**Welcome to Just Have Another Think – our bi-weekly look at the ecological, environmental and social impacts of the climate emergency.**

**The increase in atmospheric warming from all the greenhouse gas emissions we humans have created since the beginning of the Industrial revolution would quite possibly have already wiped out our species and most other land-based animals, if it wasn’t for one major feature of our planet. The oceans.**

**Our oceans are very big indeed, I think we can all agree on that.**

**They cover seventy-one percent of the surface of earth at an average depth of about twelve thousand feet, or just under 4000 metres. And by the way, if you’re wondering where the deepest bit is, it’s a place, quite appropriately called Challenger Deep, at the southern end of the Mariana Trench in the Western Pacific. This abyss of water reaches a depth of thirty-six thousand, two hundred feet. That’s eleven kilometres, or nearly seven miles straight down.**

**The water in our world today is all the water that has ever existed and all the water that ever will exist on our planet, and ninety seven percent of it is currently held by our oceans.**

**According to this 2019 IPCC report, these vast bodies of water have absorbed about a third of all the Carbon Dioxide we’ve emitted since 1750 and more than ninety percent of the resulting extra heat in the overall earth system.**

**Water is actually very good at absorbing CO2, but the reactions that take place on an ocean-wide scale as a result of CO2 absorption are enough to give you a headache. So I took a couple of paracetamol about half an hour ago and now I’m ready to dive in, if you’ll forgive the pun.**

**1:46 Here’s what happens as Carbon Dioxide is dissolved in water.**

**1:51 CO2 plus H2O becomes 1:53 H2CO3, which is carbonic acid. That’s fairly basic chemistry that I vaguely remember from school and if you stick one of these pH probes in a glass of sparkling water you do indeed get a pH value on the acidic side of neutral.**

**2:08 But in our oceans, that’s just the beginning of the process.**

**2:13 Carbonic acid molecules can release one of their hydrogen ions 2:16 to make a bicarbonate 2:19**

**H2CO3 goes to HCO -1 3**

**Then, the bicarbonate can then release another 2:22 hydrogen ion to become a simple carbonate. 2:25**

**HCO -1 3 goes to CO3 -2 H+ H+**

**At normal temperature and alkalinity levels, carbonates can combine with 2:29 calcium that’s leeched out from 2:31 rocks, organisms and soils, and been transferred via rivers into our oceans. 2:36 Calcium and carbon, unsurprisingly, make 2:39 Calcium Carbonate. And that’s what forms the 2:42 shells of shellfish and the vast 2:44 skeletal structures that coral polyps 2:46 grow on.**

**About a century ago 2:48 the surface of our oceans had an average pH value of about 2:52 eight point two five which, as this chart shows, is clearly on the alkaline side of neutral.**

**2:57 The ocean surface today has an average pH 3:00 of about 8.14, 3:01 which on the face of it, really doesn’t sound all that different does it?**

**3:04 But the pH scale is logarithmic, 3:07 which is scientific jargon that means that on this scale, two is no longer one more than one 3:11 – it’s ten times more than one. 3:13 And three is ten times more than two and a hundred times more than one, and 3:17 so on and so on. 3:19**

**So, a reduction from 8.25 to 8.14 on the pH scale 3:24 actually represents a 3:25 30% decrease in alkalinity. 3:28**

**But pH 8.14 is still alkaline. So, what’s the problem?**

**Well according to our scientists that move towards acidity is a significant shift, because the reaction of CO2 and water is reversible, and that reversibility depends entirely on temperature and alkalinity.**

**3:46 As CO2 concentrations increase and 3:49 more and more of the free hydrogen ions become available, 3:51 the simple carbonates that were previously happy to hook up with 3:55 calcium to make shells and coral skeletons, 3:57 now tend to favour combining back up 4:00 with the more abundant hydrogen ions 4:03 to go back to being bicarbonates. 4:05 That’s just the way nature is – it takes the course of least resistance. 4:08:18**

**To show how this complicated mechanism works, the science bods created a fancy graph that they call a 4:14 Bjerrum plot.**

**4:16 The vertical axis shows another logarithmic scale. This one is of concentrations of Carbonic acid, Bicarbonate and Simple Carbonate. 4:24**

**4:25 The horizontal axis shows the pH values ranging from very acidic 4:28 over here to very alkaline 4:30 over here. 4:31**

**So, when the water is very acidic, you get mostly carbonic acid, 4:35 with just a little bit of bicarbonate going 4:37 on down here.**

**When the water reaches pH neutral, 4:40 the bicarbonate combo becomes the dominant reaction. 4:44**

**Then as the water moves into alkaline territory 4:47, the simple carbonate end of the reaction becomes the most prevalent. 4:51 It’s in this alkalinity ‘Goldilocks’ zone 4:54 that Calcium Carbonate structures in our oceans can be created, which is good news for shells and corals and all of that.**

**If we draw a 5:03 vertical line down at pH levels from around a hundred years ago 5:06 and another one at today’s 5:09 pH level you can 5:10 start to see the direction of travel as more and more CO2 gets dissolved into the oceans. 5:15 Simple carbonate levels go down and bicarbonate levels go up. 5:20 That means less carbonate available to combine with calcium to make calcium carbonate, which in turn means that shellfish and corals are less able to grow or repair themselves. 5:31**

**What isn’t known with any certainty is just how much more CO2 is going to be emitted in the coming decades as a result of human activity.**

**But if we continue our current way of life, then according to the IPCC we can expect a further lowering of average pH values of about 0.3 to 0.4 by 2100. That’ll drop the average pH level of our oceans down to about 7.8 which is very likely indeed to have a hugely negative impact on the overall ecosystem.**

**5:58 A 2014 study by the Royal Society carried out a survey of phytoplankton called pteropods 6:04 in the waters along the Washington–Oregon–California 6:06 coast in August 2011. Even a decade ago, researchers found that 6:10 fifty three percent of onshore pteropods 6:13 and 24% of offshore pteropods had what they called “severe dissolution damage”. 6:18**

**The Royal Society study estimated that the incidence of severe pteropod shell dissolution 6:24 owing to anthropogenic Ocean Acidification has doubled in near shore habitats 6:29 since pre-industrial conditions across this region, and is on track to triple by 2050. 6:36**

**Onshore, 53% of pteropod individuals on average were affected by severe shell dissolution in August 2011; more than double the proportion calculated for the pre-industrial era. Our model suggests that the projected increase in anthropogenic CO2 uptake by 2050 may result in 70% of individuals being affected by severe shell dissolution, or about a tripling of severe damage relative to the pre-industrial era throughout most of the coastal region.**

**Now, like most things that go on in our atmosphere and ocean, there are other variables that may be influencing the process.**

**For example, some argue that as the waters get warmer, then the metabolisms of organisms like phytoplankton get faster. And that means they take up more Carbon dioxide as they grow more quickly, which would potentially be a good thing.**

**6:57 But other studies, 6:58 like this one from the American Geophysical Union, 7:01 suggest that the nutrients the phytoplankton need to grow 7:05 are supplied from deeper waters 7:07 and that as the oceans get warmer, 7:09 there’s more temperature separation between the different depths 7:13 and so there’s less mixing of the layers that make these nutrients available. 7:18 That could actually be causing phytoplankton CO2 uptake and 7:22 growth to decrease, which leaves more CO2 available to be dissolved into the water. 7:28**

**All that extra heat energy in the oceans doesn’t just contribute to this relentless carbon and calcium cycle either. It has it’s own set of direct consequences too. The IPCC say that marine heat waves are very likely to have doubled in frequency since 1982 and are also increasing in intensity as a result of the extra energy available.**

**A marine heatwave is defined as occurring when the daily sea surface temperature exceeds the local 99th percentile of temperatures over the period between 1982 and 2016.**

**Around 90 percent of all marine heat waves that occurred between 2006 and 2015 have been attributed to the absorption of heat from the atmosphere caused by our greenhouse gas emissions.**

**These events present all sorts of problems. They certainly have the potential to cause catastrophic bleaching of coral reefs. 8:05 In fact, according to this IPCC chart, 8:09 the risk to coral reefs is very high as temperatures continue to rise But the impacts are also being seen in 8:14 kelp forests and seagrass meadows and to a certain 8:17 extent in mangrove forests too.8:19**

**Seagrass meadows cover about nought point two percent of the ocean floor but they capture ten percent of the so-called Blue Carbon that gets dissolved into the ocean each year – and they can store that carbon for thousands of years. This 2020 paper published at nature.com found that the kelp forests on the Australian coastline were storing 30% of all blue carbon around Australia and three percent of the global total. If we get above 2 degrees Celsius of warming, which looks more and more likely as every day goes by, both these resources are in trouble. And if we stray towards three degrees of warming then we’re severely jeopardising coastal mangrove forests, which right now hold more carbon per unit area than all the land-based forests on the planet.**

**It doesn’t end there though. Ocean warming is fundamentally altering the habitats of all the marine life. Since 1950, a large number of fish species that live in the top two hundred metres of the sea have been migrating from the warming equatorial regions towards the poles at a rate of between fifteen and thirty kilometres every year, which over the course of seventy years has in some cases resulted in a displacement of more than two thousand kilometres. Great if you live in Greenland but not so good for the millions of people in equatorial regions who rely on those species for their food and livelihood.**

**And as the oceans get warmer, the volume of the water increases, because that’s what water does when you heat it up. Around six hundred and eighty million of the world’s most vulnerable people live in low-lying coastal zones - a number that's predicted to reach more than a billion by 2050. Another sixty-five million are indigenous to small island developing states. And if that all feels a long way away, then remember that half the world's mega cities are situated on coasts or alongside inland river estuaries, taking the total at risk from rising sea levels to two billion.**

**We’re already seeing the damage that hurricanes, cyclones and storm surges are causing in many parts of the world. Once we get past 2 degrees of warming then century level events will become decadal events, and in some cases even more regular than that, costing our economies several trillion dollars every single year in damage reparation and resulting in a level of emergency human migration that’ll dwarf the numbers of refugees from recent conflicts in the middle east.**

**10:48 This map based on real world IPCC data shows the areas of the world already experiencing 10:53 hundred-year events every year – they’re the ones with the black circle. 10:57 The purple, orange and yellow circles 11:00 are areas where these events will become annual 11:03 during the middle and second half of this century if we stay on our current trajectory. 11:07**

**If you’ve tried getting property insurance on the US eastern seaboard or in some of those Australian or Japanese coastal areas, you’ll no doubt already be very well aware that the financial institutions have factored these events into their business models and are bracing themselves for the worst.**

**And that’s why so many of our climate scientists and environmental groups are suggesting that the question our governments should be asking is not whether we can afford to put in place multi-trillion dollar green recovery plans, but whether we can afford not to.**

**So that’s your mid-week food for thought for this week folks. I’ll be back with a new episode of Just Have Another Think in two weeks’ time, and I’ll see you for our regular Just Have a Think program this Sunday.**

**Bye for now.**