in a season, wouldn't you want to spend more of your money preserving those adult oysters so they can keep producing those babies rather than spending your money on the babies themselves?

Sarah M.: How could you preserve adults, what would that look like to a dredger or an oyster harvester?

Rowan Lockwood: Right now in the bay, it depends on whether you're talking about Virginia or Maryland, but we have very few sanctuaries and the sanctuaries that we have, basically the no harvest areas that we have, they only last one or two years. Well, that might make sense. If an oyster is only supposed to live for five years,

but if these oysters are supposed to live for 25 years, it would make sense to have many more sanctuaries that lasted longer over a larger area. I think it really comes down to sanctuaries.

Sarah M.: Could we do that, could we have a 25 year moratorium on harvesting in certain areas?

Rowan Lockwood: It's a matter of political will, it's that balance between the socio-cultural side of oyster harvesting with the biology. I think from a biological standpoint, it would cost us a lot less money, it would be a lot less time and energy just to do those sanctuaries.

Sarah M.: Do you love to eat oysters?

Rowan Lockwood: I do. I'm an oyster lover, I think there are fabulous and I would love to know what an oyster that was ... 500,000 years ago, one that you had to cut up into small pieces before you'd eat it, I'd love to know what that tasted like. I also know that the more of those oysters that I eat, the tougher it is for the Chesapeake Bay to be restored.

Sarah M.: Rowan Lockwood is a professor of geology at William and Mary, she was named a 2019 Virginia Outstanding Faculty Award recipient. Coming up next, mountain side surgery on wolverines in Montana. Deborah McCauley is a veterinarian, but she doesn't treat fluffy the cat or sparky the dog, she treats tigers and wolverines and rhinos. McCauley is founder and executive director of VIEW, a nonprofit that's focused on treating diseases in endangered wildlife.

Deborah M.: I had been working for a decade as a wildlife veterinarian in Montana, in the greater Yellowstone ecosystem and I continued to see that there was a missing piece to conservation. Conservation largely approaches saving our endangered wildlife by habitat encroachment, poaching investigating behavior, counting numbers and climate change. Although those are really important issues, wildlife health is missing in our approach to including it in the toolkit for conservation.

Sarah M.: What do you mean wildlife health? Do you mean individual animals are stressed and we need to care for them?

Deborah M.: It's more, I would say prevention, a disease surveillance program. A comprehensive disease surveillance program is critical to helping our endangered wildlife, so investigating the animals that are on our priority endangered species list or threatened species list, also the diseases that most affect those animals, what diseases are wiping out a whole population. The saiga antelope in Kazakhstan, 210,000 animals died within a fortnight due to disease. In that case, there wasn't enough infrastructure and disease surveillance programs on the front end to understand if there was an issue, but yet tens of millions of dollars was put into anti-poaching efforts and more land,

but disease was not included or investigating disease was not included in their conservation package.

Sarah M.: Tell me about saiga antelope.

Deborah M.: Saiga antelope, one of the veterinarians who worked on that project in London and works with us in Nepal and it was an international story, and within two weeks time, 70% of the global endangered wildlife population of the saiga antelope died due to disease. There were dying or dead saiga antelope littered across the whole landscape, I actually didn't see any live animals at all. I saw this same picture when I was working as a wildlife veterinarian in Montana with a big horn sheep local die off, and that does happen. It's been happening for decades in the rocky mountains, where they will interact with domestic sheep, cause no sickness and domestic sheep at all, but will wipe out up to 90% of that wild sheep population and from a disease that the domestic sheep share with wild sheep.

Sarah M.: You worked out west on the big horn sheep project, what other projects?

Deborah M.: I worked for wolverines and we tracked up to 10,000 feet to capture wolverines on islands of snow and always when the grizzly bears are sleeping because if you trap them, we have to bait them and the grizzly bears we don't want to have to interact with at the time. It's often eight hours of hiking up to the top of a mountain and doing surgery in the middle of the night. We would have to do surgery because wolverines had this thick neck and tiny little head and you can't fit a GPS collar on them, so they needed to have a veterinary surgeon to be able to implant these small radio transmitters into their abdominal cavity. Then I'd sew them up really quickly after anesthesia and wake them up and away they would go. I was also very fortunate, it was a perfect job for me because I was an ultra runner and I just loved to climb mountains, that's what I like to do. I was able to combine my passion of running with my passion of saving a threatened species.

Sarah M.: You didn't know you liked wolverines until then, right?

Deborah M.: Absolutely, but I love them. Tigers and wolverines are definitely my favorite animals.

Sarah M.: Tell me about wolverines.

Deborah M.: Not Too many people have touched them as much as I have. They definitely have their big claws that you would think of and these ferocious mouths. They're lovely when they're sleeping, but funny, interesting thing, they're beautiful little animals, but they have a very thick oily coat and they're stinky. I actually like that stinky smell, I don't know why. We would often be doing surgery, I'd have a headlamp on my head and they would hold a heater over my hands so I could obviously do sterile surgery. We were a very small team, but

we would either check out, often snowshoe out, ski out and when I was pregnant helicopter out to the dens, and we'd capture the wolverines. We were able to find ... There was unlimited trapping of wolverines at the time and we found that there was about 300 wolverines in the lower 48 so they need to have a little bit more protection.

Sarah M.: There are only 300 in America?

Deborah M.: Yes. The Endangered Species Act needs to have research on it first, in order to understand if an animal can go on the Endangered Species Act, that's why we did the work. Since there's so many animals, endangered species, on Endangered Species Act, there's only a limited amount that can go on them.

Sarah M.: When you talk about the habitat, it reminds me of a proposal not so long ago by the great biologist E. O. Wilson, he calls it half the earth. His outlandish, exciting visionary proposal is that we set aside half the earth to preserve it for habitat.

Deborah M.: Yeah, but as we know that's not actually realistic, we have so many people. For example, in Nepal ... There are 30 million people that live in Nepal and there is I think 6.2 animals per person, and we share disease with our animals, in our wildlife, 60% of diseases, infectious diseases, humans share with animals. Therefore, if you think of it in the other way around, how agriculture, animals and humans living in a very close quarter, where there are endangered wildlife can share disease with the endangered wildlife. Through veterinary medicine, it's very hopeful in that we have ... Once we investigate diseases that we need to mitigate, then there are preventative and treatment measures.

Sarah M.: What are the wildlife animals in Nepal that you have treated?

Deborah M.: It's wonderful, they have Bengal tigers, greater one-horned rhinos, they have red pandas, they have snow leopards, they have an array of exotic birds and reptiles. It's a really biodiverse area in Nepal. In Chitwan National Park, they have about 200 Bengal tigers and so what we're trying to do is investigate what types of diseases they are exposed to. Our organization, VIEW, Veterinary Initiative for Endangered Wildlife, we're about initiating a program so it can be sustainable within a country. We've been able to help the wildlife veterinarian there, develop a program in Chitwan National Park to be able to collect samples of tigers when they have conflict in the buffer zone to investigate the diseases that these tigers are exposed to.

Sarah M.: Have you trapped tigers?

Deborah M.: It's one of the most wonderful experiences of my life. When you want to capture a tiger or understand where they are in the forest, you obviously look for the paw prints on the sand, you look to see if there's any kills, you look for scratch marks on the trees beside you, but definitely the most interesting way to find a tiger is to ... If there's a scratch mark, they're often pee on that tree or

on the sand around it and if you smell their pee, it smells like popcorn. The way one catches a tiger is you go out about 10 elephants, there's a darter, so they bait the tiger and we sweep the forest and funnel that tiger towards the darter. That darter will anesthetize that tiger and will either correlate or investigate. We never ever take samples unless they're being captured for what research reasons or for management purposes.

Sarah M.: I saw a video online once where a tiger who seemed to be from fairly far away made fast ferocious leaps on top of somebody on an elephant, so they're very agile.

Deborah M.: That's a funny story that's very personal to me. The night before the first time I ever went out to capture a tiger, they showed me that tiger picture, you're in the jungle and there's grass, really, really tall grass, because the tallest grass in the world is in India and in Nepal. There's a [foreign language 00:23:22] which sits at the front of the elephant and the tourist is taking a video, and you see grass and nothing, nothing, nothing. Then, literally feet in front of the elephant, a tiger jumps out on top of the elephant's head and attacks the elephant and the [foreign language 00:23:36]. I was shown that the night before we were about to capture the first elephant and I thought, "Well, I'm the vet, I'll stay on the truck where the oxygen tanks are and all that equipment."

Deborah M.: But because it was Asia and they're really wonderful about being great hosts, let's say, I got on the first elephant in the front of the pack, in front of everybody and I was like, "Wait a second, I didn't expect to be on the first elephant." We did see that the tiger right there, but I was not attacked obviously.

Sarah M.: But you had fear.

Deborah M.: Every time we capture it. I usually cast her ferocious animals, so almost every time there is adrenaline, I would say, darting an animal every time, but that's the excitement in it.

Sarah M.: Who did you find were your mentors in this field as you were coming on?

Deborah M.: One of the key people was Dr. Gretchen Coffman, who is now my partner, but at the time she was Director of Conservation Medicine at Tufts University and she has a very comprehensive, huge love for endangered wildlife. She actually has a sister that lives in Nepal and she had been working in Nepal in the vet school for many years so we brought the university and the field wildlife work together to develop VIEW and create a comprehensive program where we partner with not only the people in the field doing the conservation work, the university, which is only 12 kilometers from our laboratory in Chitwan and also the government.

Deborah M.: One of the key things, I think amazing about VIEW is that we developed a database, a wildlife health database, tailored specifically for people that work in the field and endangered wildlife, it's the first in the world. I had been wanting

to do this for a really long time, but couldn't find any company or software company to help us, so Gretchen and I bootstrapped our way to creating a wildlife health database because it wasn't available. What we've done is, as if you would go to a human hospital and there's a database that puts your name and your medical history and your medical ailments in that database, it's the same in our database. A tiger gets a mobilized, we put a number to that tiger, we microchip that tiger and we also know who is the one that had that interaction.

Deborah M.: You can upload photographs from that interaction, and then if it's sick and it goes into the hospital, we have a whole database on following what immobilization drugs were used, what treatments were used, what worked, what didn't. Or, if an animal dies and a necropsy was done, every single sample, as if you went to the supermarket and scanned for numbers onto a scanner, you have a database that will investigate and follow all the biological samples of that tiger.

Sarah M.: How many people are working with VIEW now, this organization and what do you want? How do you want to grow?

Deborah M.: VIEW created a template in Nepal because we saw the need, we created a template for building a comprehensive wildlife program that's sustainable within a country. Not only do we have a field laboratory and an investigative laboratory and a hospital that's being built, we're also including it into the government. This can be taken to other places across the world, we've been just asked to go to India to not only one of their tiger reserves, but six of their tiger reserves and also to go to the Greater Yellowstone Ecosystem. We're just starting our work in the GYE, working with Wyoming and Grand Teton National Park.

Sarah M.: What do you need from us?

Deborah M.: Definitely support. We definitely are on a bootstrapping grassroots programs, so VIEW needs funding to be able to get veterinarians, to be able to work on a global scale, to be included into the conservation toolkit. What's happening with conservation is excellent, but this also is a piece that needs to be included, and if we can continue to do this, we can make a difference. We're already watching and making a difference.

Sarah M.: Deborah McCauley is founder and executive director of VIEW, a nonprofit that's focused on treating diseases and endangered wildlife. This is With Good Reason, we'll be right back.

Sarah M.: Welcome back, this is With Good Reason. Imagine that pristine summer vacation spot house on the lake, the cool water is clear and blue, some of America's most famous lakes like Lake Tahoe are known for their sparkling blue water, but America's blue lakes are starting to disappear. Dina Leech is a biology

professor at Longwood University working on the lakes project. Dina, are we losing our blue lakes?

Dina Leech: We may be, yeah.

Sarah M.: How many are there?

Dina Leech: It's a challenging question how many lakes are there in the United States. There's not an official list, our best estimates are around 380-some thousand and in 2007 of those, maybe about 45% would be characterized as blue lakes, but moving into 2012, it could be as low now as about 25%.

Sarah M.: So in only five years, we lost a lot of blue lakes.

Dina Leech: Yes. Yes, that is a very short time period.

Sarah M.: Why are we even counting how many blue lakes we have?

Dina Leech: The color of a lake can tell us a lot about the water quality or the health of that system. Blue lakes, those that are crystal clear that we can see deep down into the water column, those are lakes that tend to have low nutrient pollution, not a lot of organic matter coming in from the surrounding land, and that's what gives them that clear blue color. As we start to increase nutrient pollution into a lake, that stimulates all that algae to grow and so those leaks shift from being blue to green because of all that algae.

Sarah M.: Where do you mostly see blue lakes?

Dina Leech: Blue lakes tend to be in mountainous areas that have very small watersheds, so the land that drains into the lake, so small watersheds, less nutrients and organic matter coming into those systems. We also see them in areas where there's not a lot of soil around the lakes, so as water runs off, it's not carrying a lot of stuff with it to change its color.

Sarah M.: When did they create this National Lakes Assessment, which is check the health of all these lakes or at least a good sampling every five years?

Dina Leech: The National Lakes Assessment, the first one was in 2007. Of all those 380-some thousand lakes, the EPA went out and sampled over 1,000 of them and they measure all kinds of different parameters on the chemistry of the water, the biology, what kind of organisms are living in them, what sort of activities are going on in the watershed, is there agriculture, industry, recreation. Based on what's happening in these 1000 lakes that we sampled intensely, we can make projections about what's going on in thousands of more lakes across the country.

Sarah M.: What are the colors that scientists generally recognize lakes should naturally have?

Dina Leech: We as aquatic scientists, we categorize lakes into four different colors. We have blue lakes, which are those crystal clear waters with low nutrient and organic matter levels, we have brown lakes, which are lakes that have a lot of organic matter coming into the system, you can think of that like a tea bag, the more you leave your tea bag steeping in that hot water, the darker brown it gets. The same thing's going on with the lake and organic matter, the more organic matter coming in from the leaching of soils and degradation of plant matter, that's what's giving it that brown color.

Dina Leech: We also have green lakes, green lakes would be lakes with a lot of nutrient or fertilizer coming into them, which is stimulating the growth of algae, giving it that green pea soup color. Then finally, we have murky lakes, murky lakes are lakes that are brownish-green in color. That's because they're receiving both organic matter and fertilizer inputs from the watershed, so you have this brown color from the organic matter, but you also have a lot of algal growth in there because of the nutrients. We tend to think of those murky leaks as being systems that tend to be more polluted and have lower water quality.

Sarah M.: Do we know anything about what lakes looked like maybe 100 years ago compared with now?

Dina Leech: Yes. Some of the interesting data sets are out there, particularly in the northeast and the northwest, we've noticed this freshwater browning, that lakes are getting browner and color because the land for some reason is becoming more leaky to organic matter. Again, to use that tea bag analogy, for some reason the tea bag is staying in there longer, we have this darker brown color. Why is that? We don't know for sure, but it could actually be a good sign. One of the things that causes lakes to actually get bluer is acid rain, when acid rain falls on a watershed, it makes the soil more acidic, when soils are more acidic, they hold onto organic matter tighter.

Dina Leech: Because of legislation in the '70s, the Clean Air Act, we've cleaned up our air pollutants so acid rain has declined, which is a good thing. Now, soils are starting to become more basic and as they become more basic, they are not holding on to organic matter as tight as they once did when they were acidic. That could be ... Maybe some of these blue lakes are actually returning to their natural state of being a brown lake.

Sarah M.: Isn't that fascinating?

Dina Leech: It is.

Sarah M.: Well, what you just said about if we're having less acid rain, we could see a decrease in blue lakes, that would be a very natural and welcome consequence. How are we to think about the health of our lakes?

Dina Leech: It's a complex question because you have natural processes that are occurring that affect the color of a lake, but there's also a lot of human activity within the land surrounding a lake, which can influence its color for example, agriculture. We know that lakes that are near a lot of agricultural activity tend to be either green or murky in color and that's because that processing of the land and application of fertilizer increases runoff to nearby lakes, which turns them brown and also stimulates algal growth. Yes, there are natural processes that can affect the color of a lake, but we also have to be mindful about how we as humans and what we do to the land surrounding these waters or even to the waters directly. What we put in them can affect their color.

Sarah M.: I feel confused about what to think about the loss of blue lakes. I got it when I thought that we were polluting the lakes, but if we're losing blue lakes because we've cleaned up acid rain, I don't know what to think.

Dina Leech: It's a complex question and it may actually be a good sign for the environment. Like you said before, all lakes can exist in any one of these four different colors naturally and we're partial to blue lakes because we as humans find them beautiful, but a brown lake, as someone who studies organic matter, I think brown lakes are beautiful too. They're very interesting systems with organisms that like to live in them too, but the question is, has that lake always been brown or has it become brown more recently because of human activities or as a recovery to acid rain?

Sarah M.: What are scientists saying about it, the general consensus is concern?

Dina Leech: There are many people asking this question about browning, is it recovery from acid rain or is it due to climate change? We have increases and global temperature, which increases the activity of bacteria and other organisms, fungi, earthworms, they're the ones that are creating soil and processing that organic matter in the soil. As they're working faster, there's more organic matter that's available to run off into a nearby lake. Then, compound that with how climate change is altering precipitation patterns, if we have increases in precipitation, that rainfall is going to pick up that organic matter in the soil and then carry it with it downstream into the lake.

Dina Leech: Many scientists are working on this question, what is it? And what we're finding is that it depends, it depends on where that lake is. In some cases we have data that have looked at changes in acid rain over time to see if the rate of browning matches that recovery from acid rain. In some cases, for some lakes it does, but for other lakes it doesn't so that suggests that something else is going on in those systems. One of the major findings of our study is yes, we're losing blue lakes and that's cause for concern but the other part of that is that we found an

increase in murky lakes. Remember, those murky lakes are brownish-green in color because have both increased organic matter and nutrient runoff. Those murky lakes, we found that they have even more algae growing in them than green lakes and a lot of that algae tends to be cyanobacteria or blue-green algae.

Dina Leech: Those are the types of algae that produce toxins that can be harmful to human health or to our pets and the other organisms living in those systems, things like microcystin concentrations which can be harmful to your liver or even cause cancer. These murky leaks have more blue-green algae and the potential for more of these algal toxins that can make us sick. The other thing that we found is the National Lakes Assessment program does a good job with collecting data on not only the kind of algae that's in the water, but the zooplankton, zooplankton are really important to the aquatic food chain. We have algae at the base of the food chain, these zooplankton consume algae and then small fish consume the zooplankton and then big fish eat the small fish, so these zooplankton are central to the aquatic food chain.

Dina Leech: What we can do is we can take the ratio of how much zooplankton are living in the water to how much algae are living in the water and that ratio can give us a good indication about how much energy is moving up that food chain. What we've found is that the ratios are pretty low, suggesting that even though there's lots of algae in those systems, that energy is not making its way up the food chain and so there's the potential for murky lakes to have reduced fisheries maybe now or potentially in the future. Unfortunately, we couldn't test that hypothesis directly because the National Lakes Assessment program doesn't look at fish, either what kinds of fish or the number of fish living in a lake. That's just too labor-intensive, of all the other things that they're collecting but that is one of the things that we would like. Maybe there are other datasets out there with fisheries information that we can explore lake color and fisheries to know in a murky lake, are those fish suffering in some way?

Sarah M.: Dina, I had not known about the National Lakes Assessment. I'm glad it's there and that we're doing these every five years.

Dina Leech: Yeah, it's a tremendous resource and I hope that it will continue to be funded into the future because it provides a wealth of information on many different issues.

Sarah M.: Dina Leech is a professor of biology at Longwood University. Coming up next, the power of caterpillars. While forests in most of America are deep summer green right now, in a few short months the leaves will start changing colors. Actually all kinds of things affect fall foliage, including caterpillars. Rebecca Forkner is a biology professor at George Mason University, she studies caterpillars and the surprising things we can learn from them. Rebecca, I've heard that when you were a young scientist, you really wanted to study primates but you-

Rebecca Forkner: I did.

Sarah M.: ... ended up falling in love with caterpillars.

Rebecca Forkner: I did, yeah. It is just the incredible correlation when we see things that mimic tarantulas, we see things that look like poop, we say things that mimic a bird feathers, even though they're a caterpillar they look like a fluffy feather, we see things that are big and fat, larger than your thumb, that are green and smooth, we call them pebble ones, they are things that have giant eyes like snakes. There's this just enormous, beautiful variation that you wouldn't expect if you were thinking ... Most people, for example, who don't study caterpillars refer to them as worms, like you might think about a little brown earthworm, but they're just so variable, including ones that are clear and look like icicles.

Sarah M.: I saw a video last night of a caterpillar with clear skin, you could see the insides through and through and as I watched this creature pumping its heart sending little veins throughout the body as one pump-pump, pump-pump, I thought, "Oh my gosh, caterpillars are people."

Rebecca Forkner: Right. It reminds me of a toy that I had as a child, it was a invisible man and an invisible woman, you could take the different pieces apart and see all of the veins on the inside and all of the organs. It's really similar, you can actually see what the caterpillar is chewing on as it swallows so those were always fascinating to me.

Sarah M.: So often, so-called tent caterpillars, the ones that form these vast spider web-like nests in trees then eat their way through the tree when they emerge, have been what we've mostly thought of with caterpillars, and those are just seen as pests, they ruin crops. Do you see them differently?

Rebecca Forkner: I certainly do, and tent caterpillars especially I don't consider to be pests. They will certainly damage your oak trees, for example, on your front lawn or cherry tree is definitely one of their favorite foods, but they communicate with each other through chemicals they leave on the silk so they're our family essentially. They feed together, they nest together at night and they will eventually wander off on their own individual journeys and go to different trees in the forest and wind up not doing quite a lot of damage. The ones that I worry about a little more are the ones that are crop pests, things like the cabbage whites that will definitely damage your crops or eat your corn. I often find hornworms for example, the caterpillars that feed on corn when I go to the grocery store and I peel back an ear of corn and peel the husk off, those are the ones that are a little more concerning about crop damage.

Sarah M.: Do you get so into it that on one level you feel fond of them?

Rebecca Forkner: I do and I will admit that my students and I have given them names when we are rearing them in the lab and keeping track of their development. We've had in

some cases several hundred at a time, and we have had them chew through containers and escape and run around the lab so we have a constant number of babies to take care of as we say.

Sarah M.: Tell me about the kind of symbiosis that occurs between plants and caterpillars or plants and pests, plants are able to form their own repellent, their own insecticide to try to defend themselves against caterpillars?

Rebecca Forkner: That's right. In fact, nicotine in cigarettes is in fact an insecticide that tobacco makes to deter insects, often things like small beetles but it does deter some of the caterpillars as well. There's a variety of things like nicotine, cocaine, lots of things that we might commonly hear about that are toxic or hallucinogenic are plant compounds that are used as an immune system effectively to deter damage on the plant.

Sarah M.: Are there efforts underway to try to mimic these natural pesticides so we could maybe replace the roundup poisons that we're using now?

Rebecca Forkner: What we've actually tried to mimic is a bacteria compound, a chemical in a bacteria that essentially causes the insect gut to explode, that's called Bacillus thuringiensis or Bt for short, that's the chemical that we often use in genetically modified crops to make them resistant to insects. We're at George Mason University starting a drug discovery program that looks at both plants and insects and other organisms, in some cases, Komodo dragons, to look for the discovery of new medications.

Sarah M.: I've read that we're in the midst or on the brink of a kind of insect apocalypse, could that possibly be the case? It always seems like there's so many.

Rebecca Forkner: It does. I have to say that this is an open area of debate right now among entomologists, among scientists who study insects. I think we are in fact witnessing a decline, we have studies of butterflies from Britain that have been going on for hundreds of years that do document the loss, the enormous loss of species. I know from our own work here in Virginia on bumblebees that we are seeing almost a precipitous drop, a complete loss of many of the species that we rely on as pollinators and fireflies I think are the classic example that most people notice them disappearing from their backyards. We have been studying and following these caterpillars, for example, in Missouri for three decades and we have been watching a very, very slow decline in the number of individuals that we see.

Sarah M.: Is the thinking it's more because of habitat loss or because of pesticides?

Rebecca Forkner: It's a combination. You might not know that we used to have the rocky mountain locust in the United States, which caused enormous famine and it is extinct, and the cause of loss for that species was a combination. It was both us breaking up the habitat and converting grasslands to agriculture as well as

widespread use of a variety of insecticides from simple things like lead arsenate, which were some of the first insecticides, to things like DDT. It was a combination of both of those things that drove something that used to occur in the trillions and trillions of numbers to the brink of extinction. It is likely similar for a variety of other insects, whether it's pollinators or caterpillars or butterflies that we see, it's a combination of both of those factors along with some of the changes that we're seeing in the global temperature.

Sarah M.: Even when you are studying caterpillars and studying the insect effect on autumn colors, you're also seeing something much larger, you are also seeing not just seasonal change but actual climate change.

Rebecca Forkner: That's correct. We see much more changes than simply just, for example, it being warmer in the summertime. What we are seeing are things like ... I have a colleague, Jay Yang, at the University of Virginia, he and his colleagues refer to it as false springs. You will have spring coming earlier in the year, but then you will have a frost that occurs say in June so that you have what would typically be an early spring temperature later in the summer. That has a very negative effect on insect populations, we've been studying that with our longterm caterpillar data from Missouri as well, so we see false springs, we see later autumns, we see more extreme temperatures. I have a student right now who is studying how extreme summer temperatures change the color of butterfly wings, for example. There's a lot of different changes than one might expect from just simply saying the words, climate warming or global warming or temperature change. There's a number of very different seasonal things that are happening as we do change the amount of CO2 in the atmosphere.

Sarah M.: Well, Rebecca Forkner, this is fascinating. Thank you so much for sharing your insights on With Good Reason.

Rebecca Forkner: You're welcome, I'm excited to talk about caterpillars any day of the week.

Sarah M.: Rebecca Forkner is a biology professor at George Mason University. Major support for With Good Reason is provided by the law firm of McGuireWoods and by the University of Virginia Health System, connecting doctors and patients through telemedicine to deliver high quality care throughout Virginia, the US and the world, uvahealth.com. With Good Reason is produced in Charlottesville by Virginia Humanities. Our production team is Allison Quantz, Elliot Majerczyk and Cass Adair. Jeannie Palin handles listener services, some music from this week show is from Blue Dot Sessions. I'm Sarah McConnell, thanks for listening.