Student questions: Adina Paytan colloquium on "Corals on Acid - The Impact of Ocean Acidification on Corals and Coral Reefs"

2/24/21

Question 1: How do oceanographers acquire or have the Ocean pH data in the past years before the pH scale was introduced? Since the pH scale was introduced around 1909.
This can be done using models and calculations instead of direct measurements. It is possible to calculate the pH in the surface ocean if you have information on the content of CO_2 in the atmosphere and the temperature of the surface ocean. Atmospheric CO_2 data is available from gas trapped in ice cores for example and with data on temperatures of seawater it is easy to calculate the concentration of CO_2 that would dissolve in seawater (Henry's Law of gas solubility) and from that calculate the pH of the ocean.
Question 2: The equation shared in the presentation of CO2 reacting with H2O seems to produce more carbonate. Could you share how ocean acidification could decrease the amount of carbonate or carbonate ions in ocean?
The equations shows that more carbon indeed enters the ocean, but the carbon is in the form of bi-carbonate and not carbonate ions because at lower pH the carbonate ions react with protons to form more bi-carbonate.

Question 1: Is there any danger in hybridized corals to the environment, especially animals that live in reefs?
There should not be any danger. This procedure is done routinely on many of our foods most fruits and vegetables we eat have been "manipulated" over the years to produce sweeter, larger, tastier food without danger. Having said that if the hybridized corals are more resilient, they could become more dominant and successful.
Question 2: Is there a danger in breeding better corals in terms of producing better diseases/viruses that could kill off non-enhanced populations of coral?
Breeding corals to survive at low pH would not create diseases or viruses but the more fit corals would potentially outcompete other corals that are less adapted.

Question 1: How can there be pH measurements of the ocean from the year 1700?
The pH in 1700 is not measured it is calculated using models. It is possible to calculate the pH in the surface ocean if you have information on the content of CO_2 in the atmosphere and the temperature of the surface ocean. Atmospheric CO_2 data is available from gas trapped in ice cores for example and with data on temperatures of seawater it is easy to calculate the concentration of CO_2 that would dissolve in seawater (Henry's Law of gas solubility) and from that calculate the pH of the ocean.
Question 2: In what locations throughout the world are the current ocean pH measurements taken, and is there a significant variation in the measurements depending on where they were taken?
At present pH data is collected at many places in the ocean and while the pH is decreasing throughout the ocean the actual pH values differ from location to location based on the water temperature as well and other processes such as photosynthesis (which increases pH) and respiration (which decreases pH) as well as ocean circulation (upwelling of deep low pH water to the surface). Here is a link to data sources of ocean pH
https://oceanacidification.noaa.gov/WhatWeDo/Data.aspx
https://www.nodc.noaa.gov/oads/stewardship/data_assets.html

Question 1: Have we passed a "point of no return" for ocean acidification in regards to what currently constitutes a "healthy coral reef" is?
At present coral are impacted by many stressors and it seems that ocean warming is impacting coral more severely than ocean acidification. However, at some locations, ocean acidification has affected corals. It is likely that the corals species that are more sensitive would be more impacted than other corals, but I still have hope that it is not a "point of no return".
Question 2: Which of the acclimation mechanisms is likely to be most dominant / have any of them been observed to be highly successful in live specimen?
Corals that have multiple ways to obtain energetic resources (efficient metabolism) and can use the energy for compensating for the low pH conditions (do not have to spend energy combating other stressors) are more likely to acclimate better to ocean acidification.

Question 1: Ice core measurements were mentioned about calculating pH of the ocean in the past, is this something that can be consistently done for every year in history?
We have ice core records of atmospheric CO_2 that go back 700,000 years. For older times we can use other indicators (called proxies) like the density of leaf stomata or the ratio of boron isotopes that are sensitive to pH in the ocean and try to reconstruct the pH of the ocean but as we go back in time the calculations are less precise.
Question 2: Are there any ways that the coral can or have been helped?
Corals can be transplanted so they can grow at sites where they died this coral "gardening" is useful. There is ongoing research on coral hybridization see -
https://www.coris.noaa.gov/activities/CCAP_design/

Question 1: Are there any technologies under consideration to facilitate an increase in carbonation of undersaturated regions?
There are some scientists and engineers that are trying to suggest ways to combat this such as accelerating weathering processes to increase bicarbonate ions in the ocean, and thus prevent climate change and potentially ameliorate ocean acidification but it is not easy. You can read more about this here https://eos.org/editors-vox/preventing-climate-change-by-increasing-ocean-alkalinity
Question 2: Can reduced coral density be offset by an increase in abundance of coral populations, for example, by artificially breeding and seeding?
When I talked about density in the lecture, I was referring to the density of the carbonate making the coral skeleton. It would be good to increase the abundance by transplanting corals, but this will not make their skeleton stronger.

Question 1: What instruments are used to measure the dissolved CO_2 in oceans?
Typically you measure pH and TAlk (Total Alkalinity) to computed DIC (Dissolved inorganic carbon) and then pCO2 (partial pressure of CO2). This indirect method can be easily used in any field sampling condition and it is far less expensive and easier to set up than the direct one (using the IR analyzers). TAlk is measured by Gran electro titration. pH is measured with a combined electrode.
Question 2: Based on your research, which method of technologically preserving corals do you think is the most effective?
I think it is first and foremost important to reduce our C footprint. Next, we should design conservation areas to reduce the local negative impacts on corals. Then transplanting and hybridization can be used.

Question 1: What are the most affected populations of marine mammals by the effects of ocean acidification (during the presentation something related was mentioned about cetaceous in the introduction, background information)?
The most devastating impacts of rising ocean acidity on marine mammals is likely to be the collapse of food webs and food resources they depend on.
Question 2: What are the most relevant factors that contribute to the high decrease in CO3 (-2) concentrated in the Atlantic Ocean than other regions around the globe (there was a figure indicating a decrease up to 40% during the presentation)?
There are two parts to this:
The first part is pure carbonate chemistry: the pH really is mainly a function of two quantities, dissolved inorganic carbon (DIC) and Alkalinity (Alk). With rising DIC, at constant Alk, pH decreases, and with rising Alk at constant DIC, pH increases. The deep Pacific has a higher DIC, compared to the deep North Atlantic, hence its pH is lower; the tendency is somewhat moderated by the fact that Alk is also higher in the North Pacific, compared to the Atlantic, but not as much as DIC.
The second part is: Why is DIC higher in the deep Pacific than in the deep Atlantic? This has to do with the pattern of the deep ocean circulation, the overturning: Deep water is mainly formed (i.e. it had its last surface contact with the atmosphere) in the North Atlantic (North Atlantic Deep Water, NADW) and around Antarctica (Antarctic Bottom Water, AABW). From there it spreads slowly through the world's oceans in a somewhat complicated patter. The upshot is that water in the deep North Pacific is the 'oldest' water in the sense that is has been away from the

surface longest. And on its long travel towards the North Pacific, there has been a constant rain of organic particles into that water, which has been remineralised by bacteria and animals, releasing CO_2, i.e increasing DIC (and also nitrate, phosphate and silicate), and reducing O_2. In the Atlantic, the water simply hasn't had enough time to accumulate the breakdown products of the constant rain of organic particles.

Question 1: Are there estimates for the amounts of (fresh?) water discharging from the individual ojos?

Yes – This can be done my measuring certain compounds that are enriched in groundwater and not in seawater such as Ra. You can read more about it in this paper (pdf on my web page)

Kimberly A. Null, Karen L. Knee, Elizabeth D. Crook, Nicholas R. de Sieyes, Mario Rebolledo-Vieyra, Laura Hernández-Terrones and **A. Paytan** (2014). Composition and fluxes of submarine groundwater along the Caribbean coast of the Yucatan Peninsula. Continental Shelf Research 77 (2014) 38–50. http://dx.doi.org/10.1016/j.csr.2014.01.011

Question 2: How do symbionts help the coral survive?

Symbionts fix carbon through photosynthesis and hence can allocate organic matter (food) to the coral providing them energy.

Question 1: How does methane gas in the atmosphere affect the ocean?

Methane is a greenhouse gas, and it contributes to global warming increasing the temperature of both the air and the surface ocean.

Question 2: Are coral reefs going to be able to come back eventually, even if its not in our lifetime?

I sure hope so. Based on the geological record they may indeed be able to survive or at least some of them.

Question 1: When doing studies in the field, how do you tell the difference between changes seen in corals from temperature versus acidification?

This is a good question – when you do work at many sites some are impacted only by ocidification and others mostly by temperature so you can compare. Also you can do controled laboratory experiments in addition where you change only one variable at a time or both.

Question 2: Before your talk, I was not aware that the bleaching of coral reefs and their symbionts was from temperature and not acidification. Can you tell us a little bit more about what we have learned about corals' relationship with their symbionts from the different effects of acidification and temperature?

When the temperature increases coral expel their symbionts – this is called bleaching and is a result of temperature and not pH changes. The corals can sometimes get the symbionts to return but not always. Here is a nice link explaining this bleaching effect.

https://oceanservice.noaa.gov/facts/coral_bleach.html

Question 1: Are there any other gasses other than carbon dioxide that responsible for the acidification of the ocean?
It is the CO_2 because there is some much of it that is emitted into the atmosphere compared to other anthropogenic gases and mostly because of the reaction of CO_2 with water and the dissociation of carbonic acid in seawater to release protons.
Question 2: Does the acidification of the ocean had any impact on the reproducibility of the corals?
I assume you are asking about the reproduction of corals – Indeed some studies show that ocean acidification has the potential to reduce fertilization success by 12-13% and to decrease settlement success by 45–69% at pCO_2 concentrations expected in the future for the Caribbean elkhorn coral, *Acropora palmata*. This could be different for different corals.

Question 1: Which organism/species, if any would benefit from the decrease in calcium carbonate in the ocean?
Some organisms will benefit indirectly because if there are fewer calcifying organisms, they will face less competition. But most organisms that need CO_2 for photosynthesis may benefit from increase in CO_2 (not the decrease in carbonate).
Question 2: How will the trend in calcification decrease affect current marine environment sedimentary rocks and future sedimentary rocks that are composed of calcium carbonate such as limestone and dolostone?
The low pH conditions will result in lower accumulation of carbonates so likely the geological sections of the Anthropocene will have lower chalk and limestone sequences.

Question 1: If we were to stop CO2 emissions immediately would the pH of the ocean continue to decrease?
Yes at least for a while until the current levels of CO_2 equilibrate with the ocean.
Question 2: What are the short-term implications of ocean acidification?
There are direct impacts on aquaculture like oyster farms see this link
https://www.pmel.noaa.gov/co2/story/Acidifying+Water+Takes+Toll+On+Northwest+Shellfish

---

Question 1: Would it be better if the pH plumes would disperse outwards instead of staying in a column?
I am not sure what exactly you are asking but in general the more the water with low pH mixes and gets diluted the better it is.
Question 2: You said that the pH level was trending downwards; is it a linear decrease, or does it take jumps from time to time?
It seems to be directly related to the changes in atmospheric CO_2 but the record is not long enough to know if it has jumps.

Question 1: Humans haven't handled the gradual increase in toxicity in our environment, so what would make corals more likely to evolve faster to live in a more acidic ocean?
Hopefully since these organisms have been around for ~450 million years of Earth history they have genetic mechanisms to deal with such conditions.
Question 2: Could we see a die off of some species of coral that aren't capable of handling ocean acidification, and a resulting major loss of biodiversity? What would this blow to biodiversity do in the long run to coral reefs?
Indeed, this is exactly what might happen that the more sensitive corals will become less abundant and other corals or organisms like sea grasses will take their place. Depending on what the final makeup of the reef system will be this could have implications to other organisms that inhabit the reef complex.

Question 1: Will the acidification of the ocean affect organisms in the ocean that help produce most of the Earth's oxygen? How?
Acidification directly or indirectly (via competition) will impact all marine organisms but the phytoplankton (that produce oxygen) except for those calcifying are less likely to be negatively impacted.
Question 2: Could the acidification of the ocean have an effect on the way in which submarine eruptions flow? Additionally, could it have any effect on the composition of the flows?
I do not think that ocean acidification is likely to have any effects on volcanic eruptions in the ocean or their flow.

Question 1: Where do p. porites normally live?
In the area of this research, they lived in the front reef are and not near the submarine springs.
Question 2: Why were there less carbonates when the coral grew?
The submarine springs have low pH and because the distribution of carbonate and bicarbonate is pH dependent with less carbonate at low pH the corals that grew near these springs had less carbonate ion available.

Question 1: Brilliant costumes! I'm an avid diver myself and would love to study karst systems one day. Will ocean acidity effect systems near karst formations or the reefs around them?
Yes, diving is the best. The reefs near the karst systems will likely be impacted but I do not think the karst formation themselves will be impacted in a significant way.
Question 2: The Red Sea seems to be heather relative to other reef systems. Is this temperature dependent? I must of missed this and will have to the listen to your presentation again.
The Red Sea has on average higher temperatures than other coral areas so the corals there are acclimated to high temperatures better and hence less impacted by the increase in temperatures.

Question 1: Is CO2 on the surface ocean more detrimental to ocean systems than if it was in deeper parts?
Yes, because there is naturally more CO_2 at depth so the organisms there are used to lower pH conditions while surface organisms are less so.
Question 2: Would "Naked" polyps that survived ocean acidification be able to survive on their own in a regular ocean environment, without their protective exterior?
We do not know. Sea anemones survive but they have “stingers”. It really depends if these “naked” corals will be more preyed upon or more susceptible to diseases.

Question 1: How long would it take for the manipulation experiments to help out coral reefs permanently?
Good questions, I do not think anyone really knows but likely decades.
Question 2: Is there anything we can do at this point to reverse the damage done to the reefs or have we passed the point of no return?
We can still do a lot. First reduce our carbon emissions so we do not add more CO_2 and reduce the pH further. Second protect the coral reefs from other stressors like overfishing, pollution, or sedimentation so they can “focus” on fighting the acidification.

Question 1: What other environmental stressors, besides warming and acidification of the ocean, can be reduced by changes in human activity?
Overfishing, pollution, sedimentation – setting up marine protection areas.
Question 2: How feasible is the implantation of genetically modified coral species into reefs and is it possible that assisted evolution will do more harm than good?
This is at its infancy and we really do not know if it would be successful so there are many other things to do in the meantime 😊 Having said that humankind has been doing such assisted evolution on land for thousands of years. Most of our fruits and vegetables, our dogs and cats and other pets are not those found in nature they have all been manipulated for our needs.

Question 1: What is your major goal in trying to understand the acidification of the ocean? Where is your goal in this?
The ultimate goal is to ensure that we do not damage the ecosystems since we depend on them. If we know which organisms are likely to be impacted, we can try to protect them.
Question 2: What would you suggest be the first step of preserving our oceans and subduing the acidification?
Reducing our carbon footprint and reducing pollution as well as setting marine protected areas.