Video Transcript – Ferns – Curious Lifecycles and Remarkable Biodiversity

Maggy Benson: Welcome everyone. Thank you so much for joining us here on Smithsonian Science How. We are behind the scenes at the Smithsonian's National Museum of Natural History with botanist Dr. Eric Schuettpelz. Eric, thank you so much for having us in your lab and office space.

Eric Schuettpelz: Thanks.

Maggy Benson: So Eric, can you start off by telling our viewers a little bit about what you do as a botanist here at the Smithsonian.

Eric Schuettpelz: As a botanist here, I do quite a few different things. I spend a little bit of time working in the lab. I spend a lot of time sitting in front of my computer, analyzing data, reading papers, writing papers. I'm fortunate that I get to spend quite a bit of time in the field collecting plants, collecting specimens, and I spent a fair amount of time right behind us the herbarium in the collection, working with those collections and collections from the past.

Maggy Benson: You actually showed our team your herbarium earlier this week, where you store all of those plant collections, and we took a video of it so that our viewers today can take a look too.

Eric Schuettpelz: Great.

Maggy Benson: Let's take a look.

Maggy Benson: Hi everyone, thank you for joining us behind the scenes here at the Smithsonian's National Museum of Natural History. We're joined by Dr. Eric Schuettpelz, a botanist here at the museum. Eric, thank you so much for inviting us into the botany collection.

Eric Schuettpelz: It's great to have you. This is the United States National Herbarium. It contains about 5 million plant specimens that have been collected, flattened out, dried and then mounted on paper and are filed away in these cabinets.

Maggy Benson: How do you use the National Herbarium in your work?

Eric Schuettpelz: I'm a pteridologist, would be the name, a scientist who studies ferns. I use specimens in nearly all of my work. Specimens provide us with information about obviously how the plants look, their microscopic features. It can also provide material for DNA based analysis as well. Our fern herbarium, which we're standing in the middle of, it contains about a quarter of a million specimens. They're stored dried, of course that's the most important feature. These dried specimens will last hundreds and hundreds of years. All this collection I think in the entire herbarium is from the 1500s. A lot are arranged

taxonomically, filed genetically in terms of how they're related to one another. Of course, many folks are going to be familiar with ferns as under storied plants. Here's an example of a maidenhair fern that could be growing on the forest floor somewhere. I've also grabbed a variety of tropical ferns. This fern has simple leaves, you might mistake it as a grass even from a distance.

Maggy Benson: I would never think that's a fern, or that like you said. So Eric, you work here in the National Herbarium, you focus on ferns, what's the big question that you're researching?

Eric Schuettpelz: I'm interested fundamentally where this adversity came from. Why do we see so many forms, why do we see so many species of ferns on our planet? What are the characteristics of these ferns that have made them successful? People generally don't think of ferns as being super important, or even super diverse. I would imagine that some folks are surprised that 306 different kinds of ferns, but in fact there are about 10,000 species which puts them in the same ballpark as the number of species of birds and many more species than there are of a group like mammals.

Maggy Benson: Wow, that's so fascinating. Thank you for giving us a short introduction to the National Herbarium.

Eric Schuettpelz: Of course.

Maggy Benson: Eric, thank you so much for showing us the herbarium and it was just so cool to see cabinets upon cabinets of all of these pressed plants, and ferns specifically. Coming from Pennsylvania, I was used to seeing ferns in the damp areas, dark areas of forests but that's not the same kind of habitat that they occupy worldwide, is it?

Eric Schuettpelz: Not everywhere. Here in another temperate areas of the world, ferns are most common as understory plants, growing in shady areas. In drier parts of the world, for example the southwest of the United States and the deserts, ferns might be tucked into little rock crevices, if you've got an image hopefully that's showing of that so little fern in the desert. In the tropics, of course ferns are growing in the understory, they're also growing in those rock crevices but a third of all fern species actually grow as epiphytes. This means that they grow on other plants and there you have an example of a small epiphytic fern growing on the side of a tree. Although ferns are distributed globally, really they're found on every continent except for Antarctica, it's really the tropics where they really come to life.

Maggy Benson: Where we see here, highlighted.

Eric Schuettpelz: Exactly.

Maggy Benson: Thanks for giving us an introduction to ferns. We have a student question, and it comes in by video.

Eric Schuettpelz: Okay.

Maggy Benson: So let's listen.

Karolina: Hi, my name is Karolina and I would like to know how many species of ferns are there throughout the world and which is your favorite?

Eric Schuettpelz: Thanks Karolina for that question, there are about 10,500 species of ferns on our planet, give or take, which is quite a few. Like I said, about the same number as bird species. As far as picking my favorite, that's really hard for me to do. It's even hard for me to pick my favorite group of ferns but it's really those epiphytes, I guess, that ultimately got me really excited about fern diversity. Those ferns that grow on other plants.

Maggy Benson: Now, you mentioned that there is a huge amount of fern diversity but I know that you're specifically interested in islands. What do fern populations look like on islands?

Eric Schuettpelz: So islands are really incredible places to look for ferns and this is because ferns tend to be overrepresented on islands. If we think globally, the worldwide picture, ferns are about ten thousand species of about 300,000 total species of plants so they're about three percent of total global species diversity. On an island, an oceanic island specifically, that number can be much, much greater. If we think of the Hawaiian Islands as an example, about 15 percent of the species on Hawaii are ferns so quite a few more. I'm really interested in trying to figure out why ferns have been so successful on oceanic islands.

Maggy Benson: That's your big research question then.

Eric Schuettpelz: Absolutely.

Maggy Benson: We see right here what features of ferns make them so successful on islands. You've recently traveled to a chain of islands, the Marquesas Islands. Can you tell our viewers where that is and why that is a great place to study this research question?

Eric Schuettpelz: The Marquesas Islands are very isolated, they are pretty much smack dab in the middle of the South Pacific Ocean. You can see on the map there, they're really in the middle of the ocean. The closest continent actually is North America but it's over five thousand kilometers away. That extreme isolation really leads to extreme over representation so again, thinking globally three percent, Hawaii 15 percent. On the Marquesas, about 30 percent of the species diversity that are native to the Marquesas are ferns.

Maggy Benson: For you, somebody who studies ferns, that must be like a kid in a candy shop.

Eric Schuettpelz: Absolutely, I sort of think of these islands as these rocky outcrops in the middle of the Pacific as fundamentally being a 5-million-year-old experiment of dispersal and establishment. Really sort of a natural lab that will hopefully provide some insight into why ferns have been successful on not only those islands but islands as a whole and possibly even why ferns have been successful as they are on a global scale.

Maggy Benson: What's it like working in such a remote location like the Marquesas?

Eric Schuettpelz: Well, as you might imagine, an island in the middle of the South Pacific is an incredibly beautiful place to work. The landscapes ...

Maggy Benson: We see it here, it's gorgeous.

Eric Schuettpelz: Really, really spectacular. As a pteridologist, somebody who studies ferns, it's really neat to be in a place where one third of the species are your study organism. I'm used to going to places where it's three percent of the diversity so that's really pretty incredible. As you might imagine, being so isolated there are also some challenges. It's not exactly easy to get there, it's not very easy to get between the islands necessarily. All of these islands have relatively low populations of people. Each of the islands we visited was only home to about 5,000 people so some of the things we might take for granted here in a big city or even a small town in the continental U.S. Some of those things that we take for granted just simply aren't available. As an example, I read the newspaper on my computer, on my phone ...

Maggy Benson: Me too.

Eric Schuettpelz: Yeah, as do many people and it seems the same is true for the people living on the Marquesas but given that they're on an island, if they're all reading the newspaper on their computer or their phone, there is no need to fly newspapers, as it turns out, for sale in the Marquesas. I can personally live without being connected to the world for a couple of weeks.

Maggy Benson: Must be kind of nice.

Eric Schuettpelz: It's something about field work I look forward to. From a processing our specimen collecting standpoint it actually poses some problems because the way that we press our plants is between newspaper. That's something that we don't bother carrying with us in the field because usually it's available everywhere. So that came as a little bit of a surprise and involved a little bit of scrambling to fly in some newspaper from Tahiti which is about 1,500 kilometers away.

Maggy Benson: That had to be a really expensive paper delivery.

Eric Schuettpelz: Yeah it was a very expensive paper delivery, indeed.

Maggy Benson: Thanks for giving us a little bit of an overview about your research and what fern diversity looks like on islands and in the tropics. Let's take a step back and actually learn about what a fern is. Before you tell us, I think it's a great opportunity to check in with our viewers.

Eric Schuettpelz: Super.

Maggy Benson: Viewers here's an opportunity to tell us what you think. We're going to do a live poll, you can respond using the window that appears to the right of your video screen. Tell us, what do all ferns have in common? Is it leaves, flowers, seeds, or spores? Take a moment to think about it and put your response in the window that appears to the right of your video screen. This is the same place that you can post questions for Dr. Eric Schuettpelz to answer during our live broadcast today. We also have another botany expert, Greg McKee, who is in the chat answering question as well.

Maggy Benson: Eric, we're looking over my shoulder with results coming in and 73 percent of our viewers say that they have spores.

Eric Schuettpelz: That is a really good answer. I think that the best definition for ferns is actually combining something that they have and something that they don't have. Ferns are plants that have true leaves but they don't have seeds. If they don't have seeds, they also don't have flowers.

Maggy Benson: So, what is it about the spores?

Eric Schuettpelz: The spores are also a characteristic of ferns but it turns out spores are characteristic of all plants. All plants produce spores. The reason we don't think of all plants as producing spores is because in seed plants, the plants that we're often most familiar with, the spores that are produced never leave the plant. They either never leave or they grow into something else before they leave. In seed-free plants, like ferns, the spores are dispersed.

Maggy Benson: Actually right here we have, are these spores that we're looking at?

Eric Schuettpelz: Yeah, these are SEM images of spores. You can see that the ornamentation of these spores is really incredible. These are really small, those scale bars there are just ten microns so the spores themselves are about 50 microns across, which is about a twentieth of a millimeter.

Maggy Benson: They're very small.

Eric Schuettpelz: Yes, very small.

Maggy Benson: These spores are meant to be dispersed and dispersal, is that kind of like when you pick a dandelion and you blow on it and those seeds go flying away in the wind?

Eric Schuettpelz: That's exactly what dispersal is. In the case of a dandelion, those fruits with the seeds inside are dispersed and seed plants are of course either dispersing their seeds, or in the case of flowering plants might actually disperse the fruits with the seeds inside. Buried in each and every one of those seeds is a tiny little version, a multicellular version that's small, of the larger plant. If you think of an acorn or an oak tree producing acorns, inside that acorn is a little tiny version of an oak tree that's ready to go. When that seed hits the ground it can germinate and a new oak tree takes its place.

Eric Schuettpelz: Seeds and fruits can be dispersed in a wide variety of ways. It can simply just fall to the ground with gravity pulling them to the place, they can be forcefully ejected from the plants in some cases, they can be carried away by wind or by water. In many cases they're collected and then carried far off places by animals.

Maggy Benson: Interesting. Which is it for ferns? Actually, don't tell us. Let's check in with our viewers again. Viewers, here's another opportunity for a live poll. Tell us how are spores dispersed. Is it water, wind, animals or gravity? Take a moment to think about it and put your response in the window that appears to the right of your video screen. You may need to minimize your window to respond.

Maggy Benson: Our responses are still coming it but it looks like most of our viewers, 67 percent, think that it is wind.

Eric Schuettpelz: That's actually an excellent answer. If you look at the underside of a piece of fern, I've got a small piece of leaf here, if you look at the underside of this you may have noticed that there are spots or lines. I'm going to go ahead and put this under the microscope, series of scopes so you can see some of these dots in this case.

Maggy Benson: Ah, there they are.

Eric Schuettpelz: There they are and if I zoom in on those and focus, you can see that those are actually made up of smaller things. Those smaller things that you're seeing are sporangium. The sporangium, undersurface of most fern leaves, are what makes the spores. That's where the spores are made. In it most ferns, spores simply don't just fall out of these sporangia, but they're actually thrown out. They're physically forced out of the sporangia. Here we have a video looping, this is real time, this sporangium is splitting open, it's pulling back that charge of spores, and then literally throwing them into the air which is pretty neat to see. All of this is happening at a very small scale right, I'm zoomed in on the microscope showed you how small these things are. This is not throwing them long distances, it's just simply throwing them a little bit further away from the leaf

and is really wind like the responses suggested, that's doing most of the work. Wind is really what's carrying the spores away from the plant.

Maggy Benson: The sporangia that are on the underside of a fern leaf is actually throwing these spores out and it's then getting picked up by the wind.

Eric Schuettpelz: Exactly.

Maggy Benson: Do you have any spores here to help us understand the scale of what we're talking about?

Eric Schuettpelz: I do have a small container of some pteridophyte spores and it looks like flour, it looks like dust. If I shoot some into the air...

Maggy Benson: Ah, there it is.

Eric Schuettpelz: You can see they just sort of hang out right where they are, they float up, they float down. The slightest little bit of current ...

Maggy Benson: Into my nose.

Eric Schuettpelz: Into all, yes. They're super small, they're super light and they can really be carried anywhere by the slightest of breeze. If you think about a wind storm, they can really be carried around the globe.

Maggy Benson: All right so, let's get back to these spores. Like the dandelion fruit, do these spores get dispersed and then grow into a new plant?

Eric Schuettpelz: They do grow into a new plant but they don't grow into the sporophyte, the spore producing plant that we're used to seeing for ferns. Instead, they grow into something that we call the gametophyte which is quite a bit smaller. I've got a small Petri dish here with some gametophytes actually growing inside. Let's put those under the scope as well and focus in.

Maggy Benson: I can see your screen, there they are.

Eric Schuettpelz: You can see that these things are rather small but they are green which means they're photosynthesizing. They're making food like most plants do. They're also multicellular, there are many, many cells involved, they're just much smaller than the stage of the fern lifecycle that we're used to seeing.

Maggy Benson: What are we looking at here?

Eric Schuettpelz: This is another example of a gametophyte, in this case growing in the wild. We typically think of the stereotypical fern gametophyte as being this sort of little heart shaped thallus, a little flat mass of cells that takes on a little bit of a heart shape.

Maggy Benson: The gametophyte, is that like a baby fern?

Eric Schuettpelz: It's not itself really a baby fern because in some cases, once these things are mature and the ones that I was showing you under the microscope as well as the one you just saw in the image, those are mature gametophytes. That's as big as they will grow and at that stage, they're producing gametes. That's where the term gametophyte comes from. That's the gamete producing stage of the fern life cycle. I've made a little bit of a model here out of Lego's to sort of walk us through what's happening in this life cycle.

Eric Schuettpelz: Here we have the typical fern that you would think of growing in a basket or what you could find on the forest floor. This, as you recall, has sori on the backside. The sori are made up of sporangia, the sporangia are going to produce spores.

Maggy Benson: And they eject those spores out.

Eric Schuettpelz: Literally throwing them away from the plant, where they'd be taken away in the wind. Those spores are going to grow into gametophytes. These gametophytes are then going to produce the sperm and the egg, in ferns the sperm are actually swimming. They swim through water, they have flagella just like animal sperm do. They would find their way to an egg cell, the fertilization would occur. At that point you'd have a zygote, it's that zygote then that grows into a young sporophyte. Eventually that young sporophyte will grow into the mature sporophyte and the life cycle continues.

Maggy Benson: How fascinating in fern life cycle, there are actually two stages and they are completely separate and they can live independently from one another.

Eric Schuettpelz: Exactly.

Maggy Benson: We have another question, this one comes from Saad. Why are ferns poisonous?

Eric Schuettpelz: Ferns are poisonous because they produce a wide variety of chemical compounds that can be toxic to vertebrates. In some cases, toxic to insects and in part that's a defense mechanism. Of course, some of them just happen to be toxic but in many cases their defense mechanism to prevent herbivory.

Maggy Benson: Wonderful. Great questions, keep them coming. Let's get back to your research question, you're really interested in why ferns are so successful on islands. What does the fern life cycle have to do with your research question?

Eric Schuettpelz: I think that ultimately the success of ferns comes down to, in part of the fact that spore dispersal brings with it so many big advantages. These tiny little propagules could be carried off to faraway places much more easily, in many cases, than seeds or fruits. This life cycle that we talked about would seem to

also pose some disadvantages but as it turns out, ferns have often been able to overcome some of these disadvantages through the flexibility that they have in their life cycle.

Maggy Benson: What do you mean by flexibility?

Eric Schuettpelz: The typical situation in ferns like I talked about involve two spores and two gametophytes so one spore would develop into one gametophyte, another spore developing into the second gametophyte. One gametophyte producing a sperm, the other producing eggs to complete its life cycle. This doesn't always have to happen like that. In some cases, in many ferns in fact, one spore can divide to form one gametophyte that produces both eggs and sperm. Fertilization can happen within that individual gametophyte. In many ferns, this is facilitated by the presence of a phenomenon which we refer to as polyploidy which is simply the presence of multiple sets of chromosomes. In those multiple sets of chromosomes within each and every cell ultimately bring greater genetic diversity to the table. So that cell fertilization within that gametophyte might actually result in a viable sporophyte.

Maggy Benson: So fascinating. That flexibility and the genetic diversity that they have and this wind dispersal to be able to bring these spores from maybe even mainland to hundreds, thousands of miles away to islands all contribute to their success.

Eric Schuettpelz: Exactly, I think the spore dispersal as well as its flexibility in their life cycle that come together to contribute to their success on islands and quite likely their success across the globe. By studying the ferns of the Marquesas in detail, I hope to better understand what's actually happening in that island system to understand each of these things, whether it be the flexibility of their life cycle, long distance dispersal, some combination of each, to really better understand the impact of each so I can better understand what's going on on those islands, oceanic islands as a whole and ultimately the globe.

Maggy Benson: Awesome, well thank you so much Eric for telling us about your research here at the Smithsonian, how you're studying that question and giving us an overview of the ferns flexible life cycle. It's pretty fascinating stuff.

Eric Schuettpelz: Thanks for having me.

Maggy Benson: Let's get to some student questions.

Eric Schuettpelz: Sounds great.

Maggy Benson: This question comes from Jason. Jason wants to know, can an ecosystem continue without ferns and how long, if so?

Eric Schuettpelz: That's a really hard question to answer. Certainly in most cases, ferns are not the dominant features of an ecosystem. Although, they can in some cases be

the dominant plants. In those situations where they're not dominant, one could certainly imagine that the ecosystem could continue without it but it's likely that other species would also become locally extinct that would depend on ferns.

Maggy Benson: We have another video question.

Eric Schuettpelz: Okay.

Maggy Benson: Let's listen.

Eric Schuettpelz: Great.

Indigo: Hi, my name is Indigo and my question is how long have ferns been around?

Eric Schuettpelz: Thanks Indigo for that question. Ferns have been around a really long time. We know from the fossil record as well as from estimates based on DNA sequence data that ferns have been around since the Devonian which is about 400 million years ago. This is a really really old lineage but the really cool thing about ferns, even though this is really old lineage, most of the species that are on our planet today are actually very young.

Maggy Benson: This question comes in from Nuso. Do ferns make their food with photosynthesis?

Eric Schuettpelz: Yes, exactly. Ferns, like all plants, photosynthesize and use light to make sugar and that's their food. Yes.

Maggy Benson: We have another question from Indigo by video.

Eric Schuettpelz: Okay, great.

Indigo: How big was the biggest fern ever recorded?

Eric Schuettpelz: The biggest fern ever recorded, today the largest ferns that live on our planet are members of what we call the tree ferns. As that name suggests, these things are very treelike. They have trunks, in many cases those trunks can reach upwards of 20 meters, or 60 feet in height. It's possible that some ferns, or things that we recall ferns from the Devonian Period or the Carboniferous, may be even bigger than that.

Maggy Benson: Those tree ferns, do they make wood?

Eric Schuettpelz: They do not make wood. Only seed plants are able to make wood.

Maggy Benson: So, this one comes in from a guest. Are there microscopic ferns?

Eric Schuettpelz: There are microscopic ferns in the sense that, there are ferns that would be very difficult to see without a microscope. The gametophytes, for example, of most ferns are pretty small. Some could be as large as your pinky fingernail, others can be even bigger than that but others might be much smaller. In terms of the smallest sporophytes, the more typical life stage that you're used to seeing, the smallest sporophytes are also probably about the size of a pinky fingernail.

Maggy Benson: Can I find a gametophyte if I went out and I looked in the right place?

Eric Schuettpelz: Absolutely and I would encourage folks to get out there and see if they can find some gametophytes. You probably want a flashlight, you'll probably want a magnifying glass and the best place to look is a dark, soil bank in a forest. Especially in a temperate area.

Maggy Benson: We have another question about what they look like, so what colors are ferns?

Eric Schuettpelz: Most ferns, that you're familiar with, are green. They come in every lovely shade of green imaginable. In some cases, the youngest leaves are actually very brilliant red in color. This happens in a number of groups and they're really quite lovely as you saw in that image that just came across.

Maggy Benson: Evie has another question. She wants to know can animals eat ferns and if so, which animals?

Eric Schuettpelz: The most common animals that are eating ferns are insects. There are some insects that are generalists and eat a lot of plants and eat ferns as one of those. There are also insects that are specialists that only eat ferns.

Maggy Benson: Wonderful. Eric, thank you so much for answering these questions and for teaching us about ferns today. Thanks for tuning in today to learn about ferns with Dr. Eric Schuettpelz and we hope to see you next time on Smithsonian Science How.