**William Figueira - "Can a GoPro & 3D printer help in the fight to save the Great Barrier Reef?"**

>> Welcome to the podcast series of Raising the Bar Sydney. Raising the bar in 2017 saw 20 University of Sydney academics take their research out of the lecture theatre and into bars across Sydney all on one night. In this podcast you'll hear William Figeuira's talk, Can a GoPro and 3D printer help in the fight to save the Great Barrier Reef? Enjoy the talk.

[ Applause ]

>> Good eve, well we're here to talk about coral reefs tonight. My own journey has nothing to do coral reefs really it's very strange that I wound up studying coral reefs. I grew up in the mountains in New Mexico. I lived in New Mexico and it wasn't until I was in grad school with kind of an interest in population biology that a friend said to me, hey how about you like the spatially structured populations. What about reefs? What about coral reefs? And I thought that sounded cool. So we scraped together some money and we headed down to the Florida Keys, bit of a pilot trip. And of course I was excited as you would be at the thought of doing all my PhD work on a -- diving on a coral reef. But I mean as soon as I put my face in the water I was definitely hooked, right. And I -- any of you who have been in that situation probably feel similarly. There's just a thousand things down there doing what they do. Right, it's a bit like a -- sort of like a shopping mall near Christmas. Right, if you stood up in the atrium and looked down lots of activity, everybody going someplace as urgently as they can because they've got to get stuff done. And then from the ecologist eyes of course hundreds of questions bumped into my mind. And that sort of lead me down the path that I'm on now and many of those questions I'm still investigating. So that's why I'm here, why are you here? Well you obviously have some interest in coral reefs. You might have heard that perhaps they're in trouble, and then you saw this title that somehow I'm going to save them with a camera and a 3D printer so that's intriguing. You may have slipped in the side thinking there was free beer, either way you're here. So you want some -- you want some -- you want some answers. So it's probably worth before we're getting in -- getting into the you know to those answers you need a bit of background. So I'm going to spend a bit of time talking about reefs because I'm thinking that's probably you know what a lot of people want to know about. So coral reefs are well they're unique right. The amount of ocean occupied by coral reefs is actually only about 1%. So a very small footprint for something we all know so much about. And the reason we know so much about it is because of the ecological and economic importance. So ecologically speaking, they're the most biodiverse ecosystem on the planet, you know more than rain forests. There's 800 odd species of coral I tend to just call them substrate because I'm not very good with my corals. And then there's 4,000 species of fish on the reefs of the world. So that -- to put that in perspective you know fish are the most specios vertebrate group on the planet. There's about 25,000 or so, sorry 15-16,000 species of marine fish. So 1/4 of those live in 1% of the ocean, right. So that gives you a little bit of a take. Now we go down the invertebrate route, don't get me started right. Partly because I don't know what I'm talking about but also because there's a lot of them. Right, there'd be 100 fold more invertebrates on coral reefs. So a staggering diversity of organisms that you're going to find there. And then of course all the ecological importance begets a lot of economic and social importance. So you know we can -- coral reefs of the world have been valued at just shy of 10 trillion dollars in their net worth. The Great Barrier Reef was recently valued at about 56 billion. About a 6 1/2 billion dollars per year contribution to the economy from the Great Barrier Reef alone right. So they have the highest, we call it ecosystem service value, of any ecosystem on the planet. $350,000 per I don't' know, heck per year means nothing to you. The point is it's a big number and it's two or three times some of the other systems that we think of as being really important like coastal sea grasses and mangroves that are nursery habitats for lots of organisms. So they're very important and there's lots of metrics but why? What are they doing? Why are they so important? Probably one of the first ones, one of the biggest ones and one of the most immediately relevant ones for most people is the food they provide. Anybody in here, well so -- about I don't know it's estimated about 1/4 of the population of the tropical regions of the world, especially developing nations, has as their sole source of food fish from coral reefs. Right, so there's not alternative in those situations. But outside of that it's estimated about a billion people in Asian -- Asia eat food from the reef. And of course being Australians and the love of seafood you may have at some point enjoyed a nice coral trout, some sort of an emperor. So those are all coming from our own Great Barrier Reef in addition to lots of invertebrates and prawns and things right. So they're and important source of food. They're also an important source of protection, so reefs are literally walls. What do we do when we want to protect a marina? We build a big wall in front of it of rock and rubble. That protects it from waves and surge. Reefs do the exact same thing there's islands all through the tropical region and the Indo-Pacific that are only there because the reefs are protecting them from being washed away. So they -- they're very valuable in that regard. And then probably the last and perhaps maybe I don't know -- I don't want to say if its least understood of so aside from the food and the habitat protection is the one I'm drawing a blank on right now. It's just super important, anybody know? This isn't staged. I knew I was going to do this. You know how you set yourself up for a fail? I knew I was going to do this, it's an important one. Yeah, there we go Oh, there wasn't another one, that's why I'm getting confused. The point is they're batting well above their weight, they're 1% of the ocean and they're doing all this for us. Right, they're protecting us 500 million people or so rely on these reefs directly. Oh, that was it, tourism. Tourism, come on people who's been to the reefs? Right, I've been to the reef. Tourism, tourism is a massimous source of money and Queensland alone it's like 65,000 jobs from the Great Barrier Reef. Right, so tourism is another massive component. So about 7% of the world's population rely in some way on the reefs for all these different things. So they provide all these ecosystem services right. And they're really important and hopefully I've established that to you. I put my face in the water and I think they're beautiful but if you don't believe that then at least you believe they're really important. So but what are coral reefs? That's the next question. There's a lot of misunderstanding about what they are and that leads us to what impacts them. So coral reefs are actually composed largely of these little beasts we call corals, reef building corals. They're a certain type of coral that secretes a calcium carbonate skeleton right. That -- they grow slowly over time, they pile on top of each other, they're hard, they're solid right. And it turns out that those things are animals, they're closely related to jelly fish and anemone. And they're not just the animal; this is the key secret to the success of the Great Barrier Reef and all the reefs of the world. They're not just an animal, they're a -- they're sort of what we call a holobiont. It's a combination of a plant and animal. So these -- these corals have within their tissues a symbiotic algae that lives there and helps them out. It helps them by photosynthesizing, grabbing CO2 out of the atmosphere right and some sun light and turning it into sugar. And the animal, then as animals do, can feed off that sugar ok. So that's the nexus of all -- making all this happen. Now we'll get to this in a little bit but corals can survive for a little bit without this symbiont. They definitely won't be building any reefs, takes a lot of energy to build reefs, but they can survive for a little bit. But the real key then to these habitats, they build this reef and it's really and this is my fish perspective coming through, it's the reef it's the habitat that causes so much diversity. Just like a rain forest you look at a rain forest there's certainly a lot of trees and animals packed into a small area. It's that third dimension, the fact that these trees stretch so high, that adds the ability for a lot more of what we often call species packing in the game. So lots more animals can fit in that habitat. Same thing happens on reefs right. And if anybody spends any time in the ocean you know you're swimming around in the middle of nowhere and you see a pile of bricks or maybe in a shopping cart and there'll be something around it, things living around that. Because it likes habitat, it likes structure. So that's kind of one of the main messages right. Is that reefs provide structure and that begets all of this other diversity that we see piling on top of it ok. So that's what corals are, that's why they're important. So where are we at with corals? What's happening with corals? A lot of misinformation out there. Unfortunately corals exist in a part of the world where there's not a lot of money floating around to be doing ongoing monitoring and really following exactly what happening over time. So there are a few regions of the world that have been relatively well studied coral reefs of the world and a couple of examples would be the Caribbean. Lots of research around the Caribbean basin and of course the Great Barrier Reef. And if you look at some long term numbers from both of those areas you're looking at on average a loss of about 1/2 the percent cover of coral right. So coral is kind of a -- we look at it from the top down as a way of quantifying how much is there and you know the percent -- you know 20% of the reef is covered by coral. So we've lost about 1/2 of that. Now coral diversity in the Caribbean is inherently just a bit lower in the percent cover. So you actually have remaining estimates around the order of 12-15 plus percent on average. And in the GBR it's more like maybe 20-25% but of course there's a lot of spatial variability right. The southern now I'm going to give a caveat on what I'm saying next, up until about two or three years ago the northern part of the GBR for instance over the long term had had relatively little loss in coral. Very, very healthy habitat that was our pristine area. The southern end of the reef had quite a lot more, almost up to 50% in some areas lost there. So yeah it's spatially variable depends on a lot of things. So what does it depend on? Why are we getting this loss right? There's a lot of things that impact coral reefs. One of the main ones, one of the most obvious ones is well you kick it over you destroy it, you smash into it, a boat runs into it, a cyclone rips it to shreds, dynamite fishing. So physical destruction of the habitat obviously is a very bad thing. That immediately wipes it out. But there's also this really interesting ecological dynamic that happens on coral reefs where you know corals are constantly doing their thing and there's lots of algae. Algae is always growing and algae is doing its thing and algae wants to grow in the coral and the coral doesn't want the algae to grow on it. So there's this little battle going on all the time. And of course the stakes are high for the coral. Now normally on healthy coral reefs the coral is obviously winning right. You see little bits of algae around and what algae there is is pretty heavily grazed especially by lots of fish herbivores swimming around eating it you know various parrot fish, sturgeon fish, things like that. Now we've seen a lot of these dynamics though, you add a little nutrients to a system. We've all fertilised our lawn that can be a good thing a little bit of nutrients is a good thing, too much nutrients though can be a bad thing. Because algae seem to be better at uptaking nutrients and growing and that gives them the advantage. And they can start to grow over, grow too fast, settle too fast, the coral cant' keep up. Then if an area happens to be over fished, right you're pulling a lot of these herbivores out you can sort of get these two squeezed from both sides affect and you wind up with the coral being overgrown and dying. So that's one affect and unfortunately the -- one of the main target groups of coral reef fish is these herbivores, they're a little bit -- they're more abundant, little bit easier to catch. So in a lot of the areas where coral reef fish are used for food, those are very common fish that are fished. So very classic examples in the Caribbean where this has happened and led to reefs turning green basically. Another big impact that worry about on the GBR quite a bit is sedimentation. So when we develop coastal areas we strip away a lot of the vegetation, nothing left to catch the sediment, flows into the rivers and if you've ever been up in an aeroplane or anything along the coast you'll see big plumes coming out from a river. So that's sedimentation, there's a lot of things that can happen associated with nutrients in the rivers. But if we're even just talking about the sedimentation effectively it's shading the reef right. These things need light, without light they can't grow they can't build reefs. They may survive, but they won't be building very good reefs. So especially our in-shore reefs are threatened by that and that's another big impact. Another one you may have heard about is COTS, crown of thorns starfish right. But immediate lately from scientist of the Australian Institute of Marine Science where they found a wealth of snail giant -- giant snail that historically seems to have possible been more abundant than it is now. But nonetheless it loves it -- it loves it some crown of thorns starfish. So these things are these incredibly armoured fantastic beast-looking, they look like a sci-fi movie character, they can be that big across, and they basically crawl across and they eat coral, they love to eat coral. But we just get these epidemic outbreaks of them and then they come like a wall across the reef and they can -- they can -- they can basically destroy almost all the cover of a reef in the area that they -- that they go past. So there's lots of programmes right now trying to deal with that. Another affect you may have heard about is ocean acidification. So that's - that's the problem that arises as we push more CO2 in the atmosphere because of chemistry, Will will understand that wherever he went. You know mass balance it gets pushed into the oceans as well, and the oceans are a big -- big reservoir for CO2, but it changes the chemistry as that happens. And in particular it can make them more acidic, right it pushes the ph lower for a variety of complicated reasons that I'll pretend I don't have time to explain. But in reality I don't understand fully. It makes it harder to accrete their skeletons right. So they lose the ability to build the skeletons as effectively. Even if it doesn't kill them out right they're not as good at reef building.

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>> And then the last affect and the one I'm sort of focussing most on because it's probably the biggest affect is bleaching. So bleaching is this phenomenon where when it gets too hot -- so I told you that you know corals are the symbiont they only live in certain parts of the world where its warm enough and there's enough light. But you know it's a bit of a too much of a good thing. It gets too warm for too long, effectively what happens is the corals the symbionts kind of misbehave so to speak and the corals kick them out. And when they kick them out they lose all their pigment and they become white. So those beautiful white corals you've seen are actually under significant stress. If the temperature drops they can reacquire and keep going, you know live their life. If they don't reacquire their symbionts though and how long this takes varies; could be weeks, could be months but they'll die. They'll eventually die and when they die they get over grown by algae. When they get overgrown by algae they stop building themselves and then the ocean just does what the ocean does right. Anybody surf? I heard a great comedian say, surfing really is just the ocean throwing you back out of it right. The ocean just kind of everything we put in there it just tries to destroy. Anything you put in the ocean is -- I know this I'm a marine scientist, I put all kinds of expensive things in the ocean. It just tries to destroy them. That's what it's doing to reefs right. All the continual wave and surge just wears down those reefs if they're not maintaining themselves. And the key here is over time you lose that structure. Some great photo series out of the Caribbean where you get these huge elk horn stands of coral, beautiful fish everywhere, and 15 years later there's just nothing because they've died, the elk horns died and it's been overgrown by algae. And now it's just this waste pile of rubble, still a few fish there, but quite different. So you lose the complexity when you get bleaching. Now in terms of what's happening with bleaching; so bleaching was first observed probably in the 70's or so. We saw kind of a first big event in the 80's but it wasn't until like 98 where we say what we really call a mass bleaching event where its corals all around the world bleached. The GBR was hit real hard; our field station on the southern GBR was hit really hard in that bleaching event. There was another one on the GBR in 2002, little bit smaller but then this other one that was kind of again a global event in 2010, didn't affect the GBR that much. But then one you hear most recently about is the event that really started in the Northern Hemisphere in 2015, hit the GBR in 2016, moved its way again back around the world through the northern hemisphere summer of 2017 and unfortunately smacked the GBR again in 2017 this year. That one had the affect of most of the bleaching was the bleaching was most severe on the northern pristine section of the reef hence my caveat from earlier. So a next cyclone Winston actually blew through the reef right in the middle of this and effectively saved cooled the water dramatically on the middle and lower reef, effectively saving it. So that's sort of an odd positive benefit of a cyclone for reefs. But the northern -- the northern part was hit and in the end when they did follow-up surveys we lost like 67% so 2/3 of the coral and the most pristine area of the GBR is dead right. This year the bleaching hit the mid section of Cairns. The cyclone came through, Debbie right, came through did a whole mess of damage but it was too late to stir the water up and cool it in time. So there was heavy bleaching but we don't know the mortality outcome. Worst case scenario, you know, if it was -- it was the bleaching was as severe as it was in 2016 so you know a betting man would predict the mortality could also be nearly that severe. If it was that severe you'd be talking about 1/2 you know of the coral was lost on the reef in the last two years. That's big right, that -- that's you know my hair just stood up a little bit too and I've been saying this a lot. Ok so there's the doom and gloom now let's get to some more positive stuff. You know what am I doing about it? So I look at this problem and so there's two key issues here. Really the main thing affecting reefs globally and the Great Barrier Reef the GBR is CO2 emissions right and warming caused by that. We need to kerb that, you've all heard this argument before. We all need to take action; we need to pressure our governments and such. So the point is people need to be convinced to take action because it's a little bit inconvenient in some ways. So I saw what could I do in that space? And then secondly ok what can I do in the short term? I'm not happy to just let it -- let it ride. What else can I do to try and help the situation? So myself, colleague Professor Maria Byrne who's here somewhere, I saw her she's back there and a couple of really keen graduate and post and [inaudible] in our lab including Gus Porter and Renata Ferrari embarked on this kind of 3D reefs project we're calling it. And the aim was really to use high tech tools to kind of map and create 3D models of the reef with one main aim being outreach, promotion of the reef. You've seen video of the reef and you've probably been stunned by them right. But go the next level and actually climb into the reef, it's even more stunning. So we can do -- I'll give you some examples but we can build these 3D models of huge areas and then we can give you and experience either on sketchfab which is kind of YouTube for models right. Where you can go there and look up 3D reefs and see our models and click them and spin them and zoom. You can put your phone into your Google card board and click the little button on the screen and then you'll be in looking around at our reef at home. Or for those of you lucky enough for who want to come by the lab you can put on your oculus rift headset and literally get in and jump around go I wonder what's down in that hole? Jump down in the hole and see all the colourful coral around you and as you go this is how the fish sees the world. Why does that fish like being here right? Is it the overhang, some fish like overhangs? Is it the little coral head with small spaces that the blenny lives in right? So you can jump around and it's a very powerful communication tool and I've seen that first hand with some of the students in our group. I gave a lecture to Maria Byrne's coral reef class telling them about these are the cool fish you're going to see. Oh and Maria said tell them about 3D reefs. I told them about 3D reefs and I left, cool. Three months later I get this email going hey Will we've got our data we're ready to make models. So Ok first of all who are you, ok? Turns out these are students in the class who were just so blown away by the idea that they went and figured out themselves, came back with all this data, and long story short they're now kind of you know critical members of the group. Sitting in there every day, well they were there today you know basically building models and doing all kinds of analysis. Occasionally misusing the oculus for some gaming but you know we forgive that. So it's very powerful communication tool right. So then the other aspect that we're hoping to get at though is solutions. What can we do with it? So just some as some examples, so as a scientist I love data I want to get data out of this and do something with it. So a couple of examples of the use of this technology. So I was at -- I was out at Lord Howe Island, so Lord Howe Island's southern extent of coral reef in the world. It's a bit cooler there so you might think it could be a bit of a, I don't know, a bright spot what we're calling hope spots right in the face of climate change. You might see more corals there right. So we want to know how corals are growing. But also because it's on the southern end and in relatively cool water the potential effects of ocean acidification are slightly higher there. There's some interesting questions about the affects of temperature and acidification on coral growth. So we want to measure coral growth, not that it hasn't been done before. It's been done quite a lot but it's difficult to do corals are these you know, they can be anything be the boulder like that, a brain coral. They're also these sinuous you know branching corals, or these little nubby corymbosus corals or big ball, leafy ball coral. So there's all kinds of morphs. How do you measure the growths of those right? You can core them but often those are destructive and you don't want to do that. You can pull it out, dunk it in water and see how much the volume goes up. Relatively destructive you don't want to do that. You can coat them with tin foil and people have done this and weigh the tin foil. That's a good way to do it, very time consuming. So we decided let's apply this technology, let's use it to build 3D models of these reefs. So a bunch of us jump in the water right we've got SLR's or even some point and shoot, some canons you. We all and we basically swarm around these sights tagging some corals. And we just you know have a protocol over five or ten minutes we collect maybe 80-150 images and take them back to the lab and in a couple hours we have a 3D model. Now we can go back, we're going to go back in March or April do it again. And then I can then compare these things and actually get these beautiful heat maps which I'd be showing you right now but they didn't give me PowerPoint. These beautiful heat maps and showing you where the tips are growing and other areas may be recessing. And how exactly these things are growing and changing. And we can compare that across latitudes. So that's one really powerful way we can extract information on you know the health of reefs and how things are growing. But I'm a fish guy right? Unabashedly I used to call coral substrate until got into this project, now begrudgingly I'm starting to learn some of the corals. But I like to know what's happening relative to fish. Now for blenny that lives in that little coral head, yeah that what I just talked about is probably super relevant. You know how far apart are the branches? That little blenny may never leave that coral head its whole life. But a lot of other fish move and they move on varying levels on reefs. It's not uncommon to have a little damsel fish, one of my favourite groups moving no more than the area up here for 10 or 15 years on the reef. But there's plenty of others parrot fish and surgeon fish and butterfly fish and angel fish that move you know they'd move around this whole room. Or even a double size of this room. So those for me are ecologically relevant scales. And that happens to also be a scale that's really powerful for communication right. It's cool to look at a coral in 3D, but to see a reefscape in 3D is much better. So to accomplish that, it's going to take too long with a SLR. So Gus, my student Gus and myself were alright we going to do this? And I say how about let's strap some GoPros to a stick right. GoPros are solving all the world's problems, creating some of them, but solving a lot of problems. Let's do it, let's just strap it to a stick and I'm not short selling what we did. We literally went to Bunnings got some [inaudible], some rivets, to be fair spent a fair amount of time figuring out how we're going to do it. But that's basically it. Then we put three expensive GoPros on this thing and we fly this thing. The GoPro's banging away every second in a lawn mower pattern and there's scale features down there so we can do this all scientifically and get real estimates. We're assessing how accurate and precise it is, but that's really the nut of it. We swim all around we get these images back and once again they may take a day or sometimes two to build. But then we get these models that cover again the size of this room or larger in ten minutes. That's how long it took us to get that data and we get the models might have 10 mm resolution. So you can pick up you know incredible detail from these things. Those are the basis for the communication, but they're also then selfishly as the scientist for me, boringly think of the matrix when it all reduces to numbers right. That's how I see the world. So suddenly all that beauty, strip it away who cares what colour it is, just substrate. And I want to know what about the structure? Why do I find more snapper on this reef than I did on that one? And over here there's a lot more of little lemon damsel fish than there are over there. What is it? Right, why are the sharks there and not there? Because there's these big over hangs that the sharks like to hang out under. So just like you, right animals as I said are there because their structure. Right so if I took your house away you probably wouldn't just sit there for ages, you'd leave right. Or possibly get killed depending on what neighbourhood you live in, but you'd leave. You wouldn't be there when I went back that's the point. But you also have your preference for the type of house you like. You might like open plan or you might like divided rooms. But animals are no different. Right, they like certain types of structure. So that whole part of the programme is all about you know pulling the matrix data out of these mesh -- out of these meshes and doing all kinds of you know crazy statistical analysis to relate these types of complexity features. You know different types of features I call them to the different types of organisms. And then from that we can do a couple things. Right, we can predict what's going to happen in the future as we lose complexity. We know a bit about which corals -- corals vary in their sensitivity to bleaching. Some of them bleach quickly, some of them are really hardy, some of them grow quickly, some of them grow slowly. So you can have some predictions about what's going to bleach first and you understand what their complexity is, you can understand what's going to be lost and then you can predict what that's going to do in this case the fish assemblages. So that's really powerful but probably the more powerful thing gets at you know really what probably brought everyone here, how are we going to save the reef with a 3D printer? That aspect is all about saying well ok if I understand really well, or maybe even not even really well, if I understand at least at some ball park level the types of features that I need, the types of corals that are important. Or even if it's not the actual coral just the shape of that coral that's important. Can I use that then to essentially supplement or remediate lost complexity due to whatever cyclone, ship grounding, bleaching right? You're not going to do it for the whole GBR, that's physically impractical. But you could certainly do it for certain areas. And so that leads us to, I brought some examples here. These are mock ups but the 3D printing right. So you can 3D print these things, now I'm -- if you were planning to ask me how that's done in the Q and A? You can just go ahead and keep that to yourself because I don't know. It's engineer stuff, its super fancy; I'll pretend I can't be bothered. So those are just a couple of examples. So these are not life size, these would be you know this one would be that tall. This one would similarly tall and round, about that big right. But these are both branching, more foliagy, a couple different species. They're not this colour naturally, that's just the plastic we use to print them on. These are examples of what you can do, these are models that we -- so these were photographs we took, 100 photographs pushed it through some software, scaled it, cleaned it, sent to some people who are super smart and this is what I got back right. So the idea is we can use this then as a template. Now we're not going to do it on plastic, the last thing we need in the ocean is more plastic obviously. It needs to be a bio -- bio compatible material. So this is very much where we're at now. We've got really good at mapping things. We got a good processing pipeline a team of really great enthusiastic people. We're working on the outreach; I'm doing this sort of stuff and it you know people really seem to be grooving on it and loving it. So the next stage is really trying to implement some of this work here on the habitat restoration. And so this sort of habitat restoration is happening everywhere right. We're doing it, I'm involved in some other projects in Sydney harbour where we're slapping things on sea walls because we had this beautiful rocky reef and then we put a seawall up and now all that habitat is gone that all those animals used to like. So we're trying to figure what can we do, still protect the opera house but give a bit more habitat. But that's -- that's the same idea, you're trying to restore some complexity. We're trying to do it in a very sort of ecologically realistic way with this 3D printing. But we need a bio-compatible material so I'm meeting literally next week with some guys from the reef design lab. Alex Goad who is an expert in this he's been doing some of the Great Barrier Reef work; he's working in other places in the -- in the tropical regions of the world trying to put in coral reefs. But he's you know he's the expert the wiz bang guy on 3D printing stuff. He can 3D print or he knows people who can 3D print in Sandstone. Sandstone's a really great settlement habitat, it's bio-compatible. Cement can work but it's always leaching Lyme out you kind of have to age the cement before you throw it in otherwise animals don't really like to settle on it because it's a bit toxic. So things like sandstone are good, you can literally print this this big in sandstone and then talk about how we're going to place it, what are we going to do. So that's kind of the phase we're at now right in terms of what I'm doing about it. So I guess I'll finish, I'll finish by saying you know what can you do about it? That may be something that's on your mind. I've told you all about my plight and some of the cool things we're doing and where I hope they can go and how I hope they can help. But I think the answers probably relatively obvious at least one of them and one of them is of course I've told you about the biggest problem is coral bleaching. And the driver of coral bleaching is increasing ocean temperature, and the driving of increasing ocean temperature is increasing CO2. Now the good news is we are -- we are bending over we're not on the you know business as usual trajectory from the intergovernmental panel on climate change right. They've got a business as usual which is the one where the sea level rises by 80 metres by 2,100 and the temperature rises by 4-5 degrees and we're all dead unless you run an air conditioning business on the hills then you're in -- you're looking pretty good. So we are starting to move off that trajectory so there's positive news despite the efforts of my current leader. I am an Australian citizen as well, which is what I'm holding onto dearly right now if you haven't picked up the accent. Well we are bending off of that trajectory so there's a bit of hope right. We're aiming for the Paris target maybe a degree and a half right. So what happens so far we've had about 3/4 of a degree warming in the tropical oceans and we kind of expect if we are on that target we are going to see another 3/4 of a degree. So have we lost some coral forever on the GBR? Probably, right some of the big corals, the massives in the north that take 200 years to grow. We keep getting bleaching every five or ten years they don't really stand a chance. But that's not to say there won't be any coral left. And so we still -- there's still time to act. So I guess my message is it really does start with us you know in our personal decisions and the pressure we put on things. So you know you're here already so I'm probably preaching to the converted but you have friends as I do who are good people who don't know about this stuff. And you can explain it. So that's one thing you can do. You can send them to our website or you know email me and see if we can bring them in the lab and put them in a reef if they can't go themselves and jump in. Maybe that'll help. So that's one thing. The other thing is kind of surprising though is the cool thing about photogrammetry to go back to the tech side, is anybody can do it. There are apps for your phone, you can you know -- I took some third year marine bio students we were doing a little photogrammetry project turned my back on them for like five minutes and came to the computer there was someone's head you know floating as a model. He just took his phone -- he just took his phone and went bang, bang, bang, bang, bang, bang, bang, bang, bang and the guy just held really still, pumped it through the software that I'd given them access to and there's this disembodied head floating around on the screen. So anybody can do it and I kind of have a vision along with some other colleagues of basically promoting that. Like increasing the area of our reefs that we've mapped and we understand so that we can target local initiatives you know as they're relevant. Once sort of complexity is lost what do you need in that situation? How can we help? Because anybody with a camera could get involved. You could collect the imagery yourself but the trick is that the putting it together in the software. We have the expertise there, but you know the dream is some sort of pipeline where everybody can sort of participate a citizens science initiative putting your data in, putting your pictures in, getting your model back with your name on it, you picture whatever. But you're contributing to a large effort. And for areas throughout the tropical Pacific right where they don't have the money to support this but badly want this sort technology we could support that. So that's kind of a dream where I hope this goes in the future, but it really is a you know anybody with a camera can get involved. So I guess I'll finish just by saying, look there's a lot of reasons to conserve coral reefs, to protect them, to do what we can to look after them in the face of some rather dyer news and insurmountable odds. I've given you all the ecological stuff right you know 1/4 of the fish are on those areas. So they're again unique -- unique habitats relative to a world full of unique habitats. Very important if you don't buy that they're important economically. Right we save our city's jobs things like that. For me of course those are important but you know I'm -- I was just talking with Will about this career being a career of passion right. You've got to go through a lot, you work a lot and you know the pay is not bad but it's not probably as other careers. And I tell my students that, it's a career of passion. And for me the you know the reward really and the motivation for a lot of this comes from chucking my six and seven year old in the water up in Queensland or in Hawaii or something and just hearing the squeals right out of the -- out of the snorkels right. First I look to make sure there wasn't something attaching them, but once I realised they were just thought the fish were really cool or oh look at that we'd found a nudibranch all that sort of stuff. You know you want your kids to be able to see their kids do that right? So there's that intergenerational equity right. Where we don't want to destroy something and that for me is very powerful motivation as well. So I hope that you have learnt a bit about reefs and some of the cool stuff that we're doing to save them and thank you very much for listening.

[ Applause ]

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