Structure from Motion: Oral History of Reef Mapping in Hawaii
Curt Storlazzi Oral History
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Interviewer: MM – Madyson Miller
Transcriber: NCC

Madyson Miller: Before we get started – actually, I already did that. I broke down exactly what you'd expect. But we're going to start at the very beginning to get a sense of who you are, and then touch on questions revolving ocean, coral reefs, your experience, expertise, and specifically, work happening in Hawaii. I am Madyson Miller, the Knauss fellow for NOAA Coral Reef Conservation program. It is Tuesday, November 22nd, 2022, at 5:00 p.m. Eastern Standard Time. Could you please state your name and the location that you're calling from?

Curt Storlazzi: Curt Storlazzi, U.S. Geological Survey Coastal Marine Hazards and Resources Program in Santa Cruz, California.

MM: I love the way you said that "In Santa Cruz, California," like you're at a radio show. Okay. So, like I mentioned, the first question is just sort of warming us up into the conversation. So, I'm wondering if you could walk us through – or me – through your education and career and background and sort of how you got into the position that you're in today.

CS: Sure. Yeah. So, I was blessed. I grew up near the beach in Delaware and New Jersey and Maryland. So, I ran around the beach a lot as a child. I was blessed to surf and sail and crab and clam and do all those things. When I got into college, I took – I thought I was going to do nuclear engineering. But then I took a really great class on – they call it Rocks for Jocks. It's introductory earth science. Starting to think about how mountains form, how the oceans evolved, the plate tectonics, global climate, oceanography, totally changed my career. It was like, oh, my gosh, all these things I – just involved me as a child, oh, my gosh, there's space in here to do great science. I grew up in a family of scientists. Although, they're all in the medical field. So, I'm kind of the black sheep of the family. So, then I just started to be like, okay, well, I'm getting good enough grades. I'd like to try to see if I can take this to the next level in graduate school. Told them I was very interested in doing beach processes. Because I was primarily doing fluvial geomorphology at the University of Delaware and so how rivers evolved through time with sandbars and things like that. But I really want to do beaches. So, got into a couple of places and flew out to Santa Cruz, California, at the University of California, Santa Cruz, sucked in fog, woke up in the morning seeing 2,000-foot mountains, 200-foot high, redwood trees, rocky cliffs, 600-pound elephant seals out on the beach. I was like, okay, well, I guess, I'm going to Santa Cruz [laughter] versus Duke, where it's another barrier island, or University of Washington, which is like five hours inland. So, I came out here, and I started working on the rocky coastlines of California. So, you have very similar things, where you have sandy pocket beaches and cliff parts coastlines and rocky offshore areas. I mean, this is bedrock, not coral reefs, but very similar process, and we just understood. There was not a lot of understanding about how sediment moves along these kinds of coastlines. That was in [19]96. In [19]99, the U.S. Coral Reef Task Force was formed at the International Year of the Reef. In 1999, the USGS held a meeting called "Our Nation's Coral Reefs" to try to figure out the USGS' space in the Coral Reef Task Force. One of the things we said we've got that are really good is we've got oceanographers and geologists, and let's focus on those kinds of things. We're good about circulation and sediment transport. So, because I was doing that on rocky reefs in California, it was translated to working on rocky reefs in Hawaii. So, some of the same tools and techniques, trying to, again, understand how the sediment was more looking at land-based pollution, like sediment – terrestrial sediment coming off the land, impacting coral reefs, burying them, causing high turbidity, being a vector for nutrients and contaminants. But we started to do the same thing. We had to understand where were corals and not. So, one of the big first things we did in the first part of the USGS was high-resolution mapping. NOAA went out – and gosh, bless you [laughter] – went out and mapped all the nation's coral reefs at an acre minimum mapping unit, so 4,000 square meters. We – being in the Department of Interior, we work with Park Service and Fish and Wildlife. So, those are more scales – you know, those park units or refuges, on the scale is more of kilometers. So, we were focused on real, high-resolution mapping, optical and geophysical methods to understand where the reefs are, their condition and health, did some of the first multispectral work. But then we were doing LiDAR. One of the things I had done during – as a graduate student, I looked at how, the geologic and oceanographic controls on sediment distribution along these bedrock reefs in California, we use more sonar and multibeam there, but basically trying to look at the morphology of coral reefs. What are the controls on it? Where are there sand channels, where's there not, where's that sediment move around, looking at things like spur and groove formations, and so did some of the first real morphologic studies of reefs. They have different shapes. Why? Why are spurs bigger here and smaller there? What are the geophysical controls on that? So, we're using, again, TOAD camera systems, airborne LiDAR, airborne multispectral. Again, it was complementary. You guys did the entire nation's reefs. We were doing focused ones. It's small. We do more – smaller place-based studies. Again, where you folks were doing it at 4,000 square meters or an acre, we're doing 100 meters, 10 by 10 unit – minimum mapping units, again, to really meet the scales of our DOI reef managers and also to do some of the science stuff, where then we were actually looking at things at a meter scale resolution. So, that's how we kind of got into the business. We focused on land-based pollution, circulation, geophysical controls on coral reefs. Like, hey, we looked at spurring groups. Why are they taller here? Why are they dominated by these kinds of corals here versus these areas? They had different kinds of corals. So, we worked with partners and academia and the state and Park Service, who did that biology component. We were still primarily doing the geophysical aspects of it. But like, okay, well, perfect example in Hawaii, you go to the North Shore. You see little Pocillopora meandrina hanging on for dear life, but not big reef complexes when you go to the north shore of Molokai. But you go to the south shore of Molokai, you have this fringing reef that's a kilometer wide with 90 percent live coral cover, and it's all very fragile, Porites compressa. So, we started to look at geophysical controls. How much does wave energy control species distribution? So, those are some of the things we did. So, we needed to map the species distribution map, the physical parameters, like waves, forces, and stuff. This sounds so archaic, but this is [laughter] late-nineties, early 2000s. But, hey, there's basically oceanographic controls on species distributions and also on the shape of the reefs, the morphology. How big is that reef flat? How big are the coral spurs and grooves on that? So, that was a lot of our initial work on mapping, again, also at the species level, just for, again, us not doing the interpretation, but our colleagues in Park Service and Fish and Wildlife or academia. Okay. These are the species there, because this park's got a thousand acres of coral reefs. This one has 400 and things like that. So, that kind of took us through the end of the 2000s, I guess. Then we started getting into – again, starting to look more place-based issues, very specifically, like American Samoa had an outbreak of crown of thorns. So, where are those impacts? Again, our expertise, are there geologic or oceanographic controls on where those impacted? Or, hey, we started to have – this park had really heavy bleaching during the 2014-to-2016 global coral reef bleaching event. How much of the park's corals were lost? So, going back and remapping things. Now we're coming to the point where this idea of the role of coral reefs and coastal protection is important. So, while we're primarily working with using

NOAA's data – again, because you've got the only consistent maps across the thing – but for us, we have to do a bunch of experiments, small place-based studies to understand – so, you folks have mapped all the nation's reefs, zero to 10 percent live coral cover, 10 to 50percent, 50 to 90 percent, 90 100 percent. We need to go in there and do experiments where we're looking at wave propagation across reefs, mapping those corals to understanding, okay, well, this is 32 percent live coral cover. How much does that attenuate wave energy? Versus, okay, this area's got 20 percent live coral cover. How does that attenuate wave energy? So, again, more on the place-based scale. So, the first person that you asked to do structure from motion mapping of coral reefs was us, was our group. So, we were comparing it. How does that compare to LiDAR, to high-resolution, multibeam sonar, to look at things like hydrodynamic roughness? Now, everyone does structure from motion. But the first paper in coral reefs, you know, that was something that we were doing. Again, we actually didn't do it with swimmer. We did it with TOAD video. So, now that technique's being used all over the world. Now, we're taking that structure from motion – and one of the things is we don't have good reef bathymetry across most of the rest of the world. They do a lot of this technique called satellite pseudobathymetry. Rick Stumpf developed it when he was at USGS. He's been at NOAA for a while. Looks at how light attenuates through the water column, and you look at blue-green ratios. It's what the Coral Allen Atlas [sic] uses. Although you need so much calibration, validation, data is bad. Perfect example, the data the U.S. has on the morphology of the reef off of American Samoa is all off by a couple of meters. For the Office of Naval Research, we're trying to do structure from motion from a satellite. So, that's absolute physics-based, no weird calibration things. So, we can hopefully map all those reefs. Because we have these reefs out of like Howland and Baker, these fish and wildlife refuges out in the middle of American Samoa. We have the Republic of the Marshall Islands, the Federated States of Micronesia and Palau, which fall under Compact of Free Association, with which the U.S. Office of Insular Affairs means we provide support to them. Let alone, the reefs of Mozambique and the Solomon Islands and all this. So, we're a lot more on the technical development side of things. Then we kind of produce guidance on then being up-taken by NOAA. We work with NOAA, or we work with academia, so that then they totally operationalize it. Because our shop's not big enough to do that, and we're more on the place-based side of things. So, that's where we primarily focused our mapping, or at least, I could say, over my career [laughter], how it's kind of gone. It's just techniques to do it quicker, cheaper, with higher accuracy. So, we're always looking for the next, the next great thing, looking into laser line scanning , that you can do that in optically clear water. One of the big things in Hawaii is Hawaii was chosen as one of the sites for DARPA's Reefense project. So, the idea to restore coral reefs to provide coastal protection. Well, we need to assess – they're going to put out these structures and look at these corals are supposed to grow super-fast and be super resilient. Well, how do you measure really accurately how corals grow? Well, we have the ability to structure from motion, and we developed a system called SQUID-5. So, instead of a person squaring around one camera, we have five cameras that have an RTK GPS, so a satellite, so we know all where that is in space. So, we developed this tool. We're using it for the Mission: Iconic Reefs in Florida, but we plan on using that for DARPA's Reefense, which we're going to be doing off of Marine Corps Base Hawaii at Kaneohe, to assess how quickly are those corals growing and also provide RGB imagery to say, it is this species, or that's algae or whatever the heck that is. So, always trying to push the technology, knowing that others have a lot deeper pockets. We're just trying to make it better and more effective. So, those are some of the things we're doing. Sorry, that was a long ramble, but hopefully that's some of what you needed.

MM: No. That's great. Rambles are the best. I do have a couple just clarifying questions. So, what is a TOAD video?

CS: Oh. Okay. So, what I mean by TOAD video is – okay. So, a diver can swim around with a self-contained camera. You have what we call a TOAD video sled. It's a toad-like submarine that's got cable to the surface. So, you put power down to it for lights and video, and you could suck data back up to it. Put it this way, in the early eighties, Ronald Reagan declared the exclusive economic zone. These took our territorial water from 14 nautical miles out to 200. We got tasked to map all that. So, usually, you do that by geophysics, side scan sonar or multibeam sonar. But all that's doing is measuring reflectivity back. So, at the end of the day, you want to put a camera down to say what that is. It's highly reflective because it's bedrock or coarse grain sand or shell hash. So, how you do that is by towing an underwater, what we call a sled. Because it really looks like a sled. It's got rails in case it runs into something [laughter]. You've got downward-looking cameras and forward-looking cameras and altimeters and temperature-salinity sensors and stuff. So, that's what I mean by underwater TOAD video. It's because, how long can you swim underwater on a tank? A kilometer? We can tow a camera, 24 hours a day, seven days a week. Literally, we've done that in places. So, there's that tool. So, that's what I mean by TOAD video.

MM: Thanks for that. I had never heard that term before [laughter]. It's an interesting name, I guess, TOAD video.

CS: Because usually, your sonars are connected to your boat, and you can put sound down great ways and back. But cameras, you've got to get down near the bed. So, it's towed. You drop it down to depth. I mean, shoot, technically, here in the U.S., we've done it at 17,000 feet, done TOAD video that deep.

MM: Wow.

CS: So, again, to get the cameras down near the bed so that when the strobes go off and the video lights are there, you can actually see the bottom.

MM: Yes. That's awesome. I will say, mapping technology blows my mind. I think it's very fascinating. I want to shift back a little. So, you talked a little bit about how you started your work in rocky shore, coastal ecosystems in California and then shifted into applying that science to coral reefs. So, I'm kind of wondering, when was the first time you knew corals were the ones [laughter]? When was the first time you saw a coral reef? How can you describe that? Just for the audience to get to know you.

CS: Oh, well, the first time I saw coral reefs, I was a kid. I was probably 12, went to Florida. In high school, I went to Jamaica. So, I saw coral reefs. Professionally doing it, I was diving out here in a 9-millimeter wetsuit with john and jacket. So, I had 18 millimeters over my torso, and we're in like 4- to 6- or 8-degrees Celsius water. Then in 2000, I went out to Hawaii, and I was in 25 degrees sea water in boardshorts and a rash guard. So, if you've ever seen the movie *A*

Christmas Story, the little brother who's in the little red suit and can barely move his arms and legs, when you realize the difference between those two [laughter] – yes. It was interesting. Because the work I was doing along the U.S. West Coast was a lot of the same things. It was looking at geologic and oceanographic controls on nearshore ecosystems through a consortium called PISCO, which was the Partnership for Interdisciplinary Studies of Coastal Ocean. So, it's how does oceanography bring larvae, nutrients, and contaminants and potentially, sediment and around – and impact these nearshore ecosystems. So, it was interesting. Because I came in with a purely hydrogen sediment transport background, got into a postdoc now doing nearshore larval dispersal, recruitment, retention, things like. Then I took both of those combined into coral reefs. So, that was my niche. No one was really doing that at the time. But again, the same kind of thing is, when you've got to really – I don't want to say it's super easy. You go along the U.S. East Coast barrier reef. The shore face is basically a decreasing, exponential shape, and it's very linear. Out here where you've got bedrock, where you're seeing the same thing, coral reefs, there's so much bathymetric variability. If you're going to try to understand the processes along then you need to know what the hell it is. Sorry, you need to know what that is. So, here, during the summer and early fall, and there's no waves, and there's no river discharge and stuff; you could start to see – sometimes see down 20 or 30 meters. So, I got really into looking at aerial imagery and doing that. I was literally hand-digitizing bedrock reefs off that and then comparing, contrasting it to side scan sonar data and things like that. What we had we then basically did the same in coral reefs. We were getting the first airborne LiDAR flight in the state of Hawaii, we paid for in [19]99 or 2000. But again, matching that up with the air photos, oh, my gosh, this is bathymetrically high, and it's super rough, as where the coral is. Hey, these flat, smooth areas that are bright white; or, hey, these sand-filled channels. So, bringing those tools and techniques, I've always come to it, you need the map first to understand, then all the other processes. So, it's always been a component of what we do is to have – again, we primarily look at the oceanographic and geologic controls. But to understand the geology and that geomorphic structure, we need those maps. So, we've always had a geographer that does remote sensing, whether it's satellite LiDAR, aerial photography, sonar, or something. We've always had that part of our toolkit. Because it's absolutely necessary to understand any geophysical processes. When I say that, I mean geologic controls on oceanography, whether it's physical oceanography, chemical oceanography and thus then biological oceanography and thus the abiotic parts of the ecosystem.

MM: Awesome. So, I'm still picking apart that first response. You used the term coastal protection. So, I'm wondering if – for the audience – you can explain how coral reefs act as coastal protection for different communities.

CS: Yes. So, basically, coral reefs basically form a big structure offshore. So, you see, usually, the waves break out, break offshore, and they're breaking because waves break relative to their water depth. So, waves break something between 80 and 120 percent of their water depth, so roughly one-to-one. So, an 8-foot wave breaks into an 8-foot water. So, if you have this reef complex that's growing out from shore and is growing up towards the surface, because it's photosynthetic and is also trying to grow up, you basically are creating this underwater breakwater, what, in an engineering field, would be called as a detached, submerged breakwater. The Army Corps of Engineers builds these things to cause waves to break, to protect coastlines. Well, nature has been doing this for half a billion years. The bigger that reef complex is, the broader it is, the more it causes the ways to break further offshore. Then they dissipate more energy as they move on shore. Also, corals are rough. So, think about, if you pull something along a smooth surface, there's very little friction. If you pull something along a rough surface, there's a lot of friction. Same thing with water moving over a surface. If the surface is very complex, when there's corals, it causes a lot of hydrodynamic friction, and a lot of energy to be dissipated. So, while it's tough to drag something along rough ground – that's because of friction – when water or waves move over a rough coral – healthy coral reef, it causes a lot of friction, a lot of energy to be dissipated. So, wave height is really a function of wave energy. So, the more energy you take out of the waves, the smaller the waves are, the less energy they have to break smack into the coastline, to people, and infrastructure and agriculture and natural historic and cultural resources. So, it's the two things; by making the offshore shallower, making it shallow even further offshore, and then having a lot of friction that it causes that wave energy to be dissipated, wave height to decrease, make it more quiescent, low energy at the shoreline. So, that's another thing we need to do is measure, again, how does that coral coverage change across the reefs? Now, one of the things that we've seen – because something like 30 percent of the worlds – and you'll correct the statistics here – 30 percent of the U.S. or the world's coral reefs have been damaged, and the other, whatever, 70 or 80 percent are being threatened. So, one of the things, hey, we need to map whether coral reefs are good and whether they're bad. If they're bad, where are those places where we can do restoration to make them healthy again, so that we can retain increased friction to make the reef shallower, to create more wave breaking, more hydrodynamic roughness, to reduce the wave energy and to bring back that coastal protection function.

MM: You actually answered my next question, which is just going to be, why is mapping corals important? You mentioned looking at the befores and the afters. But since you've answered that – and feel free to add more –

CS: Well, I –

MM: Yes. Go for it.

CS: I come to coral reefs as a geologist and oceanographer. So, I think, most of it is the structure and things like that. But that structure, if you look, think about your aquarium. You just have a plain glass aquarium, and the fish are bored. You put your little skull in there and your little sunken pirate ship, and they have lots of structure, lots of vertical things to hide in, nooks and crannies to hide in. What they've shown is that when there is more structure, when there's more live coral, more bathymetric variability, or the height of the seabed is you just have larger fish populations. So, that's one of the other reasons why we want to restore coral reefs, is to bring that back. Because when they get smashed and degraded, there's less place for the fish. When there's fish, well, that brings, often, two things. It brings tourists, and it brings fishermen. So, we provide business, jobs, and income through those mechanisms also. Now, the thing is corals are living creatures, just like humans. Every year, some live and some die. Well, when some of those corals die, they leave behind their calcium carbonate skeletons. That breaks down and creates carbonate sand. That's important because all those tropical white sand beaches, that's come primarily from corals. So, you want to just hang out on the beach and sip Mai Tais. Well, thanks to those coral reefs offshore for producing that sediment. So, recreation, tourism, fisheries, coastal protection, and then there's just the cultural aspects of it. Perfect example, the native Hawaiians, their creation story is they came from corals. They have underwater heiaus or temples to shark gods. It's part of the culture. Almost every tropical community I've ever been in has those same kinds of relationships. So, it's not just an economic thing or coastal protection thing but is truly a part of most of these island nations' cultures. So, that's why I think coral reefs are important.

MM: No, it's a great answer. It segues really nicely into my next question, which is, what is your relationship but also USGS' relationship with the local community when you're out there conducting work? Because I know, obviously Hawaii, it might vary with island nation, but I'm just wondering on that sort of human dimension.

CS: Well, I was blessed to start my work in Hawaii on the island of Molokai, which has the smallest population but the highest percentage of the Native population. I came in as a good kid. Hey, we're with the government. We're here to help. You realize a lot of people have not always had the greatest opinion of the government and understandably. The Native Hawaiian people are one of the few Native peoples in America that have not got reparations for their land that's taken from them by the government. So, I learned really quickly, having a gun pointed at me, that being a government employee was not always the most welcomed thing. However, when those folks came to understand that we – it's their reefs. It's not ours. I'm not Hawaiian. I don't live there. When you make it clear about that, like, "Hey, it's yours," and listen – and that's one of the biggest things, I think, a lot of scientists have problems with is they want to come in and, oh, come on, these tropics and have fun and make their measurements and leave. You don't listen to people. That's an important thing. We came to Molokai, and we sat down and talked with a lot of people. What's the problem? What's happening? What's your concern? Where can we do this? Where can we do that? Long before the idea of TEK, traditional ecological knowledge, it's just people have been there for generations. You meet some ohana, some elders, like, "Hey, man, this used to be like this here." They're like, "That's invaluable. We can't go back and collect past data." You can get a lot of good guidance. So, it's one thing I've really taken to heart, is usually, when you go into the field, you don't think, "Oh, I just need to have spare time to talk to people." But you know you need it because you learn a lot. You get connection. Then people want to help you. When they really understand that you're there to help them, and you acknowledge that it's their resource, not yours, their resource [laughter], I've had a lot more success, again, people helping you provide insight. "Oh, hey, you've got to talk to my cousin. My cousin has the key to that fence. Hey, my niece has a boat." It just makes it easy. But again, it's because you acknowledge that you're there to help them with their resource. It's been theirs for thousands of years [laughter]. It doesn't matter what the federal government says. I mean, we're paid by them, but our job is to help them manage their reefs. So, it becomes enjoyable then, once you've made that transition. Sometimes it comes quicker than others and sometimes slower than others. But that's the most important thing. That's one of the things that's a little bit easier for us at the USGS, because we don't do any management, is people see us as not – we don't have an angle. Okay. EPA wants to give water cleaner. NOAA has sanctuaries and wants to protect this thing. So, people sometimes get a little – your scientists come in with the most altruistic, unbiased things. They're all like, "Oh, well, you're going to do this because of that." They're like, "You don't manage anything. You can't make any rules or laws or regulations." So, in some ways, we seem a little harmless [laughter], which is a good thing. It's sad because sometimes our science is not used properly, because we can't take that angle. But being seen as unbiased is quite helpful in, again, getting buy-in from folks.

MM: This is just curious. How many times have you been to Molokai?

CS: Oh, Molokai, one year, 30-some, I don't really remember anymore.

MM: Wow. You said it's a small community. So, when you go there, are you constantly engaging with the same community leaders or community individuals? Because I know from personal conversations that Molokai is not an easy place to visit [laughter].

MM: I got a gun pointed at me one of the first times. I get it man. Because, again, they've seen what happened elsewhere, where I'm sorry, you don't have a lot of Native representation. All the stores and all the hotels and all the stuff not run by Native Hawaiians. It's run by Americans and Japanese and Chinese and whoever else. I saw people go out in an outrigger canoe to a ferry with a shotgun and an M16 and basically told all the developers and lawyers to stay on the boat [laughter]. So, it kind of provides some (transparency?). It was tough. But the thing is, I don't know, we're scientists. We're people. We're, again, just interested. That's why I love working in coral reefs. It's like, I get to meet Hawaiians and Chamorros and Puerto Ricans and Virgin Islanders and Samoans and stuff like that. Hey, men, we're all pink on the inside. Supposedly, that's why bears and sharks like to eat us, right? We all taste pretty much the same. But do we run into a lot of folks? Yes. Because it is a small community. They knew when we were coming in a lot of times. Because we'd stay at some of the same places. But then it was like, "Don't stay there. My cousin's got a house here. Rent that house. It's so much better." So, when we go back, we still catch up with folks and have beers with them and talk stories and things like that. So, yes, I've been there – I can't remember – twenty-six times or something. I can't remember.

MM: [inaudible]

CS: It's great. Because, again, these people, when they see you really want to help, and you don't have an angle, and you're not out to take something from them – which, again, most of the Native populations in the U.S. have had that happen one way or another. When they see you're really there to help, they become really nice and excited.

MM: I think that's great. Thanks for sharing. Building on that, you've been there almost thirty times or maybe [laughter] thirty times. How have you seen the reefs in Hawaii change since the time you started working there to now?

CS: Well, yes, that's just Molokai. I mean, I've been to Maui another twenty or thirty times.

MM: Yes, all of Hawaii for this question.

CS: Yes. So, in some places, they're doing better. In some places, they're doing worse. It's been neat to see that there's been some successes. It's amazing. Again, no one really knows that Molokai has got the best reef in the main Hawaiian Islands. No one goes there. It's the largest fringing reef in the main Hawaiian Islands, and a lot of it is 90 percent live coral cover. Florida averages, what, 2 or 3 percent live coral cover? Most of Hawaii's maybe 30 percent coral coverage. I mean, it's like kilometers and kilometers to the point that it's mind-numbing. So, there's some places like that where they've done – great NGOs like the Nature Conservancy and others – have done fencing and ungulate control like goat and deer and reduce some of the sediment and land-based pollution coming off reefs. Other places, I hate to say it, it's too far gone. There have been phase shifts that haven't come back. Other places, there's still continued development and continued building. So, those levels of land-based pollution are increasing. We also saw during 2014 to 2016, the global coral reef bleaching event. So, a lot of Hawaii got its teeth kicked in there. Now, a lot of those good reefs have come back, and a lot were going in the right direction, like a lot of the old pineapple and sugar cane, those fields where, again, they get stripped down to the bare dirt every year. Heavy winter rains would basically cause the islands to bleed, like Kahoʻolawe and elsewhere. That vegetation is coming back and starting to bind that sediment. That's another place, the north shore of Kahoʻolawe. Holy mackerel. Those reefs were buried under meters – and I'm talking 2, 3, 4 meters of mud. You could actually see it like bathtub rings in the spur and groove. All that mud, because they're no longer bombing and napalming the place, and the vegetation is coming back, is those sediment levels have dropped in these spurs. It looks like old bathtub rings. That coral is starting to come back. So, Hawaii is in a good place. It's isolated. Some of the reefs have a very high anthropogenic impact, Waikiki. Other places like Kahoʻolawe and Lanai and most of Molokai are very low, and they have massive coral reef tracks. So, by keeping those healthy – we call that very Maui Nui, north shore of Kahoʻolawe, north shore of Lanai, south shore of Molokai, West Maui. Because they're all protected. Again, most of Hawaii's too energetic anymore to sustain big coral reef complexes. So, the biggest coral reefs are in these protected areas. They're all sheltered by each other. Those islands can hopefully help reseed all the other islands that are being more heavily impacted by anthropogenic activities and increasingly, climate change.

MM: Something that I noticed when we were in Hawaii for the task force meeting is, we are in the water, and I will be like, "Oh, these corals are just everywhere." They're magnificent and beautiful. Somebody from Hawaii would say, "No, they weren't like this five years ago." From my perspective, it's Florida or the Virgin Islands which have just completely, basically, degraded. So, I always thought that that sort of shifting baseline of how people perceive what is healthy is so different, depending on what part of the world you're in.

CS: Oh, clearly. It's also just if it's your first experience ever. Perfect example, I went – sorry, very funny side note. I came out here to California to go to grad school. I thought, okay, this is going to be – I don't know. I'm probably going to move back to the East Coast. So, we were thinking about either doing our honeymoon in Hawaii or in Belize. I was like, I've got to do Hawaii because I'll never go back there. Now, I've been back – I think my most recent total was over 80 trips to Hawaii. But I remember going to Hanauma Bay. You go on the reef and, oh, my God, the fish and [inaudible]. That's just the reef flat that's 1 percent. If you sneak out over the submarine cable and get out into the deeper part of Hanuma Bay – I always tell people, if the water is not overhead, you're not seeing any good part of a reef. Because that's usually reef flats. You've got to get out of the floor reef. Then when I went out there, it was like, oh, my God. Perfect example, I'm working in Guam, American Samoa, Hawaii, Puerto Rico. I was like, wow, man – especially some of these places, American Samoa and stuff like that, wow. Then I went to the Republic of the Marshall Islands and U.S. military base there. So, they don't allow in any Taiwanese or Chinese fishing trawlers and stuff. So, not only was the coral great, but a school of probably 20,000 10-, 15-pound ulua went by. There are sharks everywhere. You're like, oh. This is what Guam is supposed to look like if it didn't have 3,000 years of fishing pressure. You then go to Indonesia, and you're like, "Oh, my [laughter]." Obviously, there's a decrease as we move away from the coral triangle to less species, but that shouldn't translate to less cover and less fish. So, we do see the impacts of humans there. Again, Guam is a perfect example. There's beautiful corals there. There's no fish. Because the island has been occupied for 2500 to 3500 years. I'm not criticizing people eat fish. I eat fish. But you see that across the board. But, yes, that's the thing now. It's like, okay, my friends in Florida have kids grown up. They go out to the Keys. It's like, "Oh, my gosh, look, there's some Acropora cervicornis here, 8 percent live coral cover. Some of our friends remember when it was 30 percent there, you know? So, yes, it's an issue. We have these great books around here. Oh, remember when – pictures of Santa Cruz or Honolulu back in the 1800s, and they try to retake the same picture now. We really need those for reefs to let people know that, hey, this is not what it's supposed to look like. That's the biggest thing to me, is why mapping them or videotaping them or taking pictures of them and now doing all that stuff and geo reference, so you can go back. Because that's where you can show them. Hey, you only care about something you know about, and you only love something you care about. But you also need to know that the, hey, it used to be a hell of a lot better. Or, hey, this is how it has actually gotten worse.

MM: Yes, I totally agree. When *Chasing Corals* came out, that coral documentary, they have that really powerful image of a coral bleached and then after the bleaching event in one part of the world, obviously, that was the Great Barrier Reef. But I was like, oh, that would be so cool if they did that everywhere. Because then you could take that to the local community and be like, did you know [laughter] that this is what it looked like back in the day?

CS: Yes. The problem with the coral bleaching is those local communities aren't the people driving it.

MM: Yes. You're right.

CS: China, the U.S., India, Europe. That's the thing. That's one of the big problems we have is the people are going to be the most impacted by it. Because, again, as those reefs degrade, they increase the coastal flooding hazards for those communities. You decrease the fishing stocks. You decrease the sand for the beaches. So, those communities are being increasingly impacted by these global stressors that they can't control. They can be 100 percent renewable, there's wind and solar and everything else, but they're the ones getting the impact of it. So, that's one of the things that we all need to think about, community-wise. The thing with global climate changes, is everyone plays a part in it, but the impacts are disproportionate to the people who generate the CO_2 emissions that cause those impacts.

MM: Very well said. We are getting into the last nine minutes. I had a couple more questions. So, I wondered if there's any current projects that are actively happening that you're really excited about at USGS or any other sort of projects that maybe you're involved in.

CS: Yes. Well, on the mapping side, one of the things is we mapped the coral reefs off the Kona Coast of the Big Island. There's three national parks there. We mapped them in the 2000s, and we're just remapping them now to look at the impacts of the 2014, 2016 global bleaching event. So, it's, again, trying to develop new technology to – one of the problems with – here's going back to you, Madyson – the TOAD camera is it's not attached to the boat. So, it's somewhere weird dragging it behind the boat. Think about a water skier, right? You could drive that boat the exact same way each time, but you don't know where that water skier is. So, we're trying to develop new techniques to think about the paths moved all over. So, how do we use that not perfect data to do assessments perfect? A swimmer swims at transect. That's nice because they can swim the same transect. But again, we could do 30 kilometers of transect lines in like five days, could do that by a diver, but again, we don't know exactly where that is. So, doing some cool new tools and techniques for that. One of the big things is also then geo referencing our imagery, so that people can go back and shoot it again. That's one of the big problems with the underwater stuff, is maybe it's relative to that pin, but we don't know where that pin is in space, so that we can't go back to do those long-term changes. So, how did it look in 2000 versus 2010 versus 2020 versus when we re-survey again in 2030? So, spending a little time and effort on that. Like I said, the big new thing is the DARPA Reefense program, understanding the roles of coral reefs and coral reef restoration. Just how much coral do you need? How big does that coral need to be? How to create that hydrodynamic roughness to dissipate that energy? Then how close do they need to be? The closer you are, the more you have to outplant, which means more cost. You put them further apart, they're cheaper. But maybe they don't do enough roughness and dissipate as much wave energy. But we have to map all those things and make the measurements of the waves and the energy dissipation to try to optimize, if we're going to restore reefs, how do we do that? So, again, the tools to make those measurements to measure the coral growth, then to tie that in with the energy dissipation for the coastal protection. There's a lot of neat things we're doing right now. This DARPA Reefense is putting 40 million just into adaptive biology to make corals grow faster and more resistant to climate change and things like that, which is a huge shot in the arm. So, it's going to be neat to see what they do, and then how we can map and show the effectiveness of that for coastal protection. So, those are the things I'm kind of excited about in the near future, and just provide more guidance. The states and territories want to do coral reef restoration, again, for coastal hazard risk reduction, for tourism, for recreation, for fisheries. What kind of guidance can we give them to do that more effectively, lower cost, and so that they're sustainable. So, there's a lot of science around that, which, pardon me, for a while, I spent the first ten years in my coral reef career being kind of like Doctor Death. Oh, this land-based pollution is doing this. This is killing the corals and killing the corals. I've got to tell you, it's depressing. So, now, I've really drank the Kool-Aid. I'm really into, okay, well, what do we do about this? We have a window of opportunity – I'm not sure it's going to be that long – to make these changes, to try to restore these reefs, which is all under why we do this, Executive Order 13089, Coral Reef Protection, signed by President Clinton in 1989. Basically, the goal of that was to protect and preserve coral reefs. I've grown up and spent my entire career working to serve that goal, as a lot of other folks. I feel our window of opportunity is closing. So, we've got to do something. We're learning things at an exponential rate. But, again, the door is closing. So, excited to see what we can figure out, helpfully, to do that, to protect and preserve our coral reefs and, again, for those peoples. Most of those people are Native, underserved communities, and it's their reefs. So, that makes me proud as an American scientist, to sit there and say, "Hey, we're doing it –" I mean, that's why we serve, right? Is to serve the American people and to know that we're doing it also for these communities that usually got – historically gotten the short end of the stick. I don't know. That's very fulfilling to me.

MM: That was really well said. My final question is, if a young person approached you, who was looking into a career in this realm of science and geology and physics and corals, what piece of advice would you give them? That's how I like to wrap these up.

CS: Okay. I tell this to every student. I don't care what field you're in. My daughter is looking to get into medical policy. More math, more coding, and more statistics because everything – mapping. Satellites are now passing overhead and are a hundred times the resolution than when I started. It's becoming a big data issue. It's becoming that we're getting so much data so quickly, you need to be able to write code to process that. Because you're not cutting and pasting cell anymore. You've got 50 billion data points. You need to have some kind of statistical understanding to like, okay, is this an error because this is out of range, these things like that. I always say, more math, more statistics, and more coding. Because, again, even in ecology, you're doing gene expression, stuff like that. Okay, man, you go look at CRISPR data sets or the human genome. It's all getting so much bigger data. So, that doesn't take away from the love of what you do, but there are tools you're going to need. You're a biologist, an ecologist, a geologist, an oceanographer, remote sensing, a mapper, all of those people; the data sets are just getting bigger and bigger and bigger so that you can't handle them with normal cut and paste. You need to write code. There's so much data you can't see the patterns. You need to get the statistical models to look at the patterns and, again, just some higher math to process that stuff. So, yes, it's the way of the world. But the other thing is, get outside. The thing I've always said to people, I learned more about hydrodynamics, waves, currents, and sediment transport, sitting at the beach watching things happen that you'd never get out of books. So, hey, coral reefs, go snorkel around them. You'll see things, and things will pop in your head that you'll never get from just reading a darn book.

MM: I agree with all that. It's advice I wish I would have gotten. But I also think it's a call to the American education system to make math and statistics more fun and accessible to the different students that are coming into this – hopefully coming into the STEM field.

CS: Well, that was one thing that I was really proud about. Where I went to graduate school, they had a geophysics professor – so, super good math nerd – basically said, everyone is going to – and this is still grad school, but this is early on grad school – says, "Okay. What's your topic of interest? Okay. We're going to do an entire segment on this. What does your data set look like? Okay. Lt's write code to process this. These are these statistics for those things." So, they made you interested in it. So, you're exactly right. You do need the educators to do that. There are great people out there. But, again, it's just like using terminology. You've got to find the hook. What makes me excited might not make you excited, but if you have a great educator, you find that – when I talk to some people about coral reefs, I talk purely about tourism. When I talk to others, I talk about coastal defense. Others, I talk about fisheries. When I talk to admirals, I talk about increasing the lethality of the warfighter. It just depends on what it is. But you're right. Those people are out there. It just takes a little while sometimes to find them.

MM: Awesome. Any last thoughts that you want to share?

CS: Find something you love, and you always get your mind blown that you get paid every two weeks.

MM: [laughter] Love that [laughter].

CS: I am [laughter].

MM: Yes. No, that's great, especially the paycheck does help. But it is nice doing something that when you wake up every day, you're excited about it.

CS: I mean, listen, I fly in helicopters and ride in small boats and travel all over the world and get to meet these beautiful, incredibly interesting cultures and histories and things like that. I always said, if I won the lottery, I'd have a bigger house, nicer cars, and take nicer vacations. I hate to say it, I'd still come to work. A, it's intellectually stimulating with wonderful people. But most importantly, it means something to me. Again, when I put my hand on the Bible and said to serve the American people, that meant a lot to me, and that still does today. That's what motivates me, is we're trying to make this country a better place, not only for the people here now, but my daughter and my grandchildren and things like that. So, yes, find something you love, and it makes it a lot easier.

MM: Awesome. Well, thank you so much, Curt. This was a great interview. Yes, this was just great, and I think it's going to look really nice on the story map. We talked about everything [laughter], which is awesome too.

CS: Awesome.

MM: Thank you again. I'll let you get back to your day. Happy Thanksgiving and Merry Christmas if I don't see you until then [laughter].

CS: Have a happy and safe holiday. If anything comes up and wasn't clear, like with transcription or something, just give me a holler, Madyson. Okay?

MM: Yes, definitely. Thank you so much.

CS: Okay. Good. Take care. Bye.

MM: Bye.

[end of transcript]