Interviewee Name: Ian Enochs

Project/Collection Title: Decades of Change in the Florida Reef Tract: An Oral History Project

Interviewer(s) Name(s) and affiliations: Zachary Mason, NOAA Heritage Program

Interview Location: Miami, Florida

Date of Interview: July 16, 2020

Interview Description:
Ian Enochs
Miami, FL
Marine Researcher Interviewed by Zachary Mason

Dr. Ian Enochs is the co-principal investigator of ACCRETE (Acidification, Climate, and Coral Reef Ecosystems TEam), NCRMP (National Coral Reef Monitoring Program), and AOAT (Atlantic Ocean Acidification Test-bed (NOAA). Dr. Enochs is the principal investigator of three projects: 1) Maug: a rare ocean acidification hotspot in US waters, 2) Incorporating Risk from Ocean Acidification into Acropora nurseries, and 3) Establishing numeric nutrient criteria for Southeast Florida Reefs. Enochs graduated cum laude from the University of Miami in 2006 and later earned his Ph.D. at RSMAS in 2010 for his research on the environmental determinants of coral reef cryptic metazoan biodiversity in Pacific Panama. He is a research oceanographer with the Ocean Chemistry and Ecosystems Division of NOAA's Atlantic Oceanographic and Meteorological Laboratory in Miami.

Collection Description:
Florida is home to the only barrier reef in the continental United States. This project uses oral history interviews of coral reef stakeholders in Florida to showcase major changes in the reef tract over the past few decades. The stakeholders interviewed include scientists, fishermen, and SCUBA divers.

Citation:
Ian Enochs, Decades of Change in the Florida Reef Tract: An Oral History Project Interview, July 16, 2020, by Zachary Mason, 24 pages, NOAA Voices from the Fisheries. **Online: Insert URL (Last Accessed: Insert Date).**

Transcription by: Edith Mari, NOAA Voices Oral History Project

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[01:12:47.0]
ZM: Zachary Mason (Interviewer)
IE: Ian Enochs (Interviewee)

[00:00:00.00]

[00:00:02.00]

ZM: This is Zach Mason and it is July 16, 2020. I'm here with Dr. Ian Enochs and this is for my NOAA Heritage Project. So Ian, thanks for taking the time to be here. I really appreciate it. Let's go ahead and get started. We will start at the very beginning. Can you tell me a little bit about where you grew up and your family? Early influences?

[00:00:41.00]

IE: Yes, definitely. I grew up about as far away from the ocean in the United States as you can get. I grew up in Southern Indiana. Honestly, I don't think I even saw the ocean until I was in maybe Middle School or early High School. My mother is a biology teacher. My father is a sculptor of abstract art. I grew up in a family that was always very interested in the world and science. For whatever reason, I became focused on the ocean and fish and developed a love/obsession for coral reefs from an early age. Then I pretty much focused on that and did what I could to get out of Indiana and get into the water.

[00:01:36.00]

ZM: That is really interesting. I hear a lot of scientists that spend time in or near the ocean came from very landlocked areas.

[00:01:48.00]

IE: It's hilarious. I know, so coming from Indiana, I know so many people in grad school, or several people in grad school, and even people in my lab right now that are from Indiana. I wonder if Indiana is just like this hotbed of budding young marine scientists, for whatever reason. So it goes.

[00:02:05.00]

ZM: You said your mom was a biology teacher. Did she encourage you to go into science, do you think?

[00:02:13.00]

IE: I don't think they pushed me. I think my parents were really great about kind of letting me do my own thing. But definitely encouraged me to have a scientific perspective and to answer questions myself and to research things. So yes, I think she was extremely influential in that, but I wouldn’t say she pushed me. Maybe a little, I don't know.

[00:02:39.00]

ZM: What was your favorite subject in high school?

IE: Probably biology. Yes. I’d say so.

ZM: And so you went to college, was it...

[00:02:56.00]

IE: At UM [University of Miami]. I came to UM. I got a scholarship to come there. Then I met up with… one of my teachers was Dr. Peter Glynn, who is, some may know, is one of the real godfathers of coral reef ecology, pretty much discovered coral bleaching, thermal-related bleaching. And I was very fortunate to be able to continue on and do my PhD with him. I've been extremely lucky to have an organic progression of my career.

[00:03:30.00]

ZM: Can you pinpoint when you became interested in coral specifically?

[00:03:42.00]

IE: This is really lame, but I really think that when I was probably in first grade - I’ve been focused for a really long time - probably, maybe even earlier. My parents have his picture book on the Great Barrier Reef and it just blew my mind. By that time, since my father was an artist, at that time I would just draw pictures of fish. My goal at that time was to travel around the US in a bus and make art and do stuff with fish. I think that grew into a coral reef focus. I don't know. Just another one of your routine fish-bus artists [jokes]. You know, it's a pretty common career.

[00:04:35.00]

ZM: It is the closest real profession to that really, you know.

[00:04:38.00]

IE: Yes, exactly. Instead, I dabbled around with the whole PhD thing and science. It's been all downhill since.

[00:04:45.00]

ZM: Can you explain what a coral reef actually is? I think a lot of people are not really sure. Is it a rock? Is it an animal? Is it a plant? What is it?

[00:04:57.00]

IE: You can look at it a whole bunch of different ways, as you just mentioned, but coral reefs are, in effect, ecosystems. They are also, in effect, structure; ecosystems built around that structure. Corals, which form the backbone of a coral reef ecosystem, are animals that have a symbiotic plant that lives inside of them, if you will. It provides them energy from photosynthesis and light. And essentially, they create a bunch of skeleton that things live on and live within and associate with and creates this really complex biodiversity ecosystem, up around it that provides us with a whole bunch of different services. It's really important for, I think, just in its very essence of what it is, but also from an anthropocentric viewpoint, it's really important to humans. That's why as part of NOAA [National Oceanic and Atmospheric Administration], we are really focused on it, because it's vital to a large part of our economy.

[00:06:02.00]

ZM: That is really interesting. You touched on a couple of different things that coral reefs do for us. Can you elaborate on that, and maybe why they are important for Florida specifically?

[00:06:16.00]

IE: Yes. We can list through them. This is something that I always try to - even before I was really working at NOAA - focus on. Because, if you're going to… how shall I put this? Being a marine biologist is not the most lucrative career and if you're going to spend and dedicate your life towards preserving something, it is extremely important to understand why, and to really hold that centrally in your mind. When I teach classes on coral reefs, or what have you, I always have students come back and ask themselves, “Why do we care about coral reefs?” I get all sorts of different answers, which is good and correct. They can be classified into a couple. One is: coral reefs are hotspots of biodiversity. The single highest concentration of metazoan, or animal and plant biodiversity, in the marine realm, so they're like rainforests in that sense. They are also really important for fish and fisheries. Tons of fish associate with them, which are extremely important for putting food on the table, for economies that are based around that, for island communities. They're extremely important for tourist communities, which are central to a lot of the reasons we care about them in Florida. Tourist economy, when we're not in a global pandemic, provides billions of dollars “with a B” [referring to billions, not millions]. That's important for an economy. People will want to go scuba diving or snorkeling on a reef and rightfully so; they're absolutely beautiful. That last one, the beauty is also something. It's harder to write a number next to it. It's a little bit more of an abstract idea, but I fundamentally feel - and many people bring it up - that there's a stewardship need; that it has inherent value in beauty in and of itself, and that we have a responsibility to take care of it. That's one of the reasons. I guess the final is just the actual structure of the reef. It provides protection from storms. Ultimately, if you have a million dollar beachfront villa, which I don't, but if I did, I would want it to be protected from hurricanes and from wave action and all sorts of things.

[00:00:09.09]

ZM: Before we go down a rabbit hole talking about reefs, I would like to take a step back real quick, chronologically. You went to college in Miami, and then after college, What happened? Where did you go? I guess grad school.

[00:09:28.00]

IE: Yes. I stayed with Peter Glynn, straight into my PhD at Rasmus, which is a marine campus of the University of Miami. I've been very lucky, but also limited in that I've stayed in Miami. I think that's really been helpful for me to be able to build a lot of close relationships with scientists and facilities and equipment and infrastructure. But it's also kept me here. It has been given or taken in that respect, but I've been really happy to be able to do work here. And I've been able to do it all over the world, but based here in Miami.

[00:10:20.00]

ZM: After grad school, did you just start right away working at AOML [Atlantic Oceanographic and Meteorological Lab] or...

[00:10:30.00]

IE: I worked through the Cooperative Institute as a postdoc, working with Derek Manzello at AOML. Then I became an assistant scientist, an associate scientist. Then a year and a half ago, two years, something like that, I became a federal scientist at AOML. Like I said, it's been an organic progression and I've been really fortunate in that respect of growing into where I am now.

[00:11:04.00]

ZM: Can you talk about.. I know you do a lot of different things, but can you talk about what kind of science you would say that you focus on?

[00:11:16.00]

IE: Yes. The phrase “jack of all trades, master of none” haunts me at night. I dabble in a lot of things. As you said, I primarily am interested in, if you really had to say one thing, is coral reef structure and habitat. That’s what I'm interested in. But that forms the framework, pardon the pun, of a whole bunch of different research and a whole bunch of different research questions. Because what I'm ultimately interested in is corals that create that habitat, create that structure, as well as bio rotors, which break that structure and break that habitat down. Those two processes, those two competing processes, are influenced by a whole bunch of different things, and are extremely timely right now because they're very dynamically influenced by a lot of global changes. They're ultimately, like I said, responsible for that structure that all of those ecosystem services that we discussed, are one hundred percent dependent on. For me, that is what drives me. Now, I'm also very passionate about developing new technologies to apply to answering those questions. I think that open-source and science communication are extremely, extremely important right now. And again, extremely timely, as we try to almost democratize fields that have been opaque in the past and hard to enter, and in many cases still are today. Those are the main focus, even though it's all over the place, of what I'm interested in.

[00:13:06.00]

ZM: Okay. Let's dive into that, unpack that a little bit. Let's see, where do we start? You talked about coral habitat and corals. Can you explain how the corals grow? How does that happen?

[00:13:26.00]

IE: Yes. Corals precipitate calcium carbonate out of the water and they create these skeletons, the rock that you might see washed up on a beach. It's an extremely slow process. Some of the massive boulder corals are growing about a centimeter a year, less than half of an inch a year, maybe even just a quarter of an inch a year. Those growth rates are slowed down by a whole bunch of different things. Over thousands of years, that very slow process builds up into these huge complex structures that form coral reef habitat. That's the growth process. At the same time, like I said, there's a whole bunch of other things that are constantly eating away, boring into it, scraping it away. It's not just an upward growth, it's things knocking it back at the same time. It's different, but I like to think of it almost like a forest ecosystem where you have trees growing up, creating that structure, then you have fungus and bugs eating away into the bark, breaking it down, rotting it away. Cumulatively, over time, you're creating this complex ecosystem, and it's very similar in coral reef.

[00:14:47.00]

ZM: That is an interesting analogy. I like that. To stick with that, just like in a forest, there are some trees that grow faster and taller and thicker, are there some corals that are just faster growers? You said some only grow a centimeter a year. Hopefully, is there anything that is quicker than that?

[00:15:14.00]

IE: Yes. There are different species that are quicker, some are a lot quicker. Branching coral species are classically much faster growers, but they might be prone to breaking. You have these fragile structures that are made, and something knocks into it or you get more wave action, and could break down. That's across species. Yes. To answer your question, yes, there are a lot of differences in growth rates. But what's something that we're really focused on right now, and what's really kind of exciting, is we're starting to really understand that there's a lot within species, which is kind of like a “well duh”. We know that some people are really strong and some are weak and some are fast and some are slow. The same thing applies to many coral genotypes for different individuals, different unique, genetically unique individuals. So yes, there's a remarkable amount of diversity, and also plasticity in growth rates, environmental things that will influence those growth rates. Light, as I mentioned earlier, corals have a symbiotic algae that lives within them. Many of them are very reliant on the availability of light for photosynthesis. Deeper corals that don't have as much light don't grow as fast. You get all sorts of things associated with that. That's my long-winded response to some “corals grow faster”. Yes. Sorry.

[00:16:51.00]

ZM: No, that is great. This is really interesting stuff. I guess almost for my own curiosity, you said there are specific genotypes within a species that will cause corals to grow faster. Have you identified exactly what that is, and you have isolated that?

[00:17:14.00]

IE: People smarter than myself, working in our group, are looking at transcriptomics of a bunch of different genotypes of a bunch of different species, with the idea of understanding what genes are being upregulated or downregulated, what specific, unique genes are responsible for these types of, molecularly, these types of phenotypic or organismal things we've witnessed responses. In terms of the exact single factor - this is going to be a common thread throughout this interview - I don't know. That's something that makes it really exciting and really important for the science. I think that this has relevance, especially to NOAA, has important ramifications for management and for restoration. We're starting to think more and more seriously about how we can restore these ecosystems, how we can build natural environments, how we can maximize the production of this habitat for all these ecosystem services. If we think about when we build a garden, or when we do anything in the terrestrial realm, we have a good understanding of what our specific seeds will do, where they will be beneficial, how quick they are growing. We really are just starting to pick away at that with respect to corals, understanding what these different genotypes are capable of. There's growth rates, but there's also resilience to temperature stress, resilience to disease, resilience to ocean acidification stress, resilience to all the other things that corals are getting hammered with from every single direction. This is an especially fruitful avenue of research right now with, again, real management implications.

[00:19:04.00]

ZM: We have talked about how corals grow, but you have mentioned a few times that there are a lot of things that can hinder that growth. You have mentioned some corals are susceptible to breaking. I want to ask you, if you could talk a little bit about ocean acidification, what that is and how that affects coral growth.

[00:19:31.00]

IE: Ocean acidification is one of the major focuses of my research. It's the other big effect of the fact that humans are putting a whole bunch of carbon dioxide in the atmosphere. Right? We have global warming, that is a very real and serious problem. But we also have a lot of that carbon dioxide incorporated into the oceans where ultimately decreases the pH or increases the overall acidity of the ocean. If you think about structures that are growing and made out of calcium carbonate, if the water is more acidic, it's more likely that they're going to either dissolve - but it's also more difficult for corals to precipitate that and grow those skeletons. The process ultimately - this acidification of the ocean - ultimately makes it harder for many of these species to grow and, over time, makes it harder to form habitat. At the same time, it can increase erosion rates that are done by numerous other bio-eroding organisms. It's slowing that growth and accelerating bio-erosion. It tips, if you think about the two processes on a teeter totter, we're sitting in the balance and at the same time it's pushing down on the coral growth and then pushing up on the bio-erosion and it's throwing the whole ecosystem out of whack.

ZM: This is happening in Florida?

[00:21:04.00]

IE: This is happening across the world. So yes, absolutely. There are hotspots for… the Caribbean is especially problematic with respect to ocean acidification. It is especially problematic in areas like the Caribbean where coral cover is already quite low due to warming and disease. We have higher prevalences of bio rotors and less calcification, so every little bit of calcification matters even more. It's extremely depressing. Rather than stick our heads in the sand, we need to study and understand what's going on so that we can hopefully do something about it.

ZM: Ocean acidification.

[00:21:49.00]

ZM: So do we have a plan to stop ocean acidification? Is this something that can be stopped?

[00:21:55.00]

IE: Man, I wish we had a really solid plan. I think NOAA's doing a lot of really interesting things to understand what it is, how it's progressing, how it's going to influence ecosystems so that we can better model out and predict exactly what's going to happen. That's where a lot of the science is right now: measuring its progression, both chemically as well as biologically, and then predicting, hopefully predicting it. I think we're starting to really start to focus, also, on things that we can potentially do to hopefully help this global problem, right? I mean, there are obvious things that we can do: cut down our carbon footprint. Full stop, that will do it. Yep, we got the solution. we got a plan. Done. But that's obviously easier said than done. On a local scale, we could potentially use carbon-capture mechanisms, one of them being biological photosynthesis. Seagrasses might be able to reduce carbon dioxide. We see that, actually in the Florida Keys. In areas and the Upper Keys, we see seagrass photosynthesis leads to better carbonate chemistry, better acidification conditions. Seagrasses are especially interesting because they bury that carbon under the sediments in the rhizomes, whereas things like algae or whatever will get eaten instead and then respired, and CO_2 [carbon dioxide] comes back out. Another thing that we've been really studying here in South Florida is that our water systems are so linked, absolutely everything is linked. What we find, and what we published a paper on last year, is that there's a lot of high CO_2 water coming out of inlets. This is due to - potentially due to, this is, again, something we're still studying - but high nutrients, high organic matter, that comes out and gets respired leading to CO_2. These are local factors that ultimately lead to localized acidification.

What an organism experiences in the field is obviously the response of these cumulative oceanic factors as well as localized things. What this ultimately means - it's depressing that we have these other sources of CO_2, -but it means that there are real, tangible things that we can do to make conditions better offshore in the reefs. That's exciting. That gives us power. I think that's something that we need to focus on. A lot of our water use practices in South Florida are especially relevant to that carbonate chemistry. My long-winded answer is: Yes. On a global scale, absolutely, there's stuff we can do and, on a local scale, yes absolutely, there's stuff we can do, but we need to do it and we need to understand what tools we have better.

[00:25:03.00]

ZM: That's slightly more hopeful than the note we ended on in the previous question.

[00:25:11.00]

IE: I teeter back and forth between complete abject "everything's terrible", but I say that in jest, just because day in, day out, I deal with a lot of depressing things and you have to have some humor around it, but you also can't give up. You know, it's like, it's space for that - again, do you put your head in the sand? No, you have to figure something out. I think we're making progress in those directions.

[00:25:42.00]

ZM: How do you measure something like ocean acidification? What techniques do you guys use?

[00:25:51.00]

IE: This is one of those things where I am a biologist, but I have found myself wearing a chemist hat more than I would have ever expected to or said I wanted to in college or in high school. It's really quite fascinating. In order to do this, we measure a couple of different parameters of the carbonate system. We measure in our laboratory total alkalinity, and we measure dissolved inorganic carbon, as well as partial pressure of CO_2, as well as pH. Probably one of the most meaningful parameters that we use for coral reef work, we calculate from this, which is known as the aragonite saturation state [a measure of carbonate ion concentration]. This is a number that expresses how easy it is for aragonite, which is the crystalline form of calcium carbonate that corals use to make their skeletons, how easy it is to precipitate that, to actually take it from a solution of water. There are other crystalline forms of calcium carbonate, there's calcite as well, some organisms precipitate that, there's high magnesium calcite, but corals, scleractinian corals, are primarily aragonite. Without teaching a masterclass on this, which there are arguably many people more qualified to do than myself, what I would like to say is that ocean acidification is a small, oversimplified kind of thing; there are a whole bunch of other parameters that we deal with in order to understand how these organisms are responding and what specifically they're responding to.

[00:27:36.00]

ZM: Got you.

[00:27:39.00]

IE: Do you? Because I'm not sure I totally have it. This is one of those things that is amazing. I'll write a paper and then I will notice this detail, and it's fascinating, because there’s always something to learn. And honestly, one of the great things about my department at AOML, Social Chemistry and Ecosystem Division, there are people infinitely smarter and more qualified to speak to ocean acidification than myself. It's really nice to come in with a little bit more of an ecosystem perspective, to bridge that gap with somebody that's coming in with a chemistry perspective, because ultimately, the ocean is a whole bunch of everything. We’ve got physical oceanography, chemical oceanography, ecology, and all this stuff comes together and is completely always interacting and always dependent on each other. It's extremely important to have an understanding of all of these different things. The world is complicated.

[00:28:33.00]

ZM: I guess I should say, AOML is the Atlantic Oceanographic Meteorological Laboratory. Learning my acronyms.

[00:28:44.00]

IE: That's an important NOAA step. I'm still learning my acronyms as well.

[00:28:48.00]

ZM: We have a big cheat sheet on our website, actually. So that has helped me a lot. I have to confess I have just been looking at that.

IE: No, that's not a confession. I think it's absolutely necessary. I often say on my staff, people will get deep into acronyms, and I'll have no idea what we're talking about. But anyway, yes, AOML. That’s where I work. Atlantic Oceanographic and Meteorological Laboratory.

ZM: It sounds like you guys do a lot of different things. You have a lot going on at that lab. You talked a little bit about restoration earlier. As we are on an upward hope trajectory here, can you talk about any kind of restoration efforts that you have been a part of?

[00:29:30.00]

IE: Yes, absolutely. We are more focused on the science behind restoration than actually doing the restoration ourselves. Many groups that we are very fortunate to work with in South Florida are doing amazing restoration work. Particularly, we work with University of Miami's restoration efforts. We work with Mote's [Mote Marine Laboratory] restoration efforts. Those are our main partners in that, though I'm probably forgetting people. We have a couple different directions of things that we're really interested in and excited about right now, some of it I already mentioned: understanding genetic differences and capabilities, the resilience of these different corals. Being able to rapidly assess which corals are good at what. That's one of the research avenues that we're looking at. We're also looking at seeing if we can stress-harden these corals. One of the things that people will fuss about about restoration - and they're not wrong - is that if a coral died in a place and you put it back out, isn't it going to die again? In some situations, that's true. There are many counterpoints to that. But one of the things that we are trying to investigate is whether we can actually increase their resilience to whatever stress may have killed them, to see if they might be able to tolerate some adverse warming or temperature conditions just a little bit better. These are things that we are testing in our lab. We're trying to see if we can contribute to restoration.

[00:31:45.00]

ZM: Stress testing corals, can you describe that process a little bit more? What exactly are you subjecting these corals to?

[00:31:55.00]

IE: That's a great question, and something that I spend a lot of my time on. There are a lot of papers on and a lot of people arguing that their one way is better than the other. I guess the real answer, and I'm going to say it again, is I don't know what the best way to do it is. I can tell you what we're trying. One of the things that we're doing is trying to really focus on whether we can develop technologies that are scalable, because the size of the restoration problems is so huge, and we need to figure out ways to do stuff that is applicable on a large scale. I've been developing an automated approach to essentially build on some of the chemistry principles that I just introduced, but measure some of those properties of the water to infer growth rates or to infer stress responses. We'll take a coral through a bunch of different temperature and acidification stress levels and then measure its response. This is a rapid kind of approach. That's something that we're really working on to make this quick. Another approach that people use, which is - I don't know if it's better or if it's worse, but it's a different one - is to simply take a lot of fragments of corals and put them in tanks and turn up the temperature or turn up CO_2. That's something we've done a lot as well. It's kind of depressing, because a lot of times what you're looking for is who dies first. If your endpoint is just a bunch of death, then it can be extremely informative and helpful, but ultimately, I think we should be moving towards approaches where death isn't the necessary outcome. This is in early stages, I think it's really exciting research. What's needed is to test and develop these methodologies, try them against each other, throw a whole bunch of things against a wall and see what sticks. That’s what we're doing. One of the interesting things we're applying this kind of bridging the two gaps between the two topics I mentioned with respect to restoration is, is we're interested in identifying populations or even genotypes of corals that are being naturally stress-hardened. One of the areas that we're working in and I had mentioned earlier was the inlets in South Florida and one is the Port of Miami. If you had to develop a list of places you would want to scuba dive, it would be on the bottom or off the list. It's really nasty water with a whole bunch of ship traffic, shopping carts and trash in the water. It's not what you would consider to be a place to hang out. But what's really amazing is that we have populations of corals there that are thriving, and you can see them just walking down the sidewalk looking over the seawall. You can see it's a backyard urban coral environment. These guys are experiencing ocean acidification conditions, they're experiencing temperature fluctuations, like crazy, salinity fluctuations like crazy; they're dealing with all sorts of nutrients, runoff, human activity, and yet they're still doing alright. You see some genotypes of, rather some species of corals that have been almost extinct. I have offshore control sites that are still hanging on there. So why? I don't know. And I'd like to know, because I want to know if it's these genotypes that are especially strong, maybe they're super coral so to speak. Maybe it's something that's going on specifically that we could use to actually help resilience and restoration. It kind of bridges the gaps between stress testing and stress hardening.

[00:36:18.00]

ZM: That is really interesting. Sorry, one second.

AUDIO CUTS OUT FROM [00:36:22.00] to [00:37:37.00]

[00:37:38.00]

ZM: All right, cool. So let's see. We just talked about some restoration, stress-testing corals, and just cranking up the CO_2 and seeing which corals die first. The corals you are seeing that are stressed that you are not stressing yourself, like in Miami, you mentioned super corals, what could possibly be keeping them alive?

[00:38:28.00]

IE: Well, there could be a whole bunch of different things. One of them could be their genetic capabilities and that they're, again, more resilient. I hope that we can identify some individuals that are stronger than others for a given stressor. We talked about a symbiotic algae that is associated inside of the coral. So it was [audio glitch] clades or different genera, different species that have different tolerances to temperature. There's evidence that these communities of this algae can shuffle different types around and potentially different composition will lead to more resilient corals. It's also likely that things like feeding can potentially lead to greater resilience. So maybe corals that are eating more can deal with more stress. They have greater amounts of fat built up and they can use those potentially when they're not getting food from their algae. All sorts of different things. I think we have to really chase down all these leads right now just because it's such a dire situation, and, you know, not put all of our eggs in one basket but try to identify... the fact of the matter is ecosystems corals in and of themselves are complicated. I doubt that there is one silver bullet. It's going to be a combination of these different approaches, of identifying genotypes that can survive, of treating them in the best way possible to maximize their success, and to understanding the different environmental factors that contribute to their natural resilience. Those hopefully will come together to lead towards more productive, more effective, more cost-effective restoration efforts.

[00:40:36.00]

ZM: Cool. I want to change gears just a little bit here and, way earlier in the interview, you mentioned that something that is very important to you is kind of democratizing science, making science more accessible. Can you talk about, more specifically, what that means, and elaborate on that a little bit?

[00:40:59.00]

IE: One of things that I really am aware of, is how lucky and fortunate I am to work for NOAA, because we have the resources - I mean this one hundred percent - we have resources that are available to us that are not easily accessible to scientists, both some scientists within the United States as well as scientists throughout the world, as well as to people that aren't trained scientists. That's a lot of people. When we talked about ocean acidification and the different parameters that we measure: if I want to log pH in a way that is scientifically robust, I have to use an instrument that is probably about twelve thousand dollars. I don't know about you, but that's a lot of money, in my book. Especially if you need to compare two places, now you got two of them, you're at twenty-four thousand [dollars]; if you need to develop a monitoring program - and they don't last for a very long time and you need to calibrate - so there's all of these things that just make the fundamentals of the science really removed from what is accessible to people and to other countries, to other communities, and that is a huge problem. If we are dealing with a global issue, we need to be able to deal with it together. I think that those instruments are absolutely important and they have levels of quality and accuracy associated with them, and they're not a rip-off. It's not somebody trying to scam anyone. These are a lot of research and time has gone into them and they're super high quality. But there needs to be another option that is more available to people, that has an understood amount of accuracy. I know right now we are sitting at a point of an almost - I recognize that this word is loaded - but a revolution in terms of how we deal with building things and electronics and the accessibility of machines. And by that I mean that the open-source movement allows really anyone to program and to build cheap, high-accuracy equipment that can serve the needs of a lot of this otherwise inaccessible science. The people that need to push and to show how this is done are the people that have access to that really expensive stuff, because they need to show the comparability, they need to be able to bound the error around that. I feel like I'm in a very fortunate and unique position to be able to work to develop and hopefully make some of the science more accessible to people, and to prove that it's useful and has utility and to what extent people can use it. That's my long-winded answer.

[00:44:18.00]

ZM: No, that's great. What have you done, specifically, to further that goal?

[00:44:30.00]

IE: One of the things that we have done is we work a lot with a microcontroller called an Arduino or Arduino-based microcontrollers that are completely open-source. We work with a lot of sensors that are cheap and easily available and we work with 3-D printing on 3-D printers that are consumer grade. We combine these to fill gaps in the availability of equipment, but also to make things that are cheaper and more accessible. One of the things that we've built are subsurface automated samplers for collecting CO2 data. One of the most expensive things, in addition to instruments, about CO2 work is actually getting out in the field and collecting that data, especially if you have to do it from a large ship, or if you have to do it in dangerous conditions or at night, or if you need big time series and you need to constantly collect data, it's expensive, can be dangerous to be on a boat, and it takes a lot of time and effort. So we made these relatively cheap samplers that are diver-deployable, 3-D printed, programmable, use a little infrared remote control - if you can change the channels on a TV, you can program one of these guys - that will simply collect water and preserve it for carbonate chemistry for ocean acidification research whenever you want. It's extremely simple. There are numerous complexities, though, around it. So there are all sorts of - we have to establish the accuracy of it, test it, do all of these things, and then we present it and make it freely available from NOAA's website to whoever wants the 3-D design files, the programming circuitry design. It's been really exciting to see these other groups being like, “Yes, we need that” and start to build it. There's a peer reviewed paper that came with it. The peer-review process is an arduous process. It involves a lot of people that are very well set in this idea of very expensive ivory tower science. One of the reviews that we got was, “no one needs this, no one will use this”. And it was funny getting that. I mean, it was also quite frustrating getting that, but it was funny getting that because I had already pointed to all institutions internationally that were building these and starting to use them and all the excitement and all the people collecting the data, and I was like, “Incorrect. This is something that’s needed and I don't know how to tell you that. It's just one of those things”. But I've been really encouraged by that. We've subsequently built similar types of samplers for eDNA [Environmental DNA]. It's a publication that we're working on right now that uses similar procedures to sample water for eDNA, but then preserves filters for eDNA for monitoring. I've been working on building cheap auto-titrators that allow you to measure total alkalinity, one of those parameters for ocean acidification. Normally thousands of dollars, you can build it with the same level of accuracy for pennies on the dollar. Again, it's not the only option. These other very high, extremely expensive options are important, but it's also important to make these things more available so that everyone can be involved and do that kind of work.

[00:48:13.00]

ZM: It sounds like this is a really good opportunity for even citizen science, and people that are just recreational divers to get their hands into some real science. Do you know of any wreck divers that have picked this up and tested it out?

[00:48:35.00]

IE: We've developed this with that in mind. One of the co-authors is a local high school teacher here. We designed a curriculum around some of the principles of the engineering and question of building these things. Because it's like, honestly, if I can figure it out, anyone can figure it out and better. I'm not a trained electrical engineer, I'm not a trained programmer, I'm not trained at CAD-ing, but all these things you can do with freely available software online. And I do do. It's something that if you have the desire there, there are tons of resources available. That's when I say I fundamentally think that there's a revolution happening because it’s so available and so possible that if I can, just tinkering, teach myself to do these things, then other people can as well. That’s, to me, one of the exciting important aspects of it: making sure people understand that this is something that is accessible, not trying to veil it behind some Wizard of Oz screen of, “This is very complicated science”. No, this is something anyone can do.

[00:49:59.00]

ZM: I think it is really cool that one of the authors on the paper was a high school teacher. Do you guys at AOML, or you personally, do you make outreach like this part of your M.O.? Like, is that a big part of what you do is community outreach?

[00:50:21.00]

IE: I would like to tell you that it's fifty to twenty-five percent of what we do. That's not true. I wish it was. I think it's something that's extremely, extremely important. I wish that it was something that was more directly supported. Right now, I think that there are movements in that direction. We are involved with some outreach, but I have to give the credit mostly to partners that we've, by design, associated ourselves with, that have really done the heavy lift on a lot of that work. We have worked with the ANGARI Foundation, we created this virtual reality documentary where people are able to go scuba diving with us in the Florida Keys underwater and VR [virtual reality] on these headsets, also on their phone, and see around and go through our lab on VR. They've taken this to a whole bunch of different schools and allowed kids that have never seen the ocean or never been in the ocean to actually go scuba diving with us, which is awesome. Similarly, we've been really fortunate to be involved with this local science and art group called Coral Morphologic. We have, with them, installed a live video camera in the Port of Miami at this reef site. During this crazy time of COVID, tons of people are tuning in and getting a little bit of that reef time in, obviously on the screen, but seen well over one hundred species on it. I think it was several species of sharks, all sorts of manatees that come in frequently, it's crazy. It's this amazing opportunity of getting people in the water virtually when it's difficult to do so. We did this huge installation, not really installation, but activity with them where we had that camera up on these huge bars that you'd otherwise use for advertisements in the Port of Miami, and we had Perez Art Museum… you can see out over the water, this huge video of the site was just an awesome way to get people really excited about an interest and to realize it's in their backyard. We've done other documentary stuff as well. But again, I want to stress that a lot of that has just been because our partners have been so awesome in that effort. It's extremely important.

[00:53:10.00]

ZM: I think public outreach is really important. In that same vein, do you think people in Florida realize all of all the threats that face the coral reefs?

[00:53:26.00]

IE: I don't know if I realize all the threats that face the coral reefs, but I think that people in Florida are very closely associated with the water. Many are. There are some communities that are not privileged enough to be able to actually spend time or even travel to the beach, even if they're a couple of miles inland. But in general, politically, I've been very encouraged by - I guess politically is the wrong word, but community based in terms of different groups of people - I've been really encouraged that people are genuinely interested in and care about marine activity. There are exceptions to every rule, but so much of Florida economy is based on tourism that it's really abundantly obvious that these things are important. And again, there are exceptions to the rule. But yeah, I do think that people are aware.

[00:54:35.00]

ZM: That is good. I mean, that is the first step.

[00:54:42.00]

IE: There's a lot of focus on water quality, which is great. I talk to people wherever I go and they're like, "Oh, marine biologist, what do you do?" And they're like, "How are things?" and I'm like, "Things are bad". But they're always like, you know, people are aware that things are happening. I've never had anyone be like, "Oh my gosh, I thought reefs were doing great". That would be an interesting conversation.

[00:55:09.00]

ZM: That would be a person who is about to have their world rocked.

IE: Yeah, exactly. Sit down, I have something to tell you.

ZM: I guess the logical next step then - so if people are aware, right, they know that there's a problem. And I know we've touched on this a little bit throughout the interview, but what can the average person do to help or to at least not make the problem worse?

[00:55:40.00]

IE: Pick a problem, right. Ocean plastics are a huge problem. Global carbon budgets are a huge problem, reducing our carbon footprint. It's difficult to communicate sometimes because it's not a tangible link of I'm going to do this lesson and this is going to help me. Because it's a big problem, it's something we all need to contribute to. I don't have a solution that people haven't heard a thousand times before. Again, people are working on this that are, I think, more knowledgeable than myself. I know, hopefully, more knowledgeable than myself. It's a whole bunch of things.

[00:56:34.00]

ZM: There is a lot of different little problems that make up the one end result, right?

[00:56:43.00]

IE: Yeah, a lot of different big problems. I wish there were little problems. But I agree with you. It's a lot and sometimes, just that aspect of it makes it harder for people to digest. I mean, it makes it harder for me to digest, and I focus on it more than the average person.

[00:57:00.00]

ZM: People are really good if you give them one thing, right. Like that video with the sea turtle and the plastic straw. That spread everywhere so fast. And then...

[00:57:11.00]

IE: I know the guy that took that video, and it's been amazing. It's been amazing, the positive response of that video, and it has done real good. Are plastic straws the biggest problem for coral reefs? Absolutely not. But I'll tell you what, I would rather people dealt with that than didn't do anything, because plastic pollution is a monstrous problem, is a huge, huge problem. It's a step in the right direction. Full stop.

[00:57:44.00]

ZM: Yes, definitely. Definitely. So let's see. Changing gears again a little bit, but have you noticed any significant changes in Florida's reef system from the time you started your education in Florida to now? How have things changed?

[00:58:09.00]

IE: Yeah, it's kind of hard to say. I mean, I've witnessed - well, let me just take a step back and say that the people that I think have noticed it the most and who are fascinating to talk to are not the marine biologists. They're the local fishermen or local divers, or even people that are just living down the Keys. You can learn a lot from grabbing a beer with some salty old person in a bar because they will tell you stories of beautiful coral reefs and how much it has changed since they have been in their lifetimes. And I, unfortunately, have witnessed that to a certain extent recently, with respect to the stony coral tissue loss disease that's really been rapidly ravaging - and I don't use that word lightly- really ravaging coral reefs in our area and has been moving throughout the Caribbean. I have had study sites, off of Emerald Reef off Key Biscayne, where we had a couple of species of corals that now would take hours to find, scuba diving would take hours to find, where before, we could pal around for a little while and see a couple colonies. Pseudo [???] Rugosa is one, a lot of the brain corals have just been totally hammered by this disease. That's not even just been like, since I got to Florida. That's been since even after grad school. I'm not young, but I'm not super old and it's been the last several years that that's been huge.

[01:00:20.00]

IE: It's extremely depressing. It’s, again, one of those things where you can focus on the depressing, and you have to a little bit, but we can't turn away from it. You got to figure out what to do; get over that depressing aspect and try to figure out things to do.

[01:00:32.00]

ZM: Is there any proven treatment for that disease so far?

[01:00:41.00]

IE: There's been some recent success with an antibiotic-laced compound that is applied to the surface of corals. Anything that works, we need to investigate. Whether we're going to be able to treat every single coral on hundreds of miles, thousands of miles, throughout the Caribbean reef, or whether we want to do that with an antibiotic, I don't think we have a solution. Maybe we have a tool, which is great. We need tools and in some situations, absolutely critical. Maybe we have a coral that is especially iconic, or of real important value that should be necessarily treated. But is that going to work on a population level? We need more tools. We need more tools.

[01:01:55.00]

IE: Now our interview was not on an upswing positive.

ZM: Flattened the curve. [laughter]

IE: Yeah, exactly. It's been a roller coaster. [laughter]

[01:02:01.00]

ZM: No! That is okay. This is really important. It is also important to note that this is not the first disease outbreak that Florida's reef system has faced. It's definitely really bad.

[01:02:20.00]

IE: Yeah, I think this has been unique, really, in the number of species that are involved and the sheer extent and the amount of mortality. I cannot think of something that has occurred more recently that has had such a profound, rapid effect. We have seen other disease events in marine organisms that have been widespread. Diadema urchins, sea urchins, in the ‘80s died off pretty much across the Caribbean, and these guys are really important herbivores, important bio rotors. We know that these big disease events can happen, but we don't really know what to do about it. Unfortunately, corals and reefs are in such tenuous circumstances already that it's just another straw on the camel's back, so to speak.

[01:03:23.00]

ZM: Another plastic straw.

IE: Yeah, exactly. Exactly.

ZM: That is just - it seems like incredibly poor timing.

[01:03:35.00]

IE: It could also be related, right? I mean, it could be. That's one of the other things that's so fascinating and important about this research right now is we really have a poor understanding of what is going on. Corals are so complicated. It's not just the animal and it's not just actually the algae that's living inside it, but there are numerous microorganisms that are associated with a coral. It's called a whole consortium of organisms. We have really had a hard time identifying what is causing this. Is it one bacterium? Is it a whole bunch of different species? Is it environmental? Is it a combination of the both? I'd like to tell you we knew what it was, we knew exactly how to treat it. But quite frankly, there are some fundamental research steps that we need to figure out first.

[01:04:34.00]

ZM: Do you know - how does it spread?

[01:04:40.00]

IE: No, I do not know. That's another aspect, again, super important because that's fundamental to the management side of it, right? One of the things that we're looking at right now - and there have been hypotheses, looking at it spread throughout the Caribbean - that it could be moving in ballast water of ships. Certainly this has been a proven vector for some invasive species. So maybe that's what's going on. There’s been some areas where people have seen it after some ships were moving around. That's something that we are about to test in our lab. We are going to essentially ballast water, hold it and see if that water can actually induce disease in corals. Simultaneously, we're going to test current ballast water treatment methods. There are UV systems that are used for treating that ballast water to hopefully kill all the organisms in it. You're not against spreading invasive species and disease. We're going to see if that, but also ways to space out that because I talked about building those tools up. If we know that moves by ballast water, and we know if UV treatment is effective, then we can hopefully mitigate its spread a little bit more. I'm terrified, and I know others are terrified that it'll jump the Panama Canal and get into the Pacific. Right. I mean, talk about terrifying, it's already been spreading throughout the Caribbean. What if it goes further? What keeps me up at night and I don't know. So what do we need to figure out?

[01:06:27.00]

ZM: You know, I had not thought about that. But thank you for that. I think that is something people should think about.

[01:06:42.00]

IE: That is a question that has huge biological ramifications, but also billions of dollars worth of impact.

[01:06:51.00]

ZM: All right. Let's transition a little bit. So you are a diver, correct? I should have asked this earlier, when did you start scuba diving?

[01:07:07.00]

IE: I first started scuba diving in undergrad, then started diving more in grad school and then on into my career.

[01:07:15.00]

ZM: Did you go into undergrad knowing that you wanted to be a marine biologist and you had never scuba dive before?

[01:07:23.00]

IE: Correct. Full stop. I don't know. It was like this. Many will tell you, I'm a pretty stubborn person. I remember my first dive, just completely useless underwater. And it's just one of those things that you just learn to ride a bike and pick up. I've been very fortunate to have a lot of great, great dives and interesting adventures.

[01:07:50.00]

ZM: You must have really just known that you would love it. That is pretty cool. I do not think a lot of people can say that they have known that for that long.

[01:08:01.00]

IE: That's true. There are days when I'm not diving and in the office writing grants or papers where it's like...

[01:08:11.00]

ZM: That brings me to another question. You are a pretty prolific writer. To me, it seems like you could write a lot less and get in a lot more dive time. Why do you choose to publish so much?

[01:08:27.00]

IE: I'm not one of those people that writing just flows out of me. Those people are so annoying. But I think it's important. And it's been one of those things in my career where I've progressed, as I've moved into these different levels, I found that there are times when there's things that I have to be the one doing something. I would love to be going off having adventures and doing that kind of work. Right now, I'm the guy that has to do this. That's not to say I don't get up to some fun and some diving. Ultimately, we need to do useful things with that information, and produce and synthesize. So I force myself to do it.

[01:09:34.00]

ZM: Yes, somebody has got to do it. I figured there had to be a reason. I was looking through a bunch of publications and I was like, man, that is pretty good.

[01:09:46.00]

IE: It's part of the job. It's part of the job. Somebody's got to do it.

[01:09:56.00]

IE: Alright, I do not want to take up too much more of your time. I have just a couple quick questions. Do you have a favorite dive site in Florida?

[01:10:06.00]

IE: Oh, just in Florida? You know, I'm partial. There are some really cool sites. I really like Cheeca Rocks [Sanctuary Preservation Area]. It's a site that we've done a lot of work at and that has pretty decent coral cover for the Keys. There are some sites in the Dry Tortugas [National Park] which are beautiful. In the wider Caribbean, I've just been doing some work in The Grenadines, which have some absolutely amazing, beautiful reefs. Throughout the world, there are some reefs in Papua New Guinea that absolutely blew my mind and some reefs in French Polynesia and New Caledonia that are amazing.

[01:10:57.00]

ZM: Okay. If you could give some advice to a new generation of marine biologists, or people that are in first grade drawing fish and they just want to travel in their van and post pictures of their fish, what would you tell them?

[01:11:22.00]

IE: I would say that you're absolutely capable of doing whatever you want. I fully believe that. I think that if I can do it, as somebody that was not at all exposed to a real ocean and reef on a farm in Indiana, I think that people need to just go out there and throw themselves in uncomfortable situations, to go out, have adventures and push themselves hard to do the work and to get it done.

[01:12:12.00]

ZM: Excellent. All right. Well, thanks. I really appreciate it. I know this was a long interview. You stuck it out through the whole thing, technical difficulties and all. I really appreciate it.

[01:12:30.00]

IE: No worries. I think it's really important to communicate science and talk about stuff. I actually really enjoy talking about science, which I think is something that's important and hopefully, more and more scientists can do.

[01:12:47.00]

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