Welcome to your November Café Scientifique. My name is Jon Willis and I'll be your host this evening. For those of you who don't know me, I'm a professor in astronomy at UVic and I'm one of the members of the university who hosts these bimonthly Café Scientifique talks. If this is one of your first talks you've been to welcome you're in for a great treat tonight; if you're a regular, nice to see you again...

So with no further ado, let me introduce this evening's speaker. This evening's speaker is Julia Baum and she is an associate professor of biology at UVic and we're very lucky to have her this evening because she's doing some wonderful work. Let me just give you a little bit of a background to the work she does. Since about 2009 she's been studying the marine ecosystems of the Christmas Islands, in the Kiribati Group ["Kiribas" (kɪrɪˈbæs) is the official pronunciation as "-ti" in the Gilbertese language makes an "-s" sound], which is basically in the middle of the Pacific right on the date line, and so that's a 9-year baseline of study. She's going to tell you about some of the interesting events she's been looking at during that period.

Also, I was interested to discover with her researches, she also makes close reference between the marine ecosystems and the human ecosystems, and as I'm sure many of you are aware, as we move forward into a changing world, that link between the human world and the natural world is something that's ever more important and that we have to be aware of. She's a recipient of many prizes and awards, I'm not going to list them here, but there are many. And I just wanted to say I think that we here in Canada, and at UVic in particular, are very lucky to have such strong scientific voices. She's really an exceptional scientist on the front line of observing our changing planet, and I think we all recognize how important that is, and we are also fortunate enough to have captured her, for one evening, so she's ours to listen to and then grill. So let me introduce Julia... As usual I skipped the title... Corals and Climate Change: Glimmers of Hope from an Ecological Crisis.

I'm going to tell you a story about corals and this story starts with a phone call in March 2014, over 4 years ago, and it was a phone call that changed my life. On the other end of the line was Kim Cobb, professor of climate science at Georgia Tech University in Atlanta, and she said to me, "You're the only other scientist crazy enough to work on Christmas Island, and there's an El Niño coming, a big El Niño predicted, and they're predicting that it's going to hit Christmas really hard, and so we need to join forces -

even though we don't really work on the same things - but we need to join forces; we need to mobilize; we need to raise funding; we need to get expeditions out there; we need to study this thing. This is the big one. This is the El Niño that I have been waiting my entire career for." And that call changed my life completely and everything that I was doing scientifically.

And so as she said this I felt, really, a mix of dread, and excitement, and anticipation, and apprehension as well, all at the thought of returning to Christmas, a really, really remote atoll in the central equatorial Pacific where I had been working for 5 years at that point, and where I have expended more blood, sweat and tears than I can possibly describe tonight. And so I felt kind of sick about the thought of having to go back, because I had come to the conclusion that it was simply too hard to work there. There's no field station, there are no amenities, it's extremely expensive, and I just thought, you know, I'm at UVic, I should just set up a field program here and call it a day and quit thinking that I can be a tropical coral reef ecologist in Canada. But at the same time, of course - scientifically - my interest was piqued because I wanted to go study the big El Niño, and I knew that as a climate scientist, Kim would be there studying the actual phenomenal of the El Niño, and it's through research - through her research and other researchers like her - that we know that climate change is causing El Niños, which are a natural oceanographic cycle, but climate change is causing them to occur more frequently and to be more intense, and so she would be studying the nature of that. As an ecologist I would be studying the impacts of the El Niño on the coral reefs.

And what I would come to understand both intellectually and viscerally over the following two years is that climate change induced El Niños and other temperature phenomena really likely spell disaster and potential extinction for the world's coral reefs in the coming decades if we don't collectively change our ways as a society and get really serious about tackling climate change.

So what I'm going to share with you tonight really is the adventure that Kim and I went on. I'm going to tell you mostly about the adventure that my team and I went on over the next couple of years, and I have to say that that initial dread and apprehension and excitement and anticipation that was in the pit of my stomach during that phone call - it never really left my stomach over the next two years because it was an extremely intense period in all of our lives - who were on my team and Kim's team - for reasons that I think will become clear, most of which because, together, we watched this island that we really, really loved, absolutely melt down and die over the next two years.

And so I'm going to tell you about that, and I'm going to tell you about how despite that - despite complete ecological devastation - I'm still an optimist, and I still think that there are some glimmers of hope, and I think that we can still save corals. So hopefully I can convince you of that as well.

So I'm going to start by taking you all with me to Christmas Island. It is an atoll in the central equatorial Pacific we're going to go to the airport here, get on a plane and fly to Honolulu, and then we're going to catch a flight from Honolulu to Fiji - and it's a flight that only leaves once a week - and on its way to Fiji it will touch down on Christmas Island, and then we will emerge from the plane against blazing sun, and despite the intensity of the equatorial heat, you want to make sure that every inch of your body is covered in clothing, because otherwise your pale northwest coast skin is going to burn to a crisp very quickly.

And then we're going to walk across a really old dilapidated tarmac that is going to cause you to wonder how the plane managed to land on it, and we're going to get to a wooden dilapidated building - a one story building; sort of a hut - that is the airport, and then we'll go inside and we'll cross through customs, and if we're doing this prior to the El Niño when I first started working on Christmas, it will be just us who emerge from the plane along with two other fishermen - recreational fishermen - who are there to fish bonefish, and two missionaries who are there to convince the people on the island that despite there being no rainfall and no way to grow food, that they should have many, many children. But I'll talk about that later...

Then, after that, we're going to get in a car on the other side of the airport and we're going to drive for about 40 minutes around the atoll - because this is a huge atoll, a hundred fifty kilometers in perimeter; the world's largest - and along the way, you're going to get a very clear sense of just how poor the people on this atoll are. They live in part of the Republic of Kiribati, one of the poorest countries on the world. The island is all virtually at sea level. People are living in thatched roof huts, houses that they have constructed together with corrugated tin, some of the more well-off people are in cement block houses. There are chickens running around everywhere, there are random kind of stray, mangy looking dogs everywhere, there are pigs tied up to chains, and tiny piglets running around everywhere, and it's timed always just right that the kids have just got out of school and they're in their beautiful cute little uniforms and are walking home, or biking home, and they're running along side of the road and waving

frantically at us and saying "I-Matang", which is "Foreigner".

So it's quite the trip. And eventually we end up at the fishing lodge where we stay and once we get there we kind of hunker down, because it's from there that we eat, we sleep, we dive. We turn our tiny little hotel rooms - that we share sleeping next to each other this close - into a wet lab and process samples at night, and so we basically don't leave there except to be out on the boat diving all day for the next 4 weeks.

So Christmas is really an island of extremes that - I think I've given you some sense of some of those extremes already. As I said, it's part of the Republic of Kiribati, this is a Pacific island nation that is comprised of 32 different islands spread out across over three and a half million square kilometers of the central Pacific. Most of the country is thousands of kilometers to the west in Micronesia. But Christmas, being sort of the outpost island of the country, is way to the east, and technically in Polynesia. It has the most land mass of any other island; it has 70% of the country's land mass, so most of the people should, in theory, live there, but as I said, there's no rainfall, so very little way of raising crops. Most of the food is imported, or people are fishing on the reef and relying on their catch from the reef to sustain their families.

They have had a recent change of government. Their previous president, Anote Tong, gained global recognition because he flew around the planet collecting conservation awards and was a very outspoken leader talking about climate change, and he kind of put Christmas and Kiribati on the map because he made it clear that Kiribati is one of the nations that will likely be under water within the next 50 years because of sea level rise and he talked a lot about the need to relocate everyone in the country. With the change of leadership it became clear that the people did not want this; they flatly rejected this, this is not what they wanted; they said that he was out grandstanding on the world stage, and the current president, Taneti Maamau, instead, is saying that, for sure, the people are going to stay because that's what they want to do - they are refusing to relocate - and they believe that God is going to save them from climate change and the impending changes that are setting upon them.

It's also a country of extreme beauty. There are some of the world's largest seabird colonies on Christmas, so for any birders out there, I always wonder why there aren't more birding tourists. We always take a day to go look at the birds and it is absolutely extraordinary how many tens of thousands of birds there are - frigate birds and terns, and shearwaters, and boobies, and it is just mind-blowing. The reefs are amongst the

world's pristine. They look like what you would see on a cover of a National Geographic magazine. And the reefs were teaming with fish, with turtles, with sharks, and it was truly extraordinary. But I did say that Christmas was an island of extremes so it wasn't all like that, and that's actually what drew me to Christmas in the first place, was that the reefs had this extraordinary gradient because at the one end of the island - very far away from people - the reefs were as I just described, and at the other end of the island - where all of the villages were congregated in the northwest corner, the reefs were highly degraded. And this is why I went to Christmas in the first place.

I am not a climate scientist. I know nothing - or I knew nothing at the time - about corals. I knew about fish, and I'm trained as a marine ecologist and a fishery scientist and what I was really interested in was how fishing and fishing pressure changed coral reefs. And this was an awesome experimental system - natural experimental system - where I could go to one location and study reefs that had all different levels of fishing pressure on them and see how that fishing pressure changed the coral reef ecosystem. And so that was my original impetus, that's what I did for five years there - the first five years. Fortunately at some point I did start studying the corals, but they were sort of in the background, like they were like, you know, this thing that you also need to look at, not the focus - thankfully I was studying them a little bit.

But as you'll notice, none of what I have just described - studying the fish - we were counting fish, counting urchins, thinking about how the food web would be changing with fishing pressure, etc., and none of it had anything to do with climate change. And the reason was - I was convinced that fishing was the most pervasive, ubiquitous, intense, important stressor on coral reefs in the world, and I thought that climate change was something that these other people were concerned with but I didn't really understand why, and thought they kind of weren't focusing on the most important thing. And in my personal life I basically thought that climate change was something that happened to other people in other places... so that was nice.

So the reason that I think that I had this naive belief about climate change - that I hadn't really sat up and taken notice of it - might be similar to what you've experienced, and that is because climate change is often described as these slow gradual increases that will take place over the coming decades, and in decades we might end up one or two degrees, or maybe 3 or 4 degrees, higher than it is now, and I think sometimes some Canadians think... Doesn't sound so bad, really.

And that's a problem really, because that is one way that climate change manifests, but the other way that climate change manifests is by simply increasing the variability of weather patterns in the world, and it's this increased variability that we know is causing increases in extreme weather events, and it's these extreme weather events - these intense shocks - that I think bring climate change home for all of us. And there's certainly no shortage of examples of these intense shocks happening everywhere in the world over the past couple of years, whether it's the hurricane that devastated Puerto Rico over a year ago - and those people are still not recovered, and might never. At the same time as that hurricane, there were monsoons that covered Nepal and Bangladesh and India and over 40 million people lost their homes, but it barely even made the news. Imagine if everyone in Canada lost their homes. I think we'd be sitting up and taking notice.

More recently, I think we probably all lived through the wildfires that were happening in BC this summer. I had a very strange apocalyptic-like holiday up on Hornby Island where everything looked just gray and kind of like we were in Blade Runner, and right now California's on fire and it's not the summer, so it's very strange that California just keeps burning year after year but now it's doing it - not even in the summer - it's doing it in November. So these shocks really, to me, are what bring climate change home to people and what, hopefully, will make us all sit up and take notice and start taking action.

So in the ocean, El Niño is one type of intense shock to the system that can happen. It is, as I said, a natural phenomenon, but it's also becoming more intense and more frequent with climate change. So the last really massive, mega mega El Niño, was in 1997-98. And that El Niño caused over 35 billion in damage around the world. Several thousand people died, and a lot of what El Niños do, when they're really intense, is reverse weather patterns around the world, so areas that are typically wet become dry, and have droughts and wildfires, and areas that are dry become wet and flood and everything is kind of topsy-turvy and reverso.

Okay, why does El Niño matter for corals? It matters because corals live really, really close to their upper thermal tolerance level, and that means that even though a change of 1 degree Celsius is really nothing for us - we barely even register that it happens - for corals, a change of 1 degree Celsius can spell disaster. And why is that? and what happens? Corals live in really close - a tight, intimate symbiosis with tiny plants like algae, called Symbiodinium, that used to be called Zooxanthellae - that's what they

were called when I learned about them in high school.

So normally, during the symbiosis, the microalgae, the Symbiodinium - they are little plants, essentially - and they're photosynthesizing. So they're feeding the coral; they are literally the food production centre for the coral. And the coral, which is an animal, is housing - sheltering - these tiny algae, and they're living in this really intimate relationship, which is wonderful.

And then, when the water warms up - even just a little bit - the photosynthetic reactions of the algae break down, and essentially those little algae become toxic to the coral. The coral boots them out - gets rid of them - which kind of seems like the smart thing to do, but actually also means that they're taking out their food production centre. And it's at that point that corals turn that ghostly white, and that's what we called coral bleaching. So you've probably seen photos of that - maybe from the Great Barrier Reef over the past couple of years. These really ghostly, haunting images of - when you're expecting this bright vibrant coral reef - those bright vibrant colors are actually not the coral, they're the little algae. So if you love the corals, you love the little algae, and hopefully you will come to love them over the next few minutes as I do now - more than the fish even.

Okay. When temperatures go back down; if the stress of abates, and the corals have been able to live through that stress - hopefully it's only a few weeks and they can tough it out; sort of live off of their energy reserves - then they're able to take their symbionts back up, reabsorb them, turn back into the vibrant colors that we all know and love, and basically heal and be fed again.

So this is sort of the cycle of bleaching. So when you see a bleached coral, it's not a dead coral, it is a sick coral without its food production centre, and hopefully the stress abates and it can heal itself. But if the stress goes on for too long, then coral essentially starves to death, and they're typically overgrown by gunky algae and things take a bad turn on the reef.

Okay, that sounds simple enough, but there's actually lots and lots of things that we don't understand about bleaching, and lots of lots of things that we don't understand about - during bleaching events, or heat stress events - why some corals bleach and some corals don't bleach. And one of the leading ideas about why we might see so much variability is because there are actually probably thousands of different types of

these symbionts that live inside the corals - and I say probably, because the taxonomy is still being worked out, and it's a big mess - but we know that there are lots of different kinds and we know that some of them are better at withstanding heat stress than others. So some can take the heat; some can't.

So there are a lot of questions about why some corals survive. You can go to a site during heat stress and you can see some coral species that are doing well, and some aren't.

And so you might think, Okay, well maybe it's just a species difference. But you can also see corals of the exact same species sitting in the exact same water at the exact same temperature, and one will be bleached, and one will be healthy, and one will already have bleached and died. And this is where the mystery arises: Why is this? what's going on? Does it all have to do with the symbionts that are inside them? are they genetically different? do they have different microbial communities? That's another whole possibility, so there's a lot of unknowns.

Okay, so hopefully that gives you some sense of why, when Kim Cobb called me, even though I was not a climate scientist and I really was trying to get out of Christmas and never going back there, my interest was piqued and I knew I couldn't pass up this opportunity. So I devised what I thought - and I was very proud of myself - I thought this was the perfect plan; the perfect scientific plan; such a good experimental design - we would go out, and we would do three trips: We would go and we would study the reef just before the El Niño, and then we would go out for a second time and study it during the El Niño, and then we would go out a third time and study it after the El Niño. Perfect. Very simple design; elegant - I loved it; very happy, very proud of myself... You know this is not going to work out at all.

So the idea - I thought in my mind - was that this El Niño would come, it would land on Christmas, it would subject the corals to this massive heat stress, and I was thinking about it as if it was this stress test. And so what I thought we would do is we would go and we would think about individual corals - so we would tag individual corals - and essentially I was considering that each individual Coral was like a patient in my medical study; my stress test.

And so we did - we went and we did that - we tagged corals. We were diving, get to the corals, put little metal dog tags on them, we color coded all the different species with

cable ties. So we had lots of fun trips to Home Depot where we needed exactly the right number of the right color of cable ties, scientifically, and a lot of retired gentleman working in Home Depot thought that we girls just liked to have fancily colored construction - I don't know what they thought we were doing. But you get a lot of strange looks when you, as an ecologist, shop at Home Depot for science. And some of the retired gentlemen are just like - I don't understand what you gals are doing. And some of them really get into it and are like - Okay, like so what size of PVC do you need? Okay, and how many blue cable ties, and how many magenta and how many pink, and we're like it's all very important, believe me, it's for science. We're trying to save the world here.

Okay, so we went out and we ended up tagging a thousand different coral colonies - are there any divers in the room? has anyone been diving? Okay, if you dive, that's a lot of dives, that's a lot of time under water - because we had to map all of them out so that we could come back and see them. And we did these thousand corals that were spread out around a dozen different sites all around the atoll - so some of them were at the very high fishing pressure level, some were at the very low, and some in between - and many, many different species et cetera, et cetera, so everything was working beautifully.

And then something happened that queued in my mind this expression... I had a professor at UBC, as a grad student, Carl Walters, a very famous Canadian fisheries scientist.

And when he was teaching us ecological modeling, every time he would tell us a story - a case story, because he'd been working in the field for, you know, 40, 50 years, and every time he would tell us something that started like the story I just told you, and then he would get to the part where nature happened, and he would look at us, and he would say, "Mother Nature's a bitch."

And that's what I thought in my head quite a lot because the El Niño didn't come. Yeah. So really good for the corals. And the problem with this, is that we had convinced the National Science Foundation in the United States to give us a grant - an emergency grant - because the El Niño was coming in 2014. And the grant was very specifically laid out to do three trips, at three times that were before, during, and after the El Niño - that didn't come - and they would not let us change it, and they would not let us extend it. And so at one point - I had this naive thought in my head - it was like: Well, I guess

we're going to have to give the money back, I don't know. And my colleague looked at me like, are you an idiot? Like no - we're going to go out and we're just going to do the three expeditions and we'll have before... before... before. So we know a lot about what happens before.

The El Niño did come. So as our third expedition was finishing up in May 2015, the El Niño started raising its head - like it literally times itself so it came two months after our last expedition... thanks a lot, Mother Nature. And it landed on Christmas in July 2015, and I managed to eke out enough money to get us out there, so we studied it in July 2015 - that was at 2 months heat stress. And then the next 6-8 months of my life, were really the most stressful - I can tell you - I was also getting divorced at the time, so overall it was a total disaster.

And for 6-8 months I just scrambled like crazy trying to convince a funder - someone, anyone - to give us money so that we could go out and study the reef again because I knew we had to get out there again, and ideally we had to get out there pretty much right at the end of the heat stress so that we knew the full magnitude of the impact, and we knew who had survived and who hadn't. And if we went out halfway through that wasn't really going to cut it, and if we went out quite a bit after that wasn't going to cut it, and I couldn't convince anyone to give me anyone to give me funding, anyone. I mean I could wallpaper my whole house if I was like that masochistic with the rejection letters. No one would fund it because it was too risky - because the 2014 El Niño didn't come. So they weren't going to find another natural catastrophe that might not come. And on top of it, I wanted them to fund me, and then I would at some point deem, like, now we have to go, it's going to be the end now. I couldn't tell them the exact timing and I couldn't tell them it was going to happen. I can only tell them that it was really, really important and they should fund me.

And everyone said no, everyone. Until, through personal connections - and I know they always tell you it's not what you know it's who you know, but wow, it really is - personal connections got me in at the Packard Foundation in Palo Alto, and I had a meeting there and convinced a wonderful program officer to take a chance on me, a complete unknown in the coral world, and give me just enough money to get back to Christmas.

Okay. So, by October 2015 when I was still scrambling, it was clear that the El Niño - I mean it was already underway at Christmas and it was underway everywhere on the planet - NOAH, the Federal agency in the United States declared that it was the third

ever global coral bleaching event, it was wreaking havoc on coral reefs all over the world. It was huge; it was devastating. And one of the headlines - because I think people were a little gun-shy at that point, because the previous one has failed - one of the media headlines I remember seeing was that this El Niño, was, quote, "Too big to fail."

And I remember talking to Kim as we were just desperately trying to raise money and just feeling like we're not going to be able to do this, and we're going to lose the opportunity of a lifetime, and she just said to me and her typical extremely powerful Kim way, "This is too big to fail. We're going to do this." And so, we did.

And I guess the reason that I'm telling that particular part is because it speaks to the importance of teamwork. I certainly didn't do this alone I did it with a huge team of amazingly talented grad students and collaborators who really were - and are - the world experts in climate change, and corals, and these tiny little creatures called Symbiodinium that I knew nothing about - but am rapidly learning about, they knew about the molecular techniques, they knew about all of the things I really knew nothing about, but I somehow convinced them to join me and let me come play in their sandbox a bit, I think because I had this phenomenal study system.

So we took tissue samples from each of our little tagged corals, we revisited them and in the end we revisited them on eight different trips now, taking tiny little tissue samples each time, and those tissue samples allow us to do molecular sequencing that tells us the genetics of the coral, tells us what types of symbionts are living inside the coral, tells us how much energy reserve that coral had, tells us about the microbial community, all sorts of things. It's a wonderful window into these animals' lives.

When the El Niño really started unfolding - as I said it did hit reefs around the world, and the reef that obviously made the news over and over and over was the Great Barrier Reef, and there are certainly wonderful reasons for that: it's a world heritage site, it's the largest barrier reef; very iconic reef. Over 90% of the Great Barrier Reef bleached - that does not mean it died; it bleached, a lot of it recovered. The heat stress that landed on Christmas was about three times as intense as what landed on the Great Barrier Reef.

And if you picture in your mind the world - a map of the world - but we're thinking mostly of the oceans right now, and this is an animated map. So it goes from the

beginning of 2015 - January 2015. And it's going to progress through all of 2015 to the middle of 2016.

And when you think about this map, think about heat stress; a little red blob landing on different parts of the world's ocean. This is what the El Niño did, starting in early 2015. Heat stress landed in one place, and then it landed in another place, and then it landed in another place. And in each place it landed if there were coral reefs there, it caused some level of devastation, but it was very dynamic in most places; it was there for a little bit and then it wasn't, and then it was somewhere else and then it wasn't. And the exception to this was Christmas, because on Christmas, and the area right around it, that heat stress landed on the island in June of 2015, and it got a choke hold on the island, and it sat on that island for 10 straight months - all the way through the end of 2015, the beginning of 2016, into early April. Corals can bleach after 4 weeks of heat stress. Mass bleaching is expected after 8 weeks of heat stress, and we expect mass coral mortality after 12 weeks of heat stress.

The level of heat stress that Christmas endured during this event was predicted to not occur anywhere on the planet until at least 2050. So this was globally unprecedented - I mean we weren't even counting the weeks of heat stress in weeks anymore, we were counting them in months. It broke the indicator - the measure that NOAH uses to count heat stress - because their measure is called degree heat-weeks, and we're talking to them now about will how do we even measure heat stress in this new world that we're in where he stress comes in months and many, many, many months. So essentially, what we had on Christmas was kind of a crystal ball into the future we could study it and learn about the types of heat stress that other reefs are likely going to endure in the coming decades.

So we did manage to launch a second expedition, in March 2016, it ended up being perfectly timed pretty much with the end of the El Niño -at least the end of it on Christmas - and we had this extremely surreal experience - I described the island for you. Normally when you go there, you kind of feel like you've gotten away from the rest of the world, I mean you're literally sitting on this little island in the middle of the central Pacific and you kind of feel like no one can find you - kind of get off the grid for your first time ever type thing... and instead, Kim and I were on our satellite phone, which we always have with us, in case we have a dive emergency and the U.S. Coast Guard come and rescue us - and so we never used it before, obviously. Suddenly, we were using our satellite phone and racking up the minutes because we were taking -

fielding calls from the Washington Post and New York Times and AP and the Globe and Mail, and we were trying to make our sat phone work and we were like frantically, like racing around on the beach trying to get a signal and do interviews with them because suddenly, Christmas was on the map because this heat stress was so intense. Everyone wanted the story because, of course, the media always want the story about, you know, what's the biggest, what's the most, what's the greatest, and this was it.

And so there we were telling them about the little islands that we work on and what we were seeing. And what we were seeing was total devastation. What we were seeing was coral reefs that 10 months previous had had, at some sites, 90% coral cover - we were seeing the loss of almost all of that coral. So we had sites where you would get underwater and you couldn't really see anything except the coral - well that is once I stop looking at the fish...

But we used to just see coral, there was coral everywhere - huge, huge corals called Acropora - that are often referred to as tabletop corals, because they form these massive tabletops that would encompass all 10 of your tables there - massive, massive corals, a huge diversity of corals; vibrant colors. And we got underwater, and a number of us cried in our dive masks. And that was something we hadn't really anticipated seeing, or happening, but it was like it was like a punch in the gut; it was just like - I don't know, I can't really liken it to anything actually, I don't know what it was like; like everything died. And it happened so quickly, and I knew intellectually before we got there, that it was very likely - in fact I was I was terrified before we got there that Packard had invested this money in me - and I was terrified that we were going to get there and literally everything would be dead because then I wouldn't have anything to tell them except heat stress kills corals; and we didn't learn anything, really, like, I don't know what to tell you... it kills corals.

So, thankfully, 10% of the corals survived. And you really have to be a glass-half-full kind of person to see the good in that. So ecologically, hugely devastating. And we saw this devastation across the entire Island. So in the area that had really heavy fishing pressure, they had pretty low coral cover to begin with - some sites 10% coral cover, some sites 20% coral cover - it all pretty much died. There's maybe 2 or 3% coral cover left at those sites. The sites with very low fishing pressure had anywhere from 60 to 80 to 90% coral cover - all gone 90% coral lost, and others 6-7-8-9 percent left; very little. So basically, this stress just came and it landed and it just squashed the fishing pressure stress that I thought was so important and changed the entire ecosystem.

Some of the sites ended up with these huge growths of macroalgae which is basically like think about if you go underwater and you look out and you're expecting to see a beautiful coral reef and instead you see what basically looks like a 1970s green shag carpet in your basement, that's what it looks like. And of course my students didn't know what I was talking about.

Some of them were to completely overgrown by that, that's a huge problem because corals have a hard time coming back from that, they're in competition the algae, the algae can grow a lot faster than the corals, they're going to have a hard time coming back from that. At other sites, the sites that had previously had a lot of coral cover, the coral died, so it bleached, then it died, then it was overgrown what kind of fuzzy filamentous algae and so when you look at it it's not this ghostly white, it's kind of dislike red fuzzy color, and I think it's sometimes hard for people to visualize or to understand what they're seeing, because it doesn't look like the ghostly white, and it hard to say no, that's way worse than the ghostly white, like they're not coming back from that. That's dead, that's overgrown; it's done. And the sort of haunting thing about it was that, of course, the structure was still there, so at the beautiful pristine sites - or previously pristine sites - there was still all this structure.

So I know those sites I know those corals, and it was just like seeing all these skeletons, I mean it was sitting skeletons, with all the beautiful forms still there, but dead. Okay I'm going to give you some glimmers of hope, I swear to God.

Okay what are the glimmers of hope in all this. First some Coral did survive. And that's super cool, because honest to God, I don't know how they did it - well I didn't at the time, I do now. Some of them actually came through it okay, so in March 2016 after 10 months of heat stress they were bleached - so they had somehow persisted in this bleached state. We've been back three times since; we know, because we have them tagged, those corals recovered; they're fine.

44:40
But there are some other ones that did something that is even more interesting, and that I referred to now - very unscientifically - as the miracle corals, because it seems like a little miracle to me, and I think it's a really striking example of Nature's resilience nature isn't always a bitch, it's also strikingly resilient. So we saw these miracle corals - several species can do this trick that these ones do - but the one I'm going to tell you

about is called platygyra; and it's a brain coral So it's basically a circular, boulder type coral with squiggles all over it; kind of looks like a brain. And when we went in July 2015, after just a couple months of heat stress, they were all bleached, so they seem to really susceptible, they seemed like they were on their way out. They were all bleached. And then we came back in March 2016, they were healed. And this is absolutely crazy, because this runs counter to everything we know about how bleaching works, because in March 2016, they were still under heat stress, they should not have been able to heal until the heat stress had abated; no one has ever seen a coral, a bleached coral, take its symbionts back up while it is still subject to stress. No one thinks that this can happen; we're having a very hard time convincing reviewers that we saw this.

And it was very, very cool because we actually have the media to thank for this, in a sense, and that's how we discovered it initially, because they said: We want photos; we want before and after photos for our story, so give us some before and after photos; so the ones of them being fine, and now they're bleached or dead. And so my assistance went and she looked at all the photos that we'd taken under water, and she came to me and said, "There's something - what's going on here? We have all these ones that are bleached and now they're fine. And that is how we learned about it was because he might not have really clued into it until we got home otherwise.

So it appears that they had regained their symbionts while still under heat stress, and we have since confirmed that using molecular techniques; we know that is what they did. We've also revisited these same corals many times since, so that we know that they did indeed heal they're growing, they're fine, they're fully recovered.

And so what's cool is that they were able to reestablish this intimate partnership with their symbionts while they were still under stress.

Okay so how did they do this? You're going to have bear with me as I explain some biology about symbionts. Essentially, we can think that there are two distinct types of symbionts. Ok, one type we're going to call C's and the other type we're going to call D's; you're going to have to bear with me, I didn't name them. The C's are really great partners; these are the ones that you want to form a relationship - this is who you want to be in a partnership with, okay. They are very giving, nurturing - like, could I possibly anthropomorphize them any more - partners. They give a lot of nutrients to the coral; very good partners - but, they can't take stress, so they're very sensitive to stress. So they're not the partners that you want when times get tough. On the other hand D's are

shitty, shitty partners. They're very selfish, they're not the ones that you want to be in a relationship with, they give very few of their nutrients to the corals, the coral are usually kind of skinny and starving and looking all stressed out when you're in a relationship with these guys, but they're very stress tolerant, so when times get tough they can make it through just fine. So as with everything else in biology, there are these huge trade-offs.

Now what we found is completely counter-intuitive, because what any coral reef biologist would tell you is that it would be the ones that had the D's - that are stress-tolerant - that would survive, but we found the exact opposite. So not only did these brain coral survive 10 months of heat stress, not only did they heal themselves while they were still under stress, they did so by having the wrong symbionts; so they did everything not according to plan.

Every single brain coral that survived started with type C symbionts; it started with the sensitive ones. And every single call that started with D, died - which is really cool and interesting and strange. And the reason that we think that they did this, or were you able to do this, is because the ones that started with C were in a really healthy relationship and they had built up a lot of energy reserves; a lot of lipid reserves. And so yes, they bleached early on into the heat stress, but then they had all of these reserves; they were pretty resilient, and they toughed it out for many, many months, living off of their energy reserves that they had built up from this healthy partnership, and at some point, they took up new symbionts, and they wisely at that point took up D symbionts because those were the only ones that were tolerant enough to take up at that point; they took up D's and they made it through the rest of the heat stress event with their kind of shitty, but stress-tolerance new symbionts. And that's how they did it.

So this to me is one of the coolest things - I mean not one of - it is the coolest thing I've ever discovered in my life, and it is the reason that I am a field biologist - that I don't study things in the lab - because I personally think that while we have a lot to learn about the mechanisms and how things work through lab experiments where we have a lot of control, I also think that nature has so much to teach us if we are watching carefully. And I think that nature can surprise us in so many ways if we're willing to watch and study and listen.

Ok, so another cool thing that's just like the icing on the cake of this: all of the corals that were in the degraded sites, where there was heavily fishing pressure, they all had

D's; they all died. All of the ones were at the pristine sites had C's; they survived. And for years, people have been debating, Is there any point in even trying to manage local pressures on coral reefs when we know that climate change is just going to get them? And I would say yes, because this study clearly shows that with a bit of protection, corals might have the right symbionts, and might be healthy enough to survive other stressors that we lay on top of them.

Okay, I'm going to finish with a quote from Rachel Carson, author of Silent Spring, that was written by her over 50 years ago, but I think is extremely present toda,y I don't know how she knew that this was exactly what we needed today. She writes: "We stand now where two roads diverge. But unlike the roads in Robert Frost's familiar poem, they are not equally fair. The road we have long been traveling is deceptively easy - a smooth super highway, on which we progressed with great speed, but at the end lies disaster.
The other fork on the road, the one less traveled by, offers our last, our only chance to reach a destination that ensures the protection of the Earth. Thank you.

Questions from the audience

The exact examples focused on brain coral, but what of the other types of coral, how did they fare in the changing environment?

They mostly died. There's some variability. Some species all died. One species did a little bit better than the brain coral and we're still actually trying to figure out why - we don't know what it's trick is yet. It is very species-specific there's a lot of variation that occurs at the species level, and we're still trying to figure out why. So I think - I mean - one thing that we can say with quite a bit of certainty is that these heat stress events are going to transform - I mean they're not going to kill everything on every coral reef all at once, - but I think it's pretty clear that they're going to transform what we see on reefs, because certain types of corals are going to survive, and certain are not. So we're going to have very different looking coral reef ecosystems with different community compositions.

Couples that survived originally had this type C symbiont, and they were taking up Ds,

having recovered, and the question was, Do they ever then, go back to their original partners; are they are they faithful in that sense?

That is such a great question; I love that question at the exact question that I had, and so far the answer seems to be no, which is very worrying, of course. My collaborator, who is actually a symbiont expert, he thinks this might be a good thing because if they get hit with a little stress, then it might be better to have Ds, but if they get hit with a big stress it's not going to be such a good thing. But so far the answer is no, but I'm just dying to know if they switch back at some point. And to dig into the mechanisms of like why? or why not?

At least on the Great Barrier Reef that has been even more control, certainly of fishing, could you speak to that in the Kiribati environment.

The way I think in general we have a pretty good sense that healthier reefs, so reset have been protected from fishing, tend to recover more quickly after these types of events, and one of the reasons that they can do that is because they tend to have larger populations of herbivorous fishes. So here if you go in the water here, most of our fishes are carnivores, but on reefs they have a lot of herbivorous fishes, which is pretty cool, and they play really important role in grazing the different types of algae, so that big green shag macroalgae that I talked about and the tiny algae, they basically mow it all down, and in doing so they're opening up space for corals and sort of shifting the balance in that competition between corals and algae. So we know that herbivores play a really important role in recovery, so that is one mechanism... I think it's is a huge component for the recovery part of things, and the study that I've just described to you, is sort of some of the first understanding of why local management might be important on the resistance side of things, helping those coral communities actually resist bleaching and mortality in the first place.

What of the people and the expanding population?

We've been running a socioeconomic monitoring program since 2007, so we have a fairly good idea of changes on the island, but what I can say is that everything is changing extremely rapidly on the Island. The island was discovered in a tourism sense 2 or 3 years ago. So now when we get off the plane there's usually 50 or 60 recreational

fishermen that got off with us, so it's just it's on the map it's very strange, and you can see the influx of wealth, so people are much more affluent, people have cars all of a sudden, which is just like mind-blowing. Every time we go back the number of things that people have has changed markedly, year-to-year. So it is an atoll, an island that is changing very, very quickly.

One of the things that's interesting is - because of course we wanted to know what was the impact of the El Niño on people and how has fishing changed for them. And the interesting - or worrying - thing, is that so far, the fish populations haven't really changed, and the reason that I think the fish populations haven't changed is because - as I was saying - the structure is still there. So there's not actually really very many types of fish that need live coral cover, what they really need is the structure. And so, until that structure breaks down. which I think might take three, four, five more years to do through storms - it's very weak it's extremely hard to work on right now because everything just you know, we're trying to install things on the reef and put tags on, and you go to touch anything and everything just crumbles under your hand, and it's just like, oh God, there's no integrity. But the fish are fine.

And so when we did surveys with people in all of the villages in 2017 and ask them know how did the El Niño affect you, and how's the fishing going, and they were just like, We don't know what you're talking about. And so they had no idea, like they had already completely forgotten because there's been no impact, and when that impact does happen, as it surely is going to happen 2, 3, 4, 5 years from now, I think it's highly unlikely that they're going to attach it, or relate it to the El Niño that happened in 2015, or relate it to climate change, and so they're sort of this disjunct there, so there's definitely a lot of opportunities for education and discussions about making those links.

Does the El Niño hurt the symbionts?

Not that I know of. So one thing we know about the symbionts is that they don't need the corals as much as the corals need them, so the symbionts can live inside the corals, but they can also just be free living in the water and they can also just live in the sediment, so they're pretty flexible and I don't know of any evidence that heat stress actually kills them. It's is not totally a reciprocal relationship in the sense that they don't need the corals as much.

Questions after the event from members of the audience
1:04:30
What exactly are super-corals?
[Genetically-modified corals or 'super corals' have received plenty of hype, but scientists say this is not the answer to coral bleaching.]

Did you dive at different depths?

No. We usually do four dives a day, so we usually do 60-70 minute dives at 10 metres.

What is the temperature range that actually occurred over this period?

Between 1 and 2 degrees - it sounds miniscule... That's why when at the Paris Agreement people were arguing about limiting climate change to 1.5 or 2, and I think most people are like, Well, who the hell cares? That's not going to make any difference. And to me, that's basically the difference between us having coral reefs or not. Or having some, or not at all, I guess, that's a little more the way I would put it. It's huge, and I don't think anybody realizes that because it sounds so small.

How were you able to know about the El Niño?

It's basically the U.S. and Australia that do the main forecasts; it's NOAH in the U.S., and it's the Bureau of Meteorology in Australia... Normally these things hit hardest around Christmas time.

The relationship between the symbionts and corals... What's the interaction?

So the symbionts are algae, so they're photosynthesizing... while they're inside the coral, and providing the coral with lipids, and sugars, and oxygen. And then the coral is processing those, and feeding back carbon dioxide to them, so there's a nutrient cycle going on between them. And then they're also providing shelter.

The colour of coral largely comes from the symbionts, so in changing from the C to the D, did that bring about color changes to those particular corals?

No... They're fairly closely related... So until this summer, they were all in the same genus, and in the summer there was a huge taxonomic revision.

Engineer's Technical Note: Behind Dr. Baum (the speaker on the stage), the snare strainer throw-off of a drum kit wasn't engaged, occasionally causing some sympathetic buzz in the right channel. The EQ of the house system was not adjusted for spoken word presentations, the SM-58 was not held off-axis, and plosives are heard throughout.