Leila Nilipour: Is it possible to travel back in time? Well, some scientists sort of do it for a living, to answer some of the most pressing questions of our time: like, how have climate change and humans affected our oceans in the past and how can we use that information to manage tropical marine ecosystems today and create a more sustainable way of life going forward?

Welcome to Biodiversa, the podcast of the Smithsonian Tropical Research Institute in Panama, also known as STRI. My name is Leila Nilipour, and I am a science journalist. In this episode, we will join a team of paleo scientists as they search for clues about the ocean's past. This journey begins on a sailboat near Isla Iguana, a volcanic island and wildlife refuge off the coast of the Azuero Peninsula in the Panamanian Pacific that is known for its abundance of iguanas, frigate birds and hermit crabs. It's also surrounded by coral reefs. And the time-travelling vehicle of these scientists is nothing like Marty's DeLorean in the Back to the Future movies. It's actually a 6.4-meter aluminum pipe.

Erin Dillon: So essentially, we start with a six-meter-long piece of aluminum pipe. It's essentially an irrigation pipe about 10 centimeters or three inches in diameter. And this pipe, I mean, it's it takes multiple people to actually hold it. It's really really long, and essentially what we're doing is pounding it into a reef. So we take a fence post pounder something you might see like on a ranch...

Aaron O'Dea: So will be lot of moving around and trying to position it and then suddenly I'll shout go and Jon will start pounding...

Go!

Erin Dillon: Which takes you know multiple hours to actually do and we have a team of you know, seven or eight people taking turns on snorkel trying to pound this thing in.

Jon Cybulski: So Maybelline you're next, it just goes in a circle and we take turns. Cambio!

So we bang this pipe down through the coral reef. We cap it off and then we pull it out...

Erin Dillon: And then we twist it and twist it and pull it and pull it

3,2,1... 3,2,1... 3,2,1... Hold it.

3,2,1... 3,2,1... break.

3,2,1...3,2,1, 3,2,1, pull... you'll have to wiggle a little bit, I think. That's it, there you go now it will come out. The wiggle always helps, a little wiggling is good for the soul. There you go, see?

Jon Cybulski: And when it comes out it maintains that structure so it maintains that those different layers and every one of those layers is a different piece back in time.

Erin Dillon: And we're able to get the whole thing out and it gives us this chronology of reef accretion over thousands of years. And we take it back to the boat and slice and that kind of is the very beginning of actually collecting these samples.

LN: It sounds intense, and it is, with all the pounding and banging and the wiggling and pulling. But it is also a very controlled process: the diameter of the pipe is only 10 centimeters, about the diameter of a medium-sized bagel, so very little live coral is actually impacted as it penetrates the reef, and the coral colonies are able to regrow. Most of the material that is extracted with the pipe comes from the layers below the live coral, which are made up of dead coral skeletons and other skeletal material from reef organisms.

Jon Cybulski: So our goal here is to add a point between the Gulf of Panama and the Gulf of Chiriqui because we have several cores from Las Perlas archipelago and Coiba Archipelago and Isla Iguana represents this central point, not only spatially, but environmentally.

In the Gulf of Panama there's strong seasonal upwelling, in the Gulf of Chiriquí obviously less upwelling, and pretty consistent throughout the year.

LN: This is Jonathan Cybulski a Tupper postdoctoral fellow at STRI and a historical ecologist. He is part of the lab of Aaron O'Dea, a marine paleobiologist at the Smithsonian in Panama. And the thing about Panama, specifically its Pacific Ocean, is that some areas experience upwelling, or cold, nutrient-rich water for several months each year, while other parts are warmer and stable all year-round. This makes it a unique place to study how this environmental variability may have impacted reef communities in the past.

JC: So, everybody at this table and then in the O'Dea lab are interested in different things in the past. For example, I'm looking at the coral communities, *arrecifes de corales*. And it's important to get kind of the central point because it could represent this in-between station of the two different environments, not as strong upwelling, not quite Coiba because its right at the end of the Azuero peninsula.

So the main goal really for these cores is to look at the coral communities, so we can build that history...

LN: The history of these coral reefs through time.

Aaron O'Dea: That's one of the things we're looking for is to see how how the coral reef grows during times of environmental change in the past. Because I think that that will give us some interesting clues about how we can predict what's going to happen to coral reefs in the future. So it's 7,000 years of environmental change. A lot of things have happened: some warming, some cooling maybe...

LN: That was Aaron O'Dea. As you may have guessed, he is the main scientist in the O'Dea lab.

AOD: And then we delve into the really good stuff as well, which is all the tiny little otoliths and the denticles. And the tiny fossils which are all in between the corals and we can build a picture of not only the corals but also the reef fishes and the sharks, and the sponges and so on. So we build a whole picture, and we can see how how those ecosystems as a whole have responded to these changes.

And then on top of that we have this super interesting system of the human history of those reefs and thanks to all the great archaeological work by Richard Cooke and Ashley Sharpe and we know that there are waxing and wanings of humans during this time as well and the interactions of those two, three things: the environment, the ecology and the humans I think is a really unique system from this part of the world that we can explore.

LN: When Aaron talks about the tiny otoliths and denticles, he's referring to the work of Brígida De Gracia and Erin Dillon, who are also on board. Brigida is a descendent of Panama's Ngäbe-Bugle indigenous group and the lab's expert on fish otoliths, tiny fish earbones made up of calcium carbonate. They preserve really well in the fossil record and offer clues about the types of fish present in the ecosystem and the type of environmental conditions that they lived through. And Erin Dillon is a Tupper postdoctoral fellow like Jon. She wants to know how shark populations, the major predators on these reefs, have changed over time and how that may inform our reef management decisions today.

ED: So trying to understand how many sharks there were on reefs before humans, before fishing, and how their communities have changed through time.

LN: She does this by using a fairly new technique looking at shark dermal denticles, which she also calls "shark dandruff". These are "microscopic tooth-like scales" that sharks shed and that are well preserved in the core sediments. Based on the characteristics of these tiny denticles, she can tell which types of sharks were swimming around these reefs hundreds or thousands of years ago.

Aside from the shark denticles, fish otoliths and fossil coral fragments, other hard remains from reef organisms, such as sponge spicules, mollusks, sea urchin spines or fish teeth can be collected from the cores. With all of these, the team may reconstruct what the ocean was like in this part of the

world and how it has changed over thousands of years. But let's get back to Isla Iguana.

ED: Yeah, so taking a core is really hard work.

LN: Pounding 6-meter aluminum pipes through coral reef and further into the ocean floor, a few times a day, for several days in a row, not only requires brute force and good snorkeling skills, but the weather and the tides must be just right.

AOD: Ok so we're going to anchor the boat off the reef so we don't kill any coral and hopefully drift backwards with the currents over the reef, and then from the side of the boat will lower the core down onto the coral reef. It will hopefully be sticking out three-and-a-half meters from the water and then Jon will be on the top of there. People in the water positioning it, so it's really really important that the core barrel is vertical it also comes out easily if it's not vertical it's really hard to pull out so...

LN: And watching a group of people pound these long pipes into the reef, off the coast of a wildlife refuge, well... it doesn't look great to passersby without context. During the first day of coring, a tour boat operator approached us. He looked upset.

Saben que el coral no se puede quebrar. Verdad? Están quebrando el coral. No, no estamos quebrando el coral... no? Es de abajo, el que está al fondo.

LN: You know the coral cannot be broken, right? You are breaking the coral, he said. One of the crew members answered back, no, we're not breaking the coral.

Kimberli García: I can go and talk to them and explain them what is happening. Show them our permits and stuff. Oh yeah, the permits are over there.

AOD: Let's focus on this first.

LN: To prevent misunderstandings, Kimberli Garcia, Aaron Odea's lab manager, visited the tour operators on the island, showed them the lab's research permits, and explained how the coring project could help us understand the past in order to protect our reefs in the future.

LN: The rest of the trip was pretty much drama-free. But getting the cores was just the beginning. Once brought onto the sailboat, they drained the seawater by poking holes near the bottom of the pipe, and then capped it to make sure the contents remained in place for the duration of the trip.

AOD: We'll try and get it as close to the to the coral as possible. Cut it through so that we have a nice clean tight cap on it. You see, most of it is water.

LN: The tube also had to be marked, so that they would know which side had the oldest coral.

AOD: So if we scratch on the barrel then the labels won't disappear, we always know which way is up. Cause if we get the core back and it's been flipped upside down, we will be going forward in time, instead of backwards in time.

LN: Back on the mainland, with a bunch of cores, it would take several months before this team could start their journey back in time. We visited their lab as Erin and Brigida showed us every step of the process. First, cutting the pipes vertically with an electric saw to access the coral sediment inside

LN: And then, taking coral samples at different intervals from the top of the core to the bottom.

ED: So what I'm going to do is just kind of roughly as we go collect some nice-looking corals. So I want to get one definitely from the top just to see what the date is. Essentially these corals are gonna be used to build what's called an age-depth model. So will give us an estimated age and then we'll know exactly like where that coral came in the course of how far down the coral barrel was...

LN: For this, they use a technique called uranium-thorium dating, which can pinpoint the age of the sampled corals to about plus or minus 10 years. This can help scientists tell how far back in time they are going as they explore the contents of the core.

ED: So was the top exact modern was it maybe maybe dates to 20 years ago? Maybe we go down a meter and we're like at 200 years maybe we're at 500 years. This will give us a sense of how much time is actually encapsulated in this core.

LN: After taking the coral samples that would be sent out for dating, Erin placed the contents from the pipe in different bags. One bag for every five centimeters down the pipe.

ED: Essentially here we just have a bag and each one is going to represent a five-centimeter interval that we're gonna sample. So I'm just gonna go like zero to five centimeters, five centimeters to 10 centimeters, all the way down, and that gives us enough material to then pull various micro fossils and other bits of skeletal material out.

Some fresh-looking coral here. And as you can see, we have some very high-tech tools including a spoon and a knife. So these intervals will get dried essentially then I'll weigh them. So we'll get a full dry weight of the sediment or whatever is in there.

LN: After that, the samples were separated according to the size of the particles with the help of sieves with different mesh sizes.

ED: And there's a bit of a technique here, so it's a lot of kind of swirling, you're using the water to kind of encourage the particles to go down to their right sieve size. Get anything that is going to fall through to fall through.

And then from there different people in the lab will work on different segments. So Jon for example will be working on some of the largest stuff that we worked on the corals. Brigida will find otoliths in some of the smaller size fractions and then I'll be looking in the really tiny ones for denticles.

LN: But in order to reach the denticles, which are present in the finest sized sediment, Erin first had to process her samples with acetic acid.

ED: And essentially we're using acetic acid which is think of as vinegar. We're using 10% the vinegar that you find in stores, I think it's like three to five maybe but essentially it's the same thing and we're using that to essentially digest all of the carbonate calcium carbonate bits that are in the samples. So bits of like ground up coral essentially in the sand.

LN: Acetic acid dissolves the calcium carbonate in the sample, such as tiny pieces of coral or animal skeletons, and releases carbon dioxide in the process. It sounds like adding an Alka seltzer tablet to a glass of water. The shark denticles are made of a tooth-like material, so while everything else is dissolving around them, they remain unaffected.

ED: And then we know they're done basically when they stop bubbling if we add more acid and they're not bubbling. There's nothing for it to react with and so at that point we can be pretty sure that most of the carbon is gone, at which point will then do a final step which involves using some hydrogen peroxide to get rid of a little bit of organic material in the samples, and then they'll be ready to pick for denticles.

LN: At this point, Erin is ready to start exploring what shark communities looked like around Isla Iguana in the past hundreds or thousands of years, and perhaps even observe if they changed after humans arrived. She has already done this work on samples from other, more nutrient-rich marine sites along the Pacific coast, such as Contadora and Saboga in the Bay of Panama and from nutrient-poor sites in the Bocas del Toro archipelago in the Caribbean.

ED: For my work we're often looking over several thousands of years. So in Bocas we have our mid-Holocene samples that are about 7,000 years and that gives us this really unique window into what these reefs look like before some of the first evidence of humans in the region and then comparing that with today.

And in terms of the denticles we find that there was about three times more denticles on the reefs in the past 7,000 years ago than there was today which suggests about a 71% decline in denticle accumulation or kind of you can think of it as a proxy for shark abundance through time.

LN: This means that the number of sharks around that particular reef really dropped after humans showed up. She also discovered that the kinds of sharks changed. The thing about denticles is that they have different shapes, and these shapes offer clues about the type of sharks they came from, which is actually part of a technique that Erin helped develop as part of her PhD. In Bocas del Toro she found declines in denticles from different types of sharks, but disproportionately higher losses from those corresponding to faster swimming sharks, such as hammerhead sharks, mako sharks, silky sharks and blacktip sharks, which makes sense given that they are also the species often targeted by humans. But how does this trend in the Panamanian Caribbean compare to the Pacific?

ED: Part of the study is to look at changes across the isthmus. So how were the shark baselines thousands of years ago on the Caribbean side different from the Pacific given that environmental conditions were very very different in both oceans. And then also looking at how the magnitude of change has has is different in each ocean. So were shark declines in the Caribbean worse than those in the Pacific or do sharks in the Pacific along the coast of Panama seem to be more resilient, let's say, to human activities.

LN: We joined her in the lab when she started picking the shark denticles that would help her tell this story. Seeing this part of the process made clear why she calls them shark dandruff. To the untrained eye, they just look like tiny particles.

ED: So I'm currently picking I think like 40 or 50 times magnification. They're super super tiny. So it's it can be really tricky to, to identify them and pull them out particularly when they're flipped over. So a lot of the diagnostic features aren't visible. So they look like little grains of sand essentially.

LN: Yet her first days picking through the samples already looked promising. That day she was picking from the bottom of the core barrel, so from one of the older samples.

ED: We haven't sent any corals out for dating yet. So I can't tell you exactly how old but probably a couple thousand years old would be a guess. And so far, I've found one two, three, four five, six, seven denticles in the sample that I just started picking. But yeah, there were about a hundred in the other sample that I picked the other day, which was absolutely incredible.

And so far the denticles looked to be quite well preserved. We found a variety of different forms. So some of them have little ridges on them and those tend to correspond with faster swimming more pelagic, oceanic sharks, but we've also found some that look like little pebbles that don't have ridges and those tend to be found on more demersal sharks that are hanging out kind of closer to I guess the bottom and so it seems like we have multiple different types of sharks that are represented.

LN: Erin was surprised by how many denticles she was finding in the oldest end of the core.

ED: I'm like shocked at how many denticles we've been finding so it's... because it was the first time you, was the first time we cored there so we'd no idea. I mean when you go out and core, I mean, yeah, so you have to find like the right type of habitat to actually core but then it's a lot of luck. Like you don't know what you're gonna find like when we went to Coiba some of the samples had no denticles in them some had some so this is it's pretty incredible that we're actually finding this many denticles there.

LN: However, no conclusions can be drawn before the age range of the core is determined and the findings are standardized.

ED: I mean, given that we're talking two orders of magnitude more at the bottom that I mean would suggest that there's probably gonna be more sharks. But yeah, until we've fully standardized it, it's it's hard to say like, for example, let's say that interval that I picked happen to represent 200 years and the other one was only two years like that could also create a similar difference so hard to say but it's it's very promising that we're finding so so many.

LN: And this is important because sharks are important for the ecosystem. And before this method was developed, there weren't many ways to really assess how many sharks were present at different times in the history of these reefs.

ED: So I mean sharks are really important in general for reefs. I mean, they're really key meso and apex predators. They're kind of controlling the energy flow. They're also really important for humans, eco-tourism. But I guess we don't have a very good understanding of what... how many sharks there were before humans. If you look at some stories from explorers, they're just they're telling these stories of seas swarming with sharks, but we don't have a lot of quantitative evidence to understand how many sharks there were before and how they've changed. And so these these cores and these data give us really important historical context for the shark decline that we see today.

LN: Knowing how many sharks, and what kinds of sharks were there in the past is necessary context as researchers talk about the possibility of restoring reefs and what a healthy marine ecosystem really looked like.

ED: And so without knowing what that that context was and what was actually natural and the natural variation in the system, it's hard to actually know what the future might look like or assess our progress toward whatever target that we actually choose.

LN: But understanding what marine ecosystems looked like in the past is not only about sharks. In the end, whatever Erin discovers about shark populations will be part of a larger set of information that tells the story of the Isla Iguana coral reef environments through time. This is Jon Cybulski, the historical ecologist you heard at the beginning.

JC: This is what's interesting about the O'Dea lab is different people with different interests want different things from these cores.

LN: Whether it be coral fossils, otoliths or denticles, fish teeth, sea urchin spines, sponge spicules, or even just the amount of carbon in the sediment, each of these elements can reveal unique clues about the coral reef diversity and productivity in the past.

JC: Really what we're trying to do is we're trying to think of as many possible angles: taphonomy, looking at how they were preserved; taxonomy, looking at the biodiversity in the past geochemistry; looking at the isotopes, which tells us about the environment and the context and we want to piece it all together so that we can really get the clearest snapshot of that environment and get the clearest snapshot of that ecosystem because at the end of the day as I started off with we're just historians and we're just historians for the ecosystem. We want to tell the most accurate history that we can so that we can learn from it, and we can learn something about it and that it can tell us something about what we're experiencing today.

LN: And Aaron O'Dea thinks this time travel technique for understanding the past in order to create a sustainable future is worth sharing. He worked with illustrator, Ian Cooke, who was also on the expedition to Iguana, to create a comic book for kids in English and Spanish called Martina and the Bridge of

Time, which is free to all online and is the perfect way to connect kids to both the geology and the indigenous groups who shaped our past.

Thank you for listening to this story about what we're working on at the Smithsonian Tropical Research Institute in Panama. We dedicate this episode to the memory of Dr. Richard Cooke, a giant of Panamanian archaeology, a mentor, friend, and inspiration to many scientists interested in exploring and understanding the past. We also want to thank Mike and Joyce Bytnar and Panama's Secretaria Nacional de Ciencia y Tecnología, SENACYT for funding the coring work in the O'Dea lab**. And of course, thanks to Juan Gramage and the supportive crew of the Sail la Vie for all their help during the expedition.**

Our podcast team includes me, Leila Nilipour, as well as Ana Endara, Linette Dutari, Elisabeth King, Lina González, Johann González, Jess Sadeq and Sharon Bryant. Episode artwork is by Paulette Guardia. Extra support comes from PRX. Our show is mixed by Melissa Pinel. This episode's music is by Epidemic Sound. If you liked this episode, please share it with other people. And, again, thank you for listening.