Prairie Pod Transcript

Season 5, Episode 43: There's a fungus among us; arbuscular mycorrhizal fungi (AMF) and their role in prairie reconstruction success.

Hosts: Sara Vacek, U.S. Fish and Wildlife Service Wildlife Biologist, Megan Benage, DNR Regional Ecologist

Guest: Diane Larson (U.S. Geological Survey), Laura Aldrich-Wolfe (North Dakota State University)

Podcast audio can be found online at mndnr.gov/prairiepod

Transcript:

((music playing - sounds of birds chirping and wind blowing))

Megan: Hey Prairie Pod listeners, I'm Megan Benage, regional ecologist with the Minnesota Department of Natural Resources.

Marissa Ahlering: And I'm Dr. Marissa Ahlering, lead scientist with the Nature Conservancy in Minnesota, North Dakota and South Dakota.

Sara Vacek: I'm Sara Vacek, wildlife biologist with the U.S. Fish Wildlife Service, based out of the Morris Wetland Management District.

Mike Worland: And I'm Mike Worland. I'm a wildlife biologist with the Minnesota DNR Nongame Wildlife Program.

Megan: We are part of the Minnesota Prairie Conservation Partnership and we are here to help you discover the prairie.

Marissa: Discover the prairie.

Sara: Discover the prairie.

Mike: Discover the prairie.

((music playing and sounds of birds chirping))

Megan: Welcome back to the Prairie Pod everybody. Oh my goodness, I am so excited about what we're talking about today and I cannot be more excited to introduce you to our brand new co-host, Sara introduce yourself.

Sara: Hi Megan. I'm Sara Vacek. I'm a wildlife biologist with the U.S. Fish and Wildlife Service and I am located at the Morris Wetland Management District in Western Minnesota and I'm super excited to be here.

Megan: You do that so well, nobody will even know that at the beginning of the podcast that it was a recording. You did great. You sounded exactly like - -

Sara: Thanks.

Megan: - - your recording. I'm really proud of you.

Sara: 'Cause we had to say it five times over practicing the intro.

(Laughter)

Megan: Hey, excellence takes time. Excellence takes time.

(Laughter)

Megan: It's true for prairies and it's true for people.

(Laughter)

Megan: That works. We're just going to jump right in here because we've got two very special guests with us and I have a lot of questions. Sara, you have a lot of questions to ask too.

Sara: I do have a lot of questions.

Megan: I know, this is a topic - -

Sara: This is going to be a good one.

Megan: It's going to be a really good one. Oh we should, no, we should set lower expectations, so then people like walk away being like oh my gosh that was amazing. We don't want that - -

Sara: This will be an okay podcast.

(Laughter)

Megan: Wow, that's – okay. Now we're just, this is no disrespect to our two guests today.

Sara: We should move on.

Megan: We should just go - - should just move right on. Okay, we have discovered a fungus among-us, so we talk a lot about diversity on this podcast. This is a thing that we talk about all the time, right? Diversity makes the world go round, particularly in prairie ecosystems. And so this week, we're again going underground to uncover the roll of our arbuscular mycorrhiza fungi, yes, I did have to practice saying that about 62 times

because it is a mouthful folks, and if you're listening to this and you're like I don't even know the words that that lady just said just say AMF and you can sound cool like all the other prairie ecologists. It's great and we're going to explain a lot more about what AMF is and how it can contribute to success in prairie reconstructions and we've brought two fabulous experts with us today and I'm just going to let them introduce themselves. Diane, do you want to start?

Diane: Sure, I'm Diane Larson. I work with the U.S. Geological Survey. I'm stationed at University of Minnesota at St. Paul, and I have gotten totally enthralled by these AMFs but I'm more on the manager side of things and Laura I think is more the expert on the actual organism.

Megan: Perfect, Laura go ahead, she's cued you right up.

Laura: Yeah, I noticed that, okay. So I'm Laura Aldrich-Wolfe and I'm at North Dakota State University and I'm a mycorrihiza researcher, as well as just really fascinated by fungi that live in and around roots and interact with plants.

Megan. Ahh this is going to be so good. Sara, I'm excited, I can't even contain it.

Sara: I'm excited.

Megan: Oh! Okay, so the first question I have to ask to both of you because everybody's going to want to know – fungi, fungee, fungeeee. How do you say it?

Laura: You get to, you get to pronounce it however you'd like.

Megan: Oh well look at that. (Laughter)

Laura: So because you know, if you're Italian, you're going to say funge right?

Megan: Oh.

Laura: 'Cause then if you're from the west coast like I am you're going to say fungi.

Megan: Yeah.

Laura: And then that lends itself to all sorts of puns, so it's good, yeah.

Megan: There it is. I say fungi all the time. Diane, do you say it different? Is there a different Midwestern – I'm Midwestern, so I say fungi too. What do you say?

Diane: You know, you know, I say it with a soft g, so fungee.

Megan: Oh fungee. That wasn't even in my original choices. I like this. It sounds like a soup.

Sara: There's a lot of choices.

Megan: A lot of choices. Fungee, fungi. What was the Italian, fungi?

Laura: Fungi, yeah.

Megan: Yeah, that's, oh, man.

Megan: All right. Well, okay. We're going to jump right in.

Sara: Whatever you say, say it with confidence and everyone will think that they're wrong.

Megan: That's what we tell people when we're learning plants and they're struggling with Latin names. It's - - we don't speak that language anymore. As long as you know what you're talking about and what plant you're looking at and you can spell it, that's all that matters. Or you can get close in your spelling don't panic - - okay - -

Laura: I was going to say spelling should be optional, right? Yeah.

Megan: Yeah. (Laughing) It's okay. Don't panic. As long as you can point it out to somebody and be like this one, this one on the list is what I'm talking about. That's all that matters. All right. Let's jump into this world of fascinating fungi. So what are AMF? Laura, you start us out.

Laura: Okay, so AMF or I often say AM fungi, are a group of fungi that have been associating with plants for as long as plants have been on land. So even when we look at really early fossils of the first land plants, we see fungi in their sort of, they're not exactly roots, right, but they're proto roots. We see really similar structures to what we see today. So this is a really ancient association between plants and fungi, and I think despite the fact that it's ancient, we're still working out what they actually do in the interactions with plants. So we have I think more questions than answers at this point, but suffice it to say this is group of fungi, they're ancient, they've been associated with plants for a really long time, and so long in fact that they've lost their ability to live without plants. So while we can set up conditions the plants can live on their own, the fungi are dependent on plants and we used to think it was for sugars, but recently, researchers have been able to show that they actually can't synthesize lipids on their own. They require precursor molecules from plants. The plants play a really important role in their nutrition, so they're dependent on plants in order to survive.

Sara: So I'm sure there's, this is one of those topics where there's 8,000 times more things that we don't know than we do, but could you give us a few examples of what kind of role they play in the ecosystem and, you know, that relationship between the plants and the fungi is part of it, but then what do we kind of think we know?

Laura: Right, what are we think at this point. So what you'll notice is that biologists when they're talking about AM fungi will generally be careful to distinguish between talking about them in terms of them being symbiotes and forming a symbiosis, so living closely with plants, versus being mutualist, where we're assuming that it's a mutually beneficial relationship. So we can show under different conditions that sometimes they're living closely with plants, but of course, they're benefitting themselves, right. And so then they may not necessarily be benefitting the plants, and the same thing it can work the other way too, that the plants may be benefitting themselves in the relationship at the expense of the fungi. But we can also certainly see plenty of cases where it is a mutually beneficial relationship, and so the idea there is the plants are providing fungi with energy that they've lost the ability to acquire in any other way, while the fungi are because they're colonizing the roots and living also as hyphae outside of the roots in the

soil. They're definitely important for plant uptake of nutrients that become depleted around roots, so nutrients that don't move easily in soil water. But then also because they're living inside the roots, they seem to play an important role in helping to protect the plants from pathogens, for example, from disease, and also from pests, so things like nematodes, or at least I should say there are good nematodes too for plants, but for nematodes that can be damaging to plants. So they play both this protective role and also definitely a nutrient acquisition role. And then I think something that's still really that needs a lot more work is thinking about their role in drought and how they might protect plants from drought as well.

Laura: What are some of the less mobile nutrients that you were just referencing?

Laura: Well so phosphorous is the key one, right? But also to some extent ammonium would be less mobile, right. So nitrate is going to be readily mobile in the soil, so we think about as the fungi not being particularly important for nitrate. But certainly potentially for ammonium is important as well. But the key one would be phosphorous, then also zinc, copper, to some extent belong. Diane, do you have things you want to add there?

Diane: No, you've covered it.

Megan: It's not every day you get to mention boron in a Prairie Podcast, - -

Laura: That’s true.

Megan: - - so I feel like that was a win, regardless of whatever happens next. We're already out of the game. Diane, fielding a lot of questions this year about fungi. But before I get into all of the pressing questions that managers are asking, let's ask the first one. Let's set the stage here or the table if you will. Diane, why should a prairie manager care about these fungi?

Diane: Well, there's several reasons, but three of them have come to mind as I think about this. And the first is that we have really poor establishment when we try to get into these really high diversity mixes of species, of prairie plant species, and there have been a number of papers that I've suggested that the fungi can improve the ability of especially these hard-to-establish species, like highly conservative species or the rarer species. They can really improve their chances of persisting in environments. So since those are the expensive things to establish and the hard things to establish, perhaps we can have a little insurance if we add their preferred fungi. The second thing is that climate is in fact changing, and as Laura pointed out, the fungi can help the plant attract or bring in nutrients that it couldn't otherwise access maybe water that it couldn't otherwise access. And they actually also help with stabilizing the soil so there's less erosion. So you've got a couple of different things that can happen with respect to climate change that would be of benefit. And finally, you know that we have problems with exotic cool season grasses, the smooth brome and the Kentucky bluegrass, and we know that smooth brome in particular, but others can in fact change the soil biota when they invade. And so if we can somehow understand the way that we can improve soil biota for the native plants as opposed to these invasive plants and give them a

competitive edge over the invasive plants, I think that would also be a reason that managers should care.

Sara: Those are all good reasons. And I've been thinking about this a little bit, Diane. You and I have been working on questions about prairie reconstructions together for a long time. Maybe I won't say how many years, but it's been a number of years. - -

Diane: You could say there, Sara. Yeah.

Megan: A number of years.

Sara: I won't, I won't date us. But, but one thing I've noticed is even aside from this conversation is how as we move along, of course, we're getting more and more refined in the kinds of questions that we're asking and the way we're thinking about things, and this feels like the natural next progression is to think about some of these things that are happen underground, and I've always, when, when I'm getting some of these questions from our managers about AMF, I'm starting to use a pollinator analogy with them that when we first started planting prairies, we really weren't thinking about pollinators per se. We were just sticking some seeds in the ground and hoping the prairie came back, and then we started to think a little bit more about some of the invertebrate populations in our prairies, and tweaking how we were doing things to favor them, and now I'm getting to like okay, so now maybe we're in a place where we need to think about AMF as like the next sort of way that we think about how to refine our prairie restorations. It's exciting to me.

Sara: So you told us a lot of reasons that we should care. Do you have any thoughts or suggestions or hints about how managers can support the AMF in our prairies? And maybe not even as far as like we'll get to the question about introducing them as part of their reconstruction I think in a little bit, but just what do they need besides having plants in there. I don't know if that's a question for Diane or Laura, both of you.

Diane: I think that's a Laura question.

Laura: Which unfortunately my phone was ringing, even though I thought I had it silenced, so I got slightly distracted by that. Would you repeat the question?

Sara: I can repeat the question. So tell me a little bit about what do we know about how managers can support AMF in our prairies. And not even maybe necessarily in prairie reconstructions, but just broadly what can we do as land managers to help support AMF?

Laura: Okay, that's such a great question. I think that, so there's a couple of things that I feel like we still don't really know the answer to that would really help us to resolve that. One is this idea of host specificity, right? So a lot of times, we see systems where mutualists are so tightly associated that specific plants species are going to have their specific beneficial fungi that they interact with. And so if those plant species that are removed, for example, if the prairie is lost, right, then the question becomes to what extent are those fungi still there later, if we were to add those same plants back in. And so we don't, we need to know more about that, right? So are there actually AM fungi that are important for particular native plant species? And are those the ones that are

going to be lost and then we would need potentially to add back in before looking at reconstructions? That one piece that we still don't have a good handle on yet is how important host specificity might be, and although we definitely know that we see shifts, right, from when you have a prairie reconstruction, when you have a remnant prairie, we can see the shifts in the AM fungal community that are caused by that change, that disturbance of, you know, either of the what was there before the reconstruction or the reconstruction itself. But the other piece is I think really if we assume that AMF are really important for plant nutrition, then thinking about how nutrient availability is changing and has changed in prairies and also in reconstruction is relative to prairies, so a lot of places in Minnesota are influenced, are affected by nitrogen deposition, and so that really changes the availability of different types of nitrogen for plants on the landscape. And then phosphorous as well, which is, and that's a key nutrient that we know AMF are really important for in terms of partners. So if there's a lot of phosphorous available to plants, then they become less dependent on their fungi. And of course as I mentioned before, the fungi are dependent on the plants, they can't exist without them, but the plants if they have sufficient phosphorous may actually be able to invest less in that partnership. And so, and that has implications not just for AM fungi, but also that means that plants are taking energy-rich resources and shunting them into their root system, and then out into the soil. So that has implications for the other types of organisms that use that energy below ground. That's definitely something that I feel like Diane has much more to say than I do about, but could say more about that. Because I think it's just being aware of how it's important to think about the entire prairie ecosystem. And so of course, that means the physical environment as well as the living organisms. And so supporting AMF means thinking about how do we, I mean, I would prefer that we didn't have to manipulate the physical environment. But if the goal is diversity, then I think often we are at the point because humans have changed that physical environment dramatically, we do need to think about how we manipulate that physical environment as well to support that diversity.

Diane: I think the thing that managers might have some control over is the fertility of the land they plant into, and there are ways to, you know, crops that you plant before you reconstruct your prairie may be able to lower some of those nutrient availabilities before you even start, which would then help with what Laura was talking about in making the partnership a little more equal between the AMF and the plants.

Megan: Oh, that makes sense to me because we talk a lot about making sure that you get your nitrogen situation under control before you plant prairie into it. I think Sara has heard me say this a bunch. We often treat prairie seeds as if they're magical beans. So because they're native, we are like we will just put them out into these environments where the soil environment has been completely changed over a history of different land uses, for, you know, tens to hundreds of years, and we will just expect that they will do fine because they are native. But that, they are not magical means, they're amazing, and they're wonderful, but we've got to figure out how we're boosting our soil health, how we're improving our soil environment, and most importantly, probably how we are dealing with excess nitrogen that may still be in the soil and create a nice environment for weeds and not so nice an environment for the natives that we want to thrive and survive. So this makes sense to me. We talk about sopping up nitrogen. There are good

ways to do that. So okay, this question comes up a lot, and so I'm going to ask it here 'cause I think while we're on this how can managers support theme, I have gotten this question multiple times over the last year of should we inoculating seeds with AMF or other fungi prior to planting. And Diane, I know that you have some pretty strong thoughts about this, so we'll start with you, and then Laura can add on to that.

Diane: Yeah. With the state of the art right now, overall buying commercial inoculant may not be your best choice. It's easier to grow AMF that are kind of weedy, and there are different, you know, some as we've been talking about, some AMF are very specific to who they're going to help, and the help they provide is context-dependent. So there can be, you know, you wouldn't go and get seeds from Texas to plant in Minnesota, right? So do you want AMF from God knows where to plant in Minnesota? I don't think so. So that's really the question is can you get local ecotype AMF, and this point, it's not clear that you can, and the ways that you might be able to think of doing it might be detrimental to our native prairies, and we don't want to go digging up your remnant prairie to apply AMF to your reconstruction.

Sara: So there might be some concerns about bringing, I'm hearing two things. There might be concerns about bringing in nonlocal species because of all the things that we know about with any other kind of plant or wildlife. But then also I heard you kind of saying there are some AMF that are maybe more generalist and some that are more specific to particular plants, and so we don't know necessarily when we're buying something commercially, I suppose. It probably that generalist side of the house, and it's going to be a little bit like what a bumblebee, right, or not, I'm sorry, a honeybee or it's going to like some stuff and maybe pollinate some things, but it certainly isn't going to do all the support functions that we are hoping.

Megan: It's kind of like doctors say first do no harm. I think that ecologists and land managers should apply that sand tenet to the work that we're doing. We should be thinking about every choice we're making, and I understand that makes it complicated, right. That means you have to think really hard. But we're already thinking really hard because our goal should be to have diverse and resilient reconstructions connecting the prairie landscape so that we can have a prairie in hundreds of years. But in order to do that, we have to be thoughtful about these choices that we're making, and I know everybody says when I start down my tangent of this, and people are like great, Meg, no pressure on us right, like there's already so many things we have to consider, and now you're telling me to consider even bigger and even more. But I do think we need to be putting our choices into the context of could this cause more harm than good if I do this. And we know from hits right, like moving things around from far distances that may or may not be native to your area is a recipe for invasion and future problems. It has happened many, many times. So I don't think that that's something we want to repeat with fungi. We already know how this story ends. So we just need to figure out how do we tell a different story, right, and is there a way, like Diane said, to get local AMF. Laura, you were going to say something too.

Laura: No, just that yeah, that very much the AMF can, that there are AMF species that can be invasives just as there are plant species that can be invasive. And with the same kinds of problems then for the ecosystem as a whole. And the commercial inocula are

incredibly, I mean, so I think one thing when I'm talking to people about AM fungi is that they often don't realize that if you were to dig up a root system of a typical, I mean, there isn't really one, but of different native prairie plant species, you're not going to find just one or two, you're going to find many different species of AMF fungi colonizing that root system. So it is a really diverse and really complicated system, and most, many commercial inocula are actually like a single species, and even the single strain, right, within that species. So there's just no comparison. It's nothing like what a plant would encounter in a remnant prairie.

Sara: Well, I know that both of you are involved in some really exciting research to help us get a little bit closer to helping managers understand how we might successfully use AMF and safely use AMF in our prairie reconstructions. And I was wondering if you'd be willing to talk to us a little bit about that research project. Diane, why don't you start?

Diane: Well, this project started. So we have a number of collaborators. We work with Nick Jordan in his lab at the University of Minnesota, and a scientist who was working with him, Sherry Heard, and Jen Larson, so we've all been sort of working on how we can, first of all, if there's a difference between the AM that occur in reconstructions versus remnant prairies, and we have found some differences that was sort of our initial project was just looking at those differences, if they occurred, and given that they did, we're moving into the second phase of the project, which is to look at what's the effect of those differences, can we apply native inoculum and see different results than if we have the reconstruction soil only for establishment of the native plants or their competitive abilities against those invasive cool season grasses. So Laura, you want to take it from there?

Laura: Yeah, I was thinking about kind of one thing that we didn't talk about. We focused on thinking about the potential when you add inoculum, that you introduce an invasive species. But I think also there's the flipside of that, right, which is that were do we get that inoculum. If we're not going to use a commercial inoculum, then we go into these remnant prairies and take samples and then add those into the reconstructions. And that always makes me nervous because we're creating a disturbance in the remnant prairie that we know can be problematic in terms of allowing invasive plant species in. But also, of course, it's not feasible, right? There's lots of places where we could have reconstructions, but there aren't that many remnants left. And so we can't, so I think, you know, we could definitely use, I'm much more comfortable with the idea of using an inoculum that's very close to the reconstruct because then you're unlikely to introduce something that wouldn't low its way in anyway. But then there's just that question of scale. How do you scale, how do you design an effective inoculum, and then how do you scale that up? And so I think that that's maybe if we see that there are these clear differences and we see that for some, at least some native prairie plant species, those differences really matter in terms of how well they're able to establish, then thinking about how do we actually then generate an inoculum that's feasible for managers to be able to actually add and add safely.

Megan: So we were talking earlier. You said some, I keep focusing in on this, some prairie species, right? That there's these different interactions and that there's certain AMF that might have specific relationships with certain species and there's others that

are generalists. We've said that a couple times now. What species, like give me an example of a species that might have difficulty establishing but benefit from an AMF association. I know, right on the spot. Are they things like restoration conservative species? Are they things like, you know, lead plant or gosh, now I can think of anything off the top of my head, ground plum, you know, blue grandma, things that, June grass, things like that that tend to be restoration conservative and we already know they have a, okay, so it is.

Laura: I mean, yeah, I was nodding because really you're getting at that complexity again, right? So Diane mentioned this idea that there's context dependency, right? And so what we see is that, and maybe this isn't too surprising, right? Is that for some native plant species, you inoculate with AM fungi and you always see a benefit, and that benefit could be in terms of germination, it could be in terms of seeding and survivable, and it could be in terms of growth. There are other species where it really depends on which soil environment, for example, you're throwing those plants in, which competitors are present, whether or not you actually see a benefit. And then there's some plants where it doesn't seem to matter. They're colonized but you don't see a clear difference in plant performance that's associated with the inoculum that you're using. So we kind of see possibilities, and so that's why, right? I was hedging my bets by always saying for some.

Megan: For some (laughing). That's a smart way to do it with ecology, right?

Laura: And then there are things that are really common, right? So the one that comes to mind is big bluestem. You know, in my experience, it's almost always going to be benefitted, but it's also not a species that we struggle to get reestablished, right, in reconstruction.

Megan: True.

Laura: But even there, you know, I can point to some work by Peggy Schultz where she shows that the relationship is, that the extent which is mutualism is context-dependent and it depends on where, you know, which sites you're planting it into. Yeah. So I think I suspect that for the things that are rare, the plant species that are rare and that we know are hard to establish, for a subset of those, I think AM fungi can be really important. Obviously for something like leadplant, the types of bacteria that they form, nitrogen fixing associations with are going to be a big piece of that as well. And I think in that mutualism, we now see that there's a lot more specificity than we used to think. And so it's quite possible, right, that the symbiotes that are the best for bed plant may be missing from some of those reconstruction sites. And so I think that's going to be the case for AM fungi as well, but the challenges when those are rare plant species especially threatened or endangered ones, then just getting the commission to manipulate them is really problematic, right? And so my lab has been focusing on blanket flower because we're interested in this species that has a broad distribution across the United States in grasslands. And but now it's a species of special concern in Minnesota, so it's very hard for us, you know, and we work with roots. It's difficult not to disturb to plant to find out more about it. But it's increasingly difficult for us to actually to work on that species in Minnesota to get permission to work at sites where we would potentially be disturbing the plants because there are so few. And so that makes it really

challenging, right, to find out, you know, do AMF play a role, are they important, and then which AM fungal species, because that almost always means we need to be able to dig up plants or at least parts of plants.

Megan: You handled that really well, especially because I asked you the question that I hate when people ask it to me. It's like the what is the holy grail moment for plants, you know. There's always this question of like well tell me the one thing that I can do that every time it's going to work, and with prairie restoration, it just doesn't work like that. It's an ecosystem and it's complex and there's all of these different choices that lead you down potentially a different path or the same path after a certain period of time has passed, but there's, it's so exciting. It's a new frontier, Sara. It's like space, but butter than space because it's prairie. Okay, sorry if you're an astronaut and you're listening to this. Space is great too. But this is about prairie and we love it so much.

Sara: Somebody told me once that he loves ecology because there's so much to know and it's so complicated and it's so just complex and exciting. There's always something new to learn, but he also hates ecology because it's so complex and so we're never going to know everything and it is that sort of little two sides of that coin there, isn't it?

Laura: Yeah, and then, I mean, I was thinking about, you know, when you asked us to recommend a paper, you know, I was thinking about how most of our research is really for obvious reasons combined to maybe a single site, a few sites, and it's one thing I really like about working with Diane because Diane is like no, we're going to look at lots of sites. And so for managers, it's such a challenge, right? Like how do you, can I take this like this work. I told you it's context dependent and then it's like but we only have this particular piece of research from one site you know in one place. And so can I take that and actually then apply that elsewhere? And of course, at this point, the only reasonable answer is we don't know. I don't know if that's going to work that way somewhere else but it’s going to be good to find out so.

Sara: I also appreciate that about working with Diane that, and that's one of the things I think is really exciting about that research project that you guys were telling us about is that you're not just using generic soil from, you know, a bag of Miracle Gro from the hardware store, right? Diane and her folks went out and actually collected soil samples from actual reconstructions and actual remnant prairies and future reconstructions that we haven't planted yet, so yeah, hopefully, we will get a little bit of that hint of the diversity of contexts, right, that are out there in the world. It's cool stuff. 10 points.

Diane: That if you're going to do this, don't do it in November in Minnesota.

(Laughter)

Megan: Diane, did you make that mistake?

Diane: Yes, I won't make it again. But I also need to say that it's a partnership that allows us to have access to those sites. So the Fish & Wildlife Service and TMC and the State of Minnesota have been very helpful in just giving us access to sites that we can sample and broaden our inferences, so that's important.

Megan: I think the best things that we do are when we do them together, particularly when we have land managers, practitioners, and researchers working hand in hand, because then you're getting real answers to real questions that we can then apply in the field to improve our prairie reconstruction and our process with all of this, which, I mean, selfishly that's what I'm most interested in. There are lots of cool things to study but I want to take what you've studied and I want use it, so I think when we're all working together just gives us better result. So we're talking a lot, I'm going to pivot a little bit 'cause we are sort of talking about soil health through all of this as a theme, but we haven't really explained, you know, why that matters in prairies and in prairie reconstructions. And so I'm going to ask each of you, you know, why is soil health a thing, why is that important? And we've touched on it with different things that we've said. We've talked about nutrient availability, we have also talked about too much nutrients and other things like that that would impact the soil environment, and therefore impact establishment and persistence of some species. So talked to us in general just so we all have a collective understanding of why does soil health matter in prairies. Why should we think about it? Laura, we'll start with you.

Laura: Well, you know, as an ecologist, as a scientist, like I really struggle with the idea of soil health.

(Laughing)

Megan: That's a good way to start.

Laura: Because so what I will say, so I guess I'll tell a story, right. So I sent some samples off from some soil samples off from Frenchman's Bluff Scientific and Natural Area, and then from an ag site nearby in Clay County, Minnesota. And so I sent them off for analysis at a soils lab, and they were supposed to just look at physical characteristics. But they, because it's really expensive to look at the things that they measure for soil health like phospholipid fatty acids. So they by mistake, they did a phospholipid fatty acid profile, and they sent me a note and they said we think there's something wrong with our analysis because the PLFA is way too high. And so I looked to see like what soil samples did they run this on, right, and it turns out so they ran the ag and they ran the Frenchman's Bluff, and they, I don't think they'd ever seen a profile from a remnant prairie. And it was astonishing to me because it wasn't like there was a little bit more phospho, you know, I'm just going to say PLFA, it's easier. It was off the charts, right. And so what that tells me is that regardless of what we want to call that, to me that just showed that that soil is living, it's alive, and it's full of organisms that are, you know, going about their day. And the ag soil isn't, right? That particular ag soil was not. Not alive in the same way at all. So I think while I might struggle a little bit with that term, the point really, I think the place where we can all agree is that a living soil is, right? By definition it's full of life. And so that becomes its own, it really becomes its own universe, right? And so we can have a very simplistic one, a really boring one, a very homogeneous one, or we can have a very heterogeneous, diverse, complex one that's more difficult to understand. And they're obviously not going to be the same and they're not going to be the same thing, and they’re not going to do the same thing.

Megan: I like that you say do the same thing because I was thinking of function 'cause I was thinking of function, like the function of that remnant prairie, you know, it's got to be higher than the function of the soil you're comparing it to.

Laura: Well, there's, yeah, so that there's a diversity below ground that's reflecting, you know, what we can see above them, and that it's probably orders of magnitude beyond. And that's where the diversity is they - - is under, underneath.

Megan: Right. Diane, do you have anything you would like to add?

Diane: I think that's a great story. I have nothing to add to that.

Megan: I love it so much. No, I like it. And I think it's interesting because to me when I hear that term soil health, I think of it in the context of just a way to make soil communities make sense because they are so complex and so diverse. So to me, it provides a useful analogy of okay, if I'm a person and all I eat every day are cheeseburgers, I might be a happy person but I am probably not a healthy person for that kind of a diet, right? But if I'm a person who takes in different things and makes my diet more diverse, then I probably would be a healthier person. And so to me, that term soil health is synonymous with diversity, what's the level of diversity in your soil. What function is in the soil. So I like the way that you describe it too 'cause I just think of it as like a helpful way to describe the ecosystem.

Diane: And I haven't really thought about why I feel that or to sort of push back against that term, but I think that that brings us to a topic I think is really important, which is this idea of negative feedback. And so what we see in soil plant interactions where we're talking about all the organisms that live in that soil, is that the most common plant species over time are the ones that begin to be attacked the most by different pests, by different pathogens as those negative associates start to, you know, do better because that's the most abundant species. And so we know that that negative feedback plays a really important role in maintaining diversity because it knocks back the most abundant, the most common organisms on the landscape, and allows other ones to proliferate. So it's maybe a little bit counterintuitive, right? But a healthy soil may actually be a soil that's full of pathogens and pests as well that are going to reduce the abundance of that most common species and allow other ones to persist.

Megan: Oh, that makes sense to me. I see. Now I understand even more, yeah. 'Cause we don't want to assume that healthy means that there's nothing, I don't know how to describe this, I don't want to say bad, but there's nothing negative in the system, right? In ecology, there are negative feedback loops and there are positive feedback loops, and arguably we might perceive them differently like disease would be an example, generally we perceive disease as bad, but it's also a really important ecological feedback loop so that we have balance in the system, particularly when you're thinking about things like overpopulation of deer or something like that, that would be where if we don't have a natural predator, we need some sort of mechanism to achieve balance. Sara, you had a question.

Sara: That's fascinating.

Megan: I know.

Sara: I do have a question but now my mind is just like what – cranking away. Well, one thing I was thinking about too is that, you know, on the topic of our podcast is AMF, but a couple times both of you have mentioned that there's lots of other organisms and the diversity of life underground is more than AMF. So part one of my question is, why are we so focused on AMF right now? Why is that the one that won our attention? And the other part of my question is, what's your other favorite?

Megan: You should have said what's your other favorite fungi, Sara. You missed a brilliant opportunity for alliteration.

Sara: My favorite soil microbe. (Laughter)

Megan: Oh, dang. It's just not as fun to say but okay, I'll allow it.

Sara: Morales, you - - morale.

Megan: No.

Sara: So why, Laura, why did they win our attention?

Laura: Oh, I think that probably because they are beneficial, right? At least in some contexts, they're definitely beneficial. So I guess I think, I don't know. I know they win my attention because actually if you look at their spores, they're beautiful. And then they're really beautiful organisms, both the spores and then also when they're - - one of the things that amazed me the first time that I stained a root and looked at it was that it was full of AM fungi. Like they were probably half of the root, and I didn't expect that. I don't know. I don't know what I thought I would see, but I was surprised. Like when you look at the root systems of a plant that forms that close association with AM fungi, you see that it really is a partnership in the sense that physically you can actually see the half and half. Not all plant species have that, cultivate that much of a community inside the roots, but certainly some of them. All right. The rest of your question was like a really tall order.

Sara: Picking favorites is always hard. No, but just tell us about some other important soil microbes that maybe we haven't thought about.

Laura: When I started working on mycorrhizas, they weren't a big topic, and it's really, like I think, I - - that's not, you know, that's not a question for a scientist. It's really a question for a social scientist I think. So not for a physical or a natural scientist because why do certain ideas take hold at certain times and then snowball? It's not necessarily because they're the best ones for that particular moment in time. Can you tell I'm a little bit of a skeptic even on own research topic.

Megan: You're a true scientist. We're always evaluating our own work, and the work of others, looking at it with a critical eye.

Laura: But yeah, and I think I wonder to some extent if it's a little bit of a shortcut because in fact, if you look at the research, we're often using whole soil inoculum because it's really difficult to isolate, for example, the spores so that you, like it's very difficult to know that you're just working with mycorrhizal fungi. It turns out even if you just, if you isolate the spores and then inoculate plants with those spores, those spores

themselves have symbiotes that live inside them, so bacteria for example, helper bacteria. We call them helper bacteria, we don't necessarily know if they're really helping or not. But so there's always a possibility that it's not being in fungi but it's other things that are being carried along with them. And of course, it's probably an and rather than an either, right? So in that inoculum, certainly AM fungi are an important part. But the other microbes that are there are also important. And so let's see. A Favorite, I mean, a favorite microbe other than AMF I think every time I look at a root system, I see a fungus when we stain them, I see fungi that I have never seen before. And sometimes those show really interesting patterns in like which root systems we see them in, and yet, you know, we don't know, we often don't know who they are and we don't know what they do. So I think my favorite thing about working in the system is probably just that there are so many unknowns and so there's, you know, there's different threads that you could pull on and - -

Sara: Diane, what about you?

Diane: You know, I don't have the experience of actually seeing the AMF, so I can't speak to their beauty. And I guess I feel like AMF came up for me because we were seeing these interactions, and I'm totally an interactions biologist, and the fact that they could change so much depending on the context, that just draws my attention right away. And I think that's as a scientist, that's what attracted me to them. But I find them incredibly frustrating because when you think about a prairie plant, you have a name of the plant, that puts in mind where it is, what its habitat is, what it wants. With an AMF, you have an OTU, an operational taxonomic unit, and that doesn't tell me anything at this point about that organism. And so I find that it's great that we have Jen Bank and we have the ability to understand the diversity, but we don't yet know what each of those does, and I think that's beginning to understand what those taxa do is for me the great challenge, and what would be fulfilling to me to know is to be able to say this is - - this species of AMF and it does and it likes that and it lives here. That's what I think would really be exciting.

Sara: Yeah, that is exciting. Good stuff.

Megan: We've got to move on to our next section 'cause we are just running out of time here.

((music plays))

LET’S SCIENCE! TO THE LITERATURE!

SCIENCE!

Megan: All right. So this is the part of the podcast where we recommend a book, a blog, or a paper, and we're just going to pile on to all this great research that we've already been talking about today, and hear about some of your Let's Science picks. Diane, let's start with you. What's your pick and what can you tell us about it?

Diane: Okay. My pick is a paper, let's see, it's by Jack et al. 2021 Microbial Inoculants: Silver Bullet or Microbial Jurassic Park. And the reason I picked it is that we really need to recognize that these are living organisms that we're interested in inoculating, for

example, and I think it's really important to recognize that all this stuff we've talking about, we've been talking about with the belowground diversity. If we're just adding just because we can't see the microbes we're adding doesn't mean that they aren't doing stuff, and it's not important in an ecosystem fashion. And I think this, even though this article is a bit more agricultural than natural area oriented, it brings up some really good points about not ignoring things that we can't see.

Megan: I love that. Laura, your pick.

Laura: Yeah, so I kind of struggled with this assignment because so many things, great things to read out there right now. But I ended up picking this article by Terra Lubin and Peggy Schultz, Jim Bever, and Helen M. Alexander, who are at the University of Kansas. And this came out in 2019 in Restoration Ecology. And it was just a single site, but they basically manipulated seeding density, you know, in their reconstruction, and then they also used whole soil inoculant from a remnant prairie, and inoculated the subset of five different native prairie plant species and looked, and then actually, you know, followed these for four years to see what it looked like in terms of cover and diversity at the end, and basically found that both were important for increasing diversity in the reconstruction. So, and I thought that was just a nice example of kind of if we have more studies like that, then we can start to really build a better sense of - - we can start to make generalities, think about what are the general rules that we know we can apply just about anywhere.

Megan: I love general rules. I do. That sounded sarcastic but I did not mean it sarcastic. I really do. I definitely try to give prairie managers all the time our guidelines, not recipes, because you don't have to do it the same way every time. There's lots of different paths for success for reconstruction, but there are also, as we know certain things you could do that would lead to failure, so we want to give people guidelines for success.

Laura: Yeah, and then the other thing about like a paper like this that I love, right? Is like they had to pick a certain time that they were going to plant these things, and we know that that matters. So, right? So it's this great little, it's this really nice study but still it raises all sorts of questions, but you see the same thing if you, you know, seed it in fall versus spring, etcetera.

Sara: All the pieces of the puzzle we have to start putting together, right? That's good. Hey Megan.

Megan: Yeah, Sara?

Sara: You know what I really like to do?

Megan: What?

Sara: I'd love to go take a hike.

Megan: Oh, I love how you guys say that. You say it so nice like we're going to take a hike together. That Mike Worland, he always says, "Why don't you take a hike?" So you know, it's just so nice that I get to hike with some pleasant folks. It's just wonderful. I'm

just kidding. Mike's pleasant too. All right, we're going to start with Laura. Where are we hiking today?

Laura: I think we should go to Frenchman's Bluff Scientific and Natural Area. So the highest point in Northwestern Minnesota, we get to stand in beautiful remnant prairie and look around, and see how much Western European expansion has modified the landscape over the last 150 years.

Megan: I like vistas, I really do. I'm a sucker for a good vista. Diane, where are we hiking?

Diane: Well, it would be a short hike, but you know how they always say the best camera is the camera you have with you? Well, I think you should take a hike in your own yard and look at your own prairie. My personal favorite place to look at prairie is in my yard. I can go out in the summer and watch the bees and I can see all the diversity that's happening right in my suburban yard, and if everybody did that, you know, we could have a lot of prairie. So that's my choice.

Megan: We'd have a lot of prairie and a lot less traffic. You don't have to go anywhere. You just stand outside your yard in your pajamas however you want to. You could just hang out and look at your own prairie. I like it. I also found over the past year that I spent a lot of time in my yard, like a lot more time in my yard and just appreciating all of my beautiful little prairie plants, and probably over-tending them since, you know, that's what I had front of mind to do. They're probably like when does this lady leave again. Would like it if she would stop trying to make sure that we're healthy all the time. Just leave us alone. We got this. We've been doing it for hundreds of years. That's how I imagine they talk to me. Okay. I just, this was just so great. Sara, you did amazing. I'm so glad.

Sara: Thanks.

Megan: You did. And Diane and Laura, this was a great episode. I'm really excited. I learned a lot. I learned a ton of stuff.

Sara: So much.

Megan: So much. And next week, the learning doesn't stop because we're going to be hosting a very special episode of the Prairie Pod where we are featuring places near and dear to our hearts. You guessed it, Minnesota State Parks and Trails, folks. We'll be joined by six prairie park managers and naturalists to share the special prairie places in the parks that they and we love. It's basically one giant Take a Hike episode where you'll hear insider tips from the people who know the parks best because they're caring for them every day so that we can go out and enjoy them. I can't wait. I'm so excited to get like this insider tour of Minnesota State Park. As always, all of the resources that we mentioned today can be found on our website at mndnr.gov/prairiepod. This episode was produced by the Minnesota Department of Natural Resources Southern Region under the Minnesota Prairie Conservation Partnership. It was edited by the fantastic Dan Ruiter and engineered by the fabulous Jed Becher. Man, go out and have a great rest of your week and find some fungi. (Laughing)

Diane: Nice. Very nice.

((sounds of birds chirping and wind blowing))