Video Transcript – Measuring Biodiversity – Life in One Cubic Foot

Maggy Benson: How do [00:00:30] you measure the biodiversity of all life on earth? Naturalists have been working for centuries, exploring remote habitats on land and in water to catalog the planet's living organisms.

Maggy Benson: Museums maintain huge collections of these specimens, which represent earth's known biodiversity. But now, new technologies allow scientists to take a snapshot of life in a way that was not possible before. [00:01:00] Today, we'll meet with Marine Biologist Chris Meyer to learn about his cutting edge work on measuring biodiversity.

Maggy Benson: Hi. Thanks for joining us. I'm Maggy Benson, host of Live from Q?rius, Smithsonian Science How?

Maggy Benson: We have an awesome show today for you, but before we get started, I want to ask you a question. You can respond using the poll that appears to the right of your video screen. Do you think it's important to know about every species on Earth? Yes, no, [00:01:30] or maybe you're not sure. Take a moment to think about it, and put your answer in the window to the right.

Maggy Benson: All right. While your results are coming in, we're going to go to our expert. Today we have with us Marine Biologist Chris Meyer from the Smithsonian's National Museum of Natural History. Thanks for joining us, Chris.

Chris Meyer: Thanks for having me, Maggy.

Maggy Benson: So Chris, I know that you study marine invertebrates. Can you tell us a little bit about what that is [00:02:00] and what you do?

Chris Meyer: Sure, I study marine invertebrates, which compose the bulk of the diversity of life in the ocean. I'm basically a biodiversity scientist. Our job is to go out and document the diversity of life on the planet, much like many researchers at the Natural History Museum. We go out and collect and try to discover the new species and also document the patterns of life on the planet.

Chris Meyer: In front of me is a variety of cowries that I've collected for my Ph.D. and we also have a number of specimens that we've brought [00:02:30] back from a recent field trip. Basically, biodiversity in a nutshell seems like maybe a complicated word people aren't familiar with, but it just means variation in life. And I see studying biodiversity is like doing a giant jigsaw puzzle, and we're identifying the pieces; we don't have the box top, so we're out there looking and exploring and finding the missing pieces, and more importantly then how they all fit together.

Chris Meyer: And we happen to do it on reefs, where it's one of the most diverse spots on the planet.

Maggy Benson: And you said you look at [00:03:00] invertebrates, so those are animals without a backbone?

Chris Meyer: That's correct.

Maggy Benson: So 80 % of our viewers think that it is important to study and understand every species on Earth. What do you think?

Chris Meyer: That's good news. I agree. And it's a lot of fun, too.

Maggy Benson: Wonderful. So you said that you go out and you actually look for these species, these pieces of the puzzle, for your research. What do you do with those?

Chris Meyer: Well, what we do is, it's important to understand the animals [00:03:30] where they live, so it's very important to document the habitats that they're found in, to take photographs of them living because oftentimes when we preserve them as reference materials for later, they lose their color if they're in preservatives. So we collect and relax and preserve the whole curation process of bringing them back to the museum so they can provide comparative material for scientists to look at for centuries to come.

Chris Meyer: Natural history museums [00:04:00] maintain these collections in order to provide the standards that other life is compared against.

Maggy Benson: So how big is a collection, say here at Smithsonian's Natural History Museum?

Chris Meyer: Well, Natural History Museum's one of the biggest ones in the world. We have, in the Department of Invertebrate Zoology, we have over 35 million specimens.

Maggy Benson: Wow.

Chris Meyer: Which actually if you lined them up, it would extend for about 15 miles of shelf space.

Maggy Benson: That's huge.

Chris Meyer: It is quite remarkable.

Maggy Benson: [00:04:30] So why should we keep all of them?

Chris Meyer: Again, this is the main comparative material. When you think you find a new species, you come and compare it. It documents life. But more importantly, museums more and more are seeing themselves as time capsules. We can't go back in time, we don't have time machines. But the collections that we have made enable us to go back and look at communities and species and ranges so we can compare the present with the past to predict the future.

Maggy Benson: I understand [00:05:00] that these are some of the collections that we actually have here at the museum?

Chris Meyer: That's right.

Maggy Benson: And what are they?

Chris Meyer: So again, these are cowries, they're snails that have a shell and they're spectacular and I was very lucky to work on my Ph.D. to go out and collect and document them.

Chris Meyer: This other collection is from a series of work we've been doing to try and use some of these new technologies to address diversity.

Maggy Benson: What kind of new technologies do you mean?

Chris Meyer: [00:05:30] It's been a relatively recent development. In the past, people would compare the bumps and the patterns on these shells or maybe some other features of the shape. Now we have new genetic technologies that allow us to get into the DNA, actually. And the DNA is the blueprint of life. (It) allows us to compare the sequences of G's, A's, T's and C's from one species to another in order to get kind of a license plate, or a bar code, for every species.

Maggy Benson: [00:06:00] So every single species has its own unique DNA, like what we're looking at now.

Chris Meyer: That's right. So on the screen, if you notice, that's a little string of DNA that we've isolated from three different species. In the top, there are two Butterfly fish species. And in the bottom, there's a Hawkfish. And if you notice, there are more similarities between the Butterfly fish species than there are between either of those Butterfly fish and the Hawkfish.

Chris Meyer: So there's about six differences between those Butterfly fish species, whereas there's about 18 differences between any of the two Butterfly [00:06:30] fish and the Hawkfish. That little region of the DNA is what allows us to differentiate them at all life stages, not just as adults, but from eggs all the way up through even when they die.

Maggy Benson: Mary from Omaha has a great question, and she wants to know how much tissue do you need to get for a DNA sample?

Chris Meyer: It's a good question, Mary. You know, we don't need very much. The cells have a lot of DNA packed in there super coiled, so we take just a tiny little fraction and we also try [00:07:00] ... if we can do it in a non-destructive way, we'll try and do that. When I was collecting these cowries, you could just take a little piece of the foot and actually as long as you photo-document and record what that was, you could let the animal go. It's a very small amount.

Maggy Benson: Wonderful. I know that you're employing these DNA techniques in some of your other projects, specifically in Moorea. Can you tell us where Moorea is and why you chose that location for some of your field work?

Chris Meyer: Yeah, so we took on this ambitious goal ... Just like we're trying to document life on the planet [00:07:30] ... To go to French Polynesia, and there's a little island called Moorea that sits next to Tahiti. It's kind of right below Hawaii on a mirror image across the Equator. And we picked this island because there's ongoing research activity. There are two long-term research stations that are conducting work. And we wanted to build a better guide book of all the diversity on this island. Because it's a tropical place. It has all the features of these diverse communities, but at the same time, it's very remote, as you've noticed. It's in the middle of the Pacific Ocean, so it had what we [00:08:00] thought was a manageable amount of diversity from plants and animals to fungi.

Maggy Benson: So going back to the poll question that we actually asked our students, you are trying to count every single species that lives in Moorea on land and in water?

Chris Meyer: That was the goal that we set ourselves with. So it was a big effort and we tasked ourselves over five years to go out and try to collect a representative individual ... because it was important to have a voucher that had tissue and DNA for every species that we encountered.

Maggy Benson: [00:08:30] How did you do that?

Chris Meyer: It was just like a huge, regional scavenger hunt. We invited experts from all over the world to come down and they partook in expeditions where we'd go from the tallest peaks ... We'd drop people out via helicopters on the highest mountains, we did light traps, we did black-lighting, we did flight intercept traps, we did any way to collect and document diversity that we could. And we let the experts try and find that as best they could. Sometimes it would last one person for a year, other times it would [00:09:00] be many people for up to say three weeks. So it was a giant bio-blitz, basically.

Maggy Benson: It sound incredibly labor-intensive. What happened? What were some of the results of that project?

Chris Meyer: Over five years, we kind of ... at current count, we've documented over 7,000 species. As we thought, more than half of them are in the ocean, between the fishes and the marine invertebrates. And here's a little reel of a handful of creatures in the portfolio that we captured. [00:09:30] And you can see we captured photographic images that tried to convey the diversity that we got so, if you saw them again, you'd notice them.

Chris Meyer: And again, it was about 7,000, but we know we didn't finish. There's still many, many species to be discovered. And one thing, if you look at the species that are rolling by, there are about maybe 80 species that are in that video montage

right there, and if you wanted to look at all 7,000, [00:10:00] it would take about 45 minutes for us to run through, which would probably be by the time we're done.

Maggy Benson: Wow.

Chris Meyer: And it's fun to think about at that rate, if you looked at all the described species on the planet, how long do you think it might take you to do that?

Maggy Benson: So if it took 45 minutes to catalog 7,000 species ... or not to catalog, but to show 7,000 species at that rate, and I know that there are over one million described species on Earth, I'm gonna have to say several days.

Chris Meyer: Yep. So we think there's about 1.5 million species described, and that's just the [00:10:30] described stuff, it would take you six continuous days of watching that movie clicking at that rate to see them all.

Maggy Benson: Wow, that's a long time.

Chris Meyer: Yeah, if you don't sleep or eat.

Maggy Benson: We don't need to do that.

Chris Meyer: No.

Maggy Benson: So we have another student question. Lillian wants to know: Have you ever personally discovered a new invertebrate species?

Chris Meyer: Yes, actually, a couple. When I was doing the work on the cowries, I stumbled across a number of things. There's a species here in the drawer. This is [00:11:00] a map cowry and it was thought to be just one species, this one here. And it turns out that there are about six different species in that group, and it was through using these genetic sequences that we could compare and then go back in and look for more clues in the shell. And we found many, many other ones that are very similar to that.

Chris Meyer: So we're in a time phase now when we're finding that there's probably much more diversity than we even thought, even in described species.

Maggy Benson: You keep saying described species and having these vouchers, meaning having the original species to be able to go back and reference [00:11:30] with the images. Why is it important to build this database, this registry?

Chris Meyer: One of the ways you can think about it is that we've done kind of a door-to-door census of the ecosystem. So we've gone and looked at where taxa, or species live. And now we can use that information to go and ask some interesting questions. Once we've done the puzzles, we can figure out how they fit

together. Some of our assumptions about how ecosystems work and how species interact, we're checking. And one of the ways we do that is by analyzing [00:12:00] gut contents because there's still DNA in the pieces that are getting eaten.

Chris Meyer: And we've analyzed ... We had one study I worked with a student, Matt Loray, who's still here at the Smithsonian, looking at the guts of two Hawkfish species. And the ecologists might-

Maggy Benson: That's looking at what they were eating.

Chris Meyer: Exactly. So we used this registry of the database and we examined their food items, and we discovered that between the two fish species, there's an Arc-eye Hawkfish and a Flame Hawkfish, [00:12:30] and they both live in the same coral head. Here's two pictures of each of those species. They live in the same neighborhood. We can think of them, they're at the same restaurant and some of the people would assume that they're eating the same thing because they're closely related. They might have similar tastes.

Chris Meyer: Well, it turned out when we did the analysis that they ate completely different prey items. The Arc-eye on the right ate bigger organisms and the Flame Hawkfish ate smaller ones. So when we think about how ecosystems function, There's less redundancy in the system; there's [00:13:00] more diversity ... There are more tightly linked interconnections, so it's important to check our assumptions about that because maybe they're a little more fragile than we thought.

Maggy Benson: So you can learn a little bit more about how everything's connected on this coral reef?

Chris Meyer: Absolutely. Yup.

Maggy Benson: You've done a lot of work on registries. How does some of the sampling actually translate to some of your other work?

Chris Meyer: Now that we've done the inventory, we can start thinking about doing observatory. We ran around and collected things, [00:13:30] not randomly, but systematically around the island. But now we want to use this tool to monitor the system. So we've developed a couple of ways of standardizing that effect. Here's a little video of these autonomous reef-monitoring structures (ARMs), which are basically pre-fab housing we put down on the reef.

Chris Meyer: Now, most of the reef diversity lives in the nooks and crannies of the reef, and it's hard to access, so we build these structures to mimic that complexity. We leave them in the ocean for a year. We come back after a year, we put a lid on them and [00:14:00] bring the entire neighborhood up and we analyze every living creature that we find in that stacked set of plates, in the ARM structure.

Chris Meyer: Here you can see some of the images. We photo-document each of the plates and they're beautiful. So all those creatures have grown on that plate in one year, and we get a better handle on the diversity. Because it's standardized, we can compare place to place, site to site, and it can be done both regionally and globally.

Maggy Benson: It's hard to believe that those are animals. It looks like artwork.

Chris Meyer: They look [00:14:30] like spectacular paintings, don't they? And we brought, just so people could see-

Maggy Benson: This one right here.

Chris Meyer: This is one of the crates that we put on top of the (ARM)... Then when we capture it, it's got a mesh and so it keeps the creatures in it. And just to get a sense of the (ARM) structure and the complexity that we use, half of them have little caves and half of them are open.

Chris Meyer: So that's the structure we take apart and analyze. And we look and see how many we have in our inventory compared to now using this device.

Maggy Benson: That's really interesting. So after you've actually picked apart [00:15:00] in this huge study in Moorea every little animal that you're finding, in this one you're saying that there could be species that you're discovering that are undescribed.

Chris Meyer: On every ARM, we find a handful of more species, in every instance, there's no doubt.

Maggy Benson: So I think we have another poll here for you. We actually want to ask you how many species you think are undescribed. And this is, again, thinking about the idea that we don't know everything about life on Earth. So [00:15:30] what percentage of all biodiversity on the planet is still uncatalogued? Twenty percent? 40 percent? 60 percent? or 80 percent? Take a moment to think about it and put your answer in the window to the right of your video screen.

Maggy Benson: [00:16:00] So Chris, we got some interesting results here. We have 86 percent of our viewers thinking that 80 percent of life on the planet is uncatalogued. What do you think?

Chris Meyer: I think that's a good answer. That's about where we stand. There's a lot of work to do. We think [00:16:30] there are about 80 percent, maybe 70 percent, still uncatalogued. So that means there are a lot of unknown species out there.

Chris Meyer: Now, we're getting a handle on how well we did in Moorea by using devices such as this ARM structure. And now through new technologies, we can start asking exactly how many things we're missing out there in the environment.

Maggy Benson: So we have another student question for you. This one is: Do you collect species that are considered endangered?

Chris Meyer: No. We try to avoid [00:17:00] collecting protected or endangered species. We're very conscientious of, there are lots of, rules and regulations that we have to abide by. It's also important, though, to study them to know. So if they are studied, there are various protocols in place such that it's done in a non-destructive, noninvasive way.

Maggy Benson: I want to get back to this ARMS structure. I want to know how you actually understand that there are undescribed and uncatalogued animals that live in this.

Chris Meyer: So once we've done the voucher approach again, we turn [00:17:30] the tables and we do a different technique. We look at the plates, try to pick out all the species that we can actually see, but then we actually take the creatures that lived on the ARMS and we scrape them off the plates and we put them in a blender. We've shifted now from a find and grind approach to a grind and find.

Chris Meyer: We literally make a reef smoothie out of them.

Maggy Benson: Uh, that doesn't look very appetizing.

Chris Meyer: It doesn't smell very good, either.

Chris Meyer: So you've got the entire community blended [00:18:00] together, and then we can extract the DNA in total of that entire community and then we can run some kind of fancy analyses of looking at that license plate. Effectively, these are basically toll booths or fast passes, so we can set them up to monitor the entire diversity. And there was a picture there where you can actually see the DNA, and then we sequenced that and we get a library of all the members of the community. Then we can compare that library to what we have in our database, and if we're missing it, they're kind of dark [00:18:30] taxa, or dark species; you can think of it as dark matter in the universe. We know it's there, but we're really not sure what it's doing.

Chris Meyer: And it's important to kind of understand how those trajectories, as there's change going on, we need to better understand the trajectories of all the communities. Is it falling off drastically? Is it falling off a cliff or does it fall kind of steadily?

Maggy Benson: I don't understand why it's important to understand all of this. Why is biodiversity important and why is it important to understand all of these undescribed [00:19:00] species?

Chris Meyer: It's a really good question, and I hope to do a little analogy here. I don't know how many of the students out there have ever played the game Uno? I think

most kids have probably run across this game. It's a pretty simple card game where it's like Crazy Eights, and I wanted to ask a poll of the students to see if they understand and try to learn a little about why biodiversity's important.

Maggy Benson: Great. So let's go to the poll. Which Uno hand do you prefer to be dealt with? Hand one? or Hand two? [00:19:30] Hand one has mostly red cards, while hand two has more variety of colors and numbers.

Maggy Benson: The answers are in and our viewers are unanimous in saying that the second hand, the one with more variety, is better. What do you think?

Chris Meyer: That's exactly the message. Again, the diversity, that variation, is a hedge against change. I mean, it's fine if it stayed on red, but if it shifts, you better have something in your back [00:20:00] pocket to adapt to that.

Chris Meyer: So in many ways, that's about biodiversity, whether it's in populations or in communities or whatever, you need to have the capacity to adapt to change. It provides you some resilience against that. It's important to document how much of that diversity is in the community to understand its capacity to adapt.

Maggy Benson: You've pioneered this work in Moorea. Where else have you applied it?

Chris Meyer: We've taken what we've learned and the lessons from Moorea, and no we're actually going to the heart of marine diversity in Indonesia. This is kind of the heart of the coral [00:20:30] triangle, where it's the most diverse marine spot on the planet, and we've set up an Indonesian Biodiversity Research Center at Udayana University in Bali, where we've been training (scientists).; Every summer we run courses on biodiversity inventories and survey methods. And we're training the next generation of Indonesian scientists to learn more about their biodiversity, to become better stewards and better managers of their natural heritage.

Maggy Benson: So that's really training the next generation of scientists. Do [00:21:00] you work with other students?

Chris Meyer: We also have thought long and hard about how to engage all levels of students in the process, and we've worked a lot with middle school students and high school students, and we've adopted another method. This is one cubic foot, and I'm gonna bring out this frame here. It's a very simple model that we've developed, and we're prototyping this process to go around and capture a cubic foot of biodiversity in any habitat.

Chris Meyer: So we've worked with students out in the Golden Gate [00:21:30] National Recreation area, and here you can see some students, piloting this project where we were looking at a pond area. And we challenged those students to find the most diverse areas and then observe the habitat and document all the

species. Again, by focusing our attention on one cubic foot, that itself, as a functioning ecosystem, becomes a bit of a biological barometer of diversity.

Chris Meyer: You can go back and monitor this same area time over time, or look at impacts along gradients, maybe away from a path or [00:22:00] away from a road or something like that. And it's really fun, the students have a great time, and they provide real data that then can be comparable from site to site or class to class.

Maggy Benson: So it's really another version of the ARMS?

Chris Meyer: It is. It's exactly a version of the ARMS. It's life in a cubic foot.

Maggy Benson: We have another question from Mrs. Hamilton. Her class wants to know: What's the most diverse ecosystem in the world?

Chris Meyer: Wow, that's a great question. It depends on the scale that you sample it at, right? That's the trick. If we were taking one [00:22:30] cubic foot and putting that anywhere, where would we find that on the planet? Well, David Liittschwager that I've worked with, he did this in tropical rainforests and tropical reefs, and tropical reefs had about 330 species in it, whereas a tropical rainforest canopy only had about 130. Now, that's just in a cubic foot. But if you aggregate it, I think the tropical rainforest might win over the reefs. Although, it's debatable. That's what we're out there testing.

Maggy Benson: Robin has a question. She wants to know how you became a marine biologist.

Chris Meyer: Good question, [00:23:00] Robin. I grew up being fascinated with diversity, visiting a lot of museums, doing a lot of reading, and I basically just kept that curiosity going and realized I had some great teachers and mentors, and they were really important and kept encouraging me to keep pursuing that passion. And I think that's what I would suggest to any students out there; just follow your heart and your passion and if you're interested in it ... and it takes work, there's no doubt, but I was [00:23:30] really curious, so it makes it easy.

Maggy Benson: All right. This one comes from Mrs. Stewart's fourth grade class. How do you name the new species that you find?

Chris Meyer: That's a good question. Oftentimes, the name conveys something about the features of the animal that make it distinct. Or oftentimes it's named after somebody to whom they want to give some sort of credit. So it could be your wife or your benefactor or whatever. Or the place. Oftentimes, the name conveys where it was found [00:24:00] first.

Maggy Benson: This one comes from Finn. And Finn wants to know how do you memorize all the names of the marine invertebrates?

Chris Meyer: I don't. That would be really hard. It takes years to ... and I don't like memorization. It's why I didn't like biology at first. But actually, then understanding it as a system makes it a lot easier, and it's just like any language; the more you do it, the more familiar it becomes.

Maggy Benson: From Humberto: What is the most amazing thing you've ever seen [00:24:30] in the ocean?

Chris Meyer: Everything's amazing.

Maggy Benson: I agree.

Chris Meyer: No, that's a great question. It is fascinating. Every species tells a story. Some of the more interesting interactions, there are really amazing Gall Crabs that actually live in the corals, and they get the corals, just like a hornbill to kind of grow around the female. And then the male goes in and out and feeds the female. It's an amazing interaction, and that's kind of a wild [00:25:00] species. There are many, many stories like that across marine ecosystems.

Maggy Benson: So Elio from Louisville: How can our class study biodiversity like you?

Chris Meyer: Well, that's one thing we're trying to do with the bio-cube project is we're trying to bring it to everybody's backyard. One of the ways is just to sit down and appreciate and observe, just try to find the most diverse spot in your local playground or your local communities.

Chris Meyer: [00:25:30] Again, we're trying to prototype this and get this out to everybody. So I think in about a year's time, we'll be able to help you out a lot and you'll be able to feed into a national effort to document diversity in your neighborhoods.

Maggy Benson: Sophie wants to know what's the most interesting thing you've discovered?

Chris Meyer: Hmm. Sophie. You know, it's great. I have a great job because everything is interesting. You keep moving on from one thing to another. But I think some of the most interesting things was when I was first starting to use [00:26:00] these DNA techniques as a tool, and realizing what it revealed as far as the diversity, particularly in these cowries, where people had studied them for centuries and could never really verify some of their ideas. And then to bring the power of the DNA to look and document that there was all this underlying diversity, I remember specifically the day where I got the data back and I was like, "Wow. This isn't one species, this is really five species." That was pretty remarkable.

Maggy Benson: [00:26:30] This one comes from Judy from Santa Fe. She wants to know what kinds of things kill biodiversity?

Chris Meyer: That's a good question, Judy. As far as threads to diversity, the two biggest threats to reefs these days, local threats, are certainly overfishing and bad water

quality. Those really threaten diversity because it changes the dynamics of the ecosystem. The fish are there to help graze down the algae, and the corals are competing with them. And you can create a complete tipping point. But we're actually looking at [00:27:00] what are the ... That's fish, algae, corals, but if you look at the underlying diversity, what's it doing to that? We really don't have a good handle on everything else that's in the reef. But definitely the big threats are fishing and water quality.

Maggy Benson: So Zack from Little Rock wants to know how their class can get bio-cubes to use. And I say we say stay tuned, right?

Chris Meyer: Yeah. I mean, again, we're really close. We're working on all the tools to capture the data, and again, stay tuned. We'll be using Q?rius, and we're working with some other [00:27:30] developers; iNaturalist has a platform to help democratize and really put this in everybody's hand.

Maggy Benson: So what is the favorite part about your job, asks Sophie.

Chris Meyer: I'm always excited to go to work. That's a good thing. Every day, you're gonna see something new or you'll come across something that's surprises you and you get to follow your passions. It's a great place to be, and it's a great line of work. And I just feel [00:28:00] lucky every day. I feel like I've never grown up; I'm still a kid at heart.

Maggy Benson: So thank you so much for tuning in today. And thank you, Chris, for being here. Is there anywhere that our viewers can go to learn a little bit more about your work?

Chris Meyer: Sure. If you're interested in following up on any of this, there are two websites that I can steer you to: Mooreabiocode.org gives you information about the Moorea Biocode project and also the IBRC.org tells you a little about what we're doing in Indonesia. And of course, also pay attention to the Q?rius [00:28:30] website, where we'll be posting more information, and follow-up as the bio-cube project matures. Thanks.

Maggy Benson: Great. Thank you, Chris. Thanks again for tuning in today. If you missed part of this broadcast or want to see it again, it'll be archived later today on Qrius.si.edu. Thanks so much for joining, and see you next time on Smithsonian Science How?