NATIONAL CENTER FOR CASE STUDY TEACHING IN SCIENCE

An Investigation into Ocean Acidification

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Part I – Ocean Acidification 101

Brandy and Ashley were on a plane heading to Miami for a vacation. They were working their way through a stack of magazines they had bought at the newsstand in the airport.

Ashley: Hey Brandy, did you see this article about the ocean?

Brandy: Yes, but I didn't understand a lot of what they were talking about. Do you understand it?

Ashley: Sure, I can try to point out a few things. Here, take another look and we can search for information to fill in what we don't know.

Read the article: "Oceans Turn More Acidic Than Last 800,000 Years" by L. Morello from *Scientific American* (2010). <http://www.scientificamerican.com/article/acidic-oceans/>

Brandy: I guess my first question after reading the article is, what's actually in ocean water? I assumed ocean water was just made of salt, like what we use in food.

Question 1: What are the major ions and gases found in ocean water?

Brandy: That's a lot more than salt!

Ashley: There are some things added by human activity that can affect it too.

Question 2: Give examples of different natural events and man-made activities that can affect ocean chemistry.

Brandy: Well there are other things in the water, but what's the big deal? How exactly is the ocean changing?

Question 3: Referring to Figure 1 (see next page), what kind of reactions are happening that affect ocean chemistry? (*Hint:* the ions found in the ocean combine in different forms to create biologically active compounds, such as HCO_3^-.)

Ashley: So you see, there is quite a bit going on in the ocean. If you look at the reaction it is easy to see that CO_2 is affecting ocean chemistry.

Brandy: Yes, I can see that happening, but why is that changing the acid level of the ocean?

Question 4: Describe ocean acidification in your own words (you can refer to Figure 2).

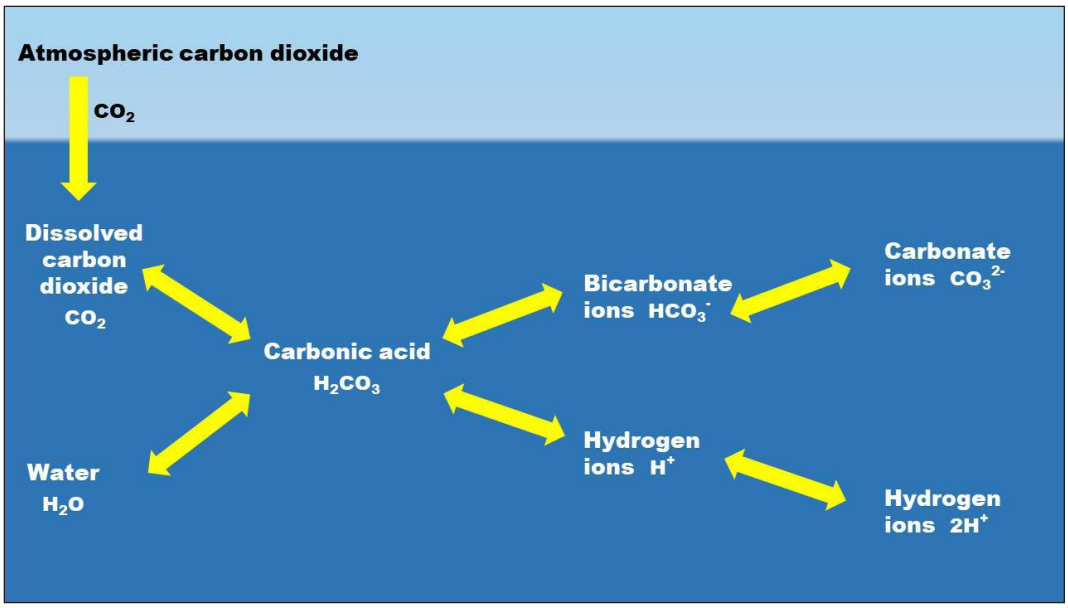

Figure 1. Basic ocean chemistry.

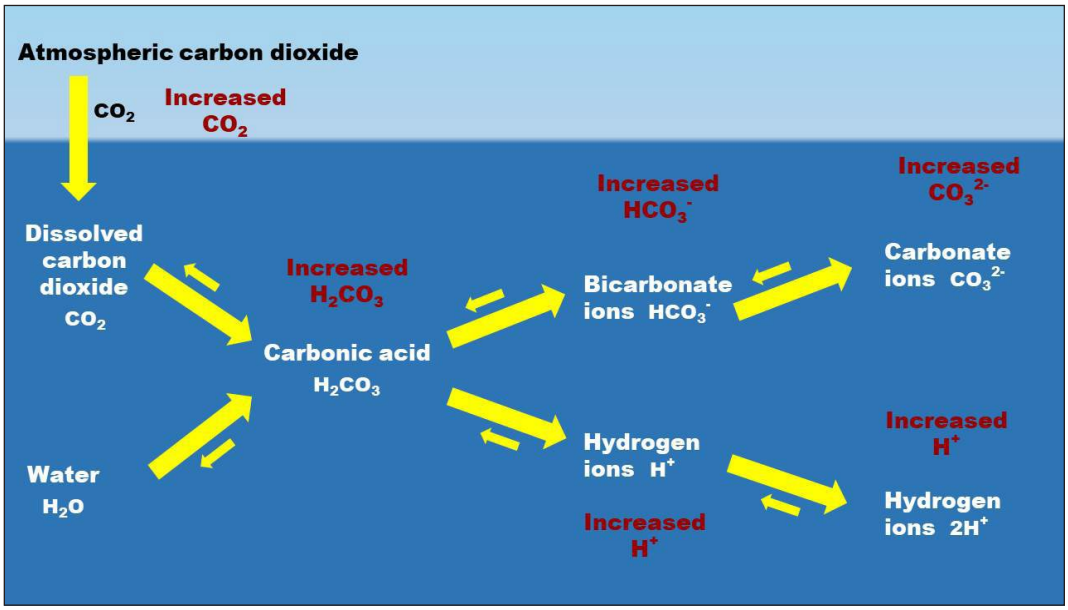

Figure 2. Ocean chemistry with increased CO_2 emission.

Brandy: What does this really mean? I have a basic understanding of pH; I know orange juice is acidic and water is neutral.

Question 5: On the pH scale, what is considered acidic, basic, and neutral? What is the pH of freshwater and saltwater? What are some examples of items that are acidic?

Part II – How Do Humans Affect Ocean Acidification?

Ashley: So Brandy, does that help?

Brandy: Well I think it's becoming clearer, and I do agree with you. We need to figure out where the CO_2 is coming from.

Question 1: How are ocean acidification and carbon dioxide linked?

Question 2: What are the most common causes of greenhouse gases attributing to ocean acidification? (Refer to Figure 3.)

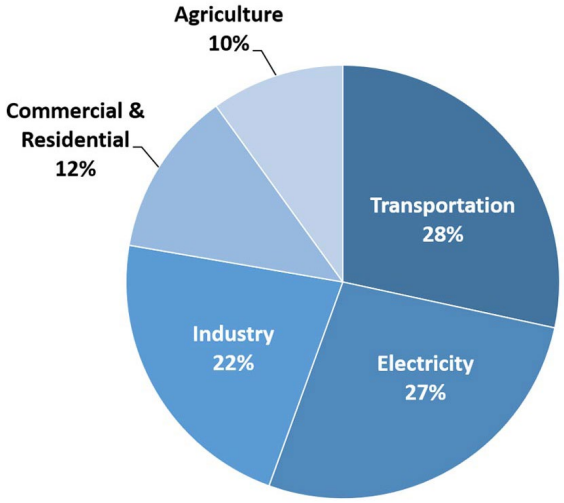

Figure 3. Total U.S. greenhouse gas emissions by economic sector in 2018. *Source:* U.S. EPA <https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions>.

Brandy: Wow! I didn't know that all of those things we do contributed to greenhouse gas emissions!

Ashely: It looks like the atmospheric changes are coming from more CO_2, which leads to global warming and ocean acidification. I wonder when all this got started?

Brandy: I remember having seen some timelines about this. Let me find them again.

Question 3: Look at Figure 4 (see next page) and circle the most appropriate answer for the following questions:

(a) How would you describe CO_2 emissions from 1750–1825? no change small increase large increase

(b) How would you describe CO_2 emissions from 1850–1900? no change small increase large increase

(c) How would you describe CO_2 emissions from 1950–2000? no change small increase large increase

Question 4: Fill in the correct answers in the paragraph below after examining Figure 5 (next page).

In the 1900s the primary contributor to global emissions was _____. This trend continued and by 1920 another major contributor emerged, _____. Emissions from _____ became the third contributor after the 1950s. After 1950 the total amount of carbon dioxide emissions began to _____ more rapidly. By 1970 the top contributor was clearly _____ with _____ as the second major source. _____ has steadily increased from 1940 to 2013. In contrast, there has been a sharp increase in the contributor, _____, since 2000.

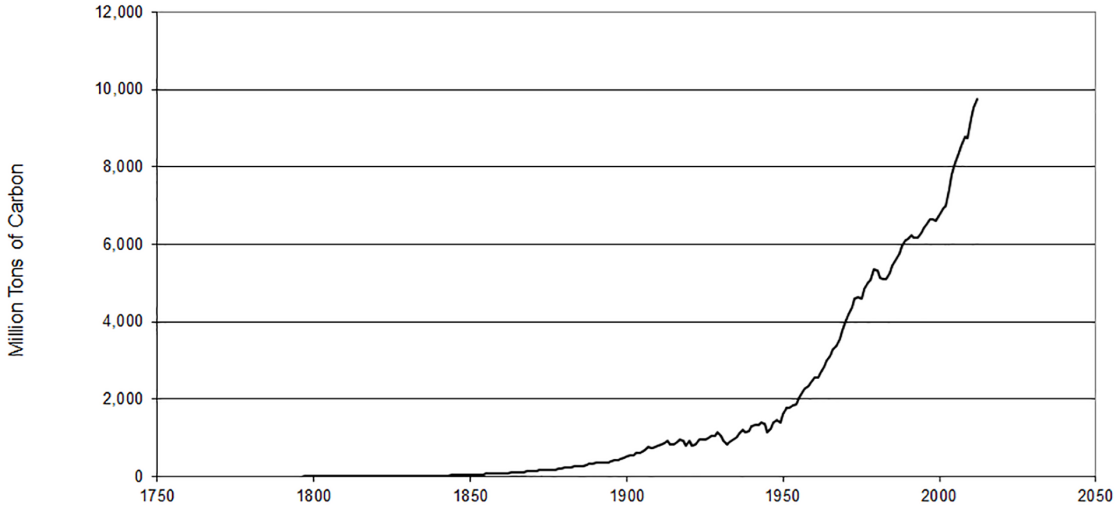

Figure 4. Global carbon dioxide emissions from fossil fuel burning, 1751–2012. Data from Earth Policy Institute, <http://www.earth-policy.org/data_center/C23>.

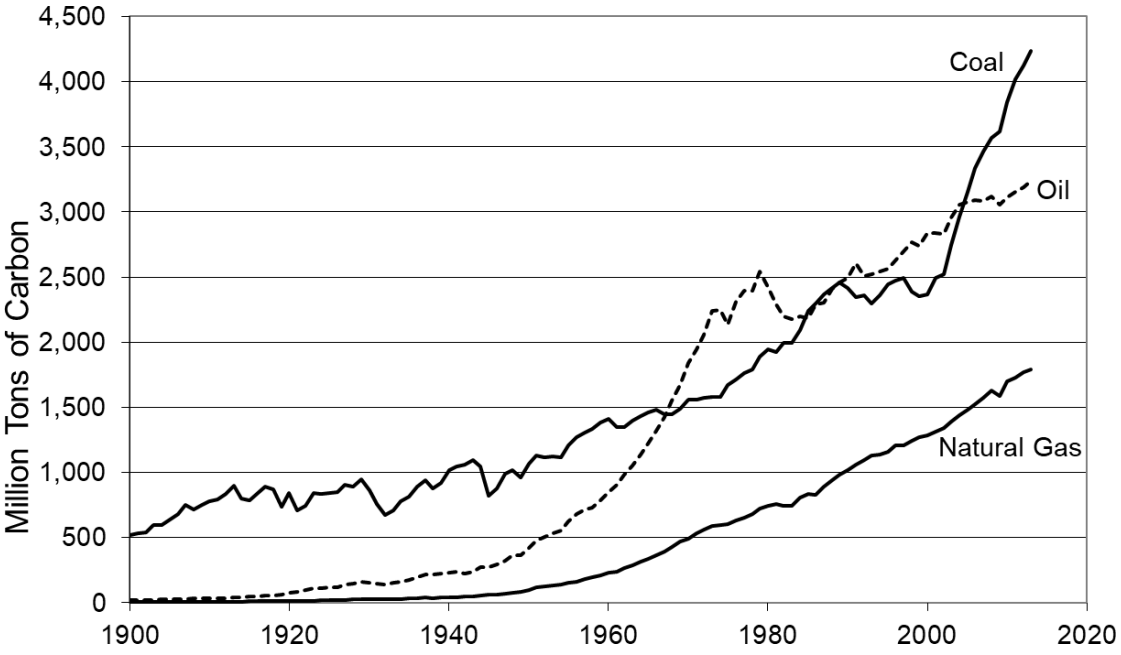

Figure 5. Global carbon dioxide emissions from fossil fuel burningby fuel type, 1900–2013. Data from Earth Policy Institute, <http://www.earth-policy.org/data_center/C23>.

Question 5: Can you connect the changes seen in the 18th and 19th centuries to another historical event? Explain your answer. (*Note:* additional research may be needed.)

Question 6: What is the Keeling curve? (*Note:* refer to Scripps Keeling Curve website.) How is it relevant for tracking CO_2 emissions, and how long have emissions been recognized as an issue?

Ashley: Take a look at this timeline; it not only shows a historical view, but it also includes pH, which we were talking about earlier.

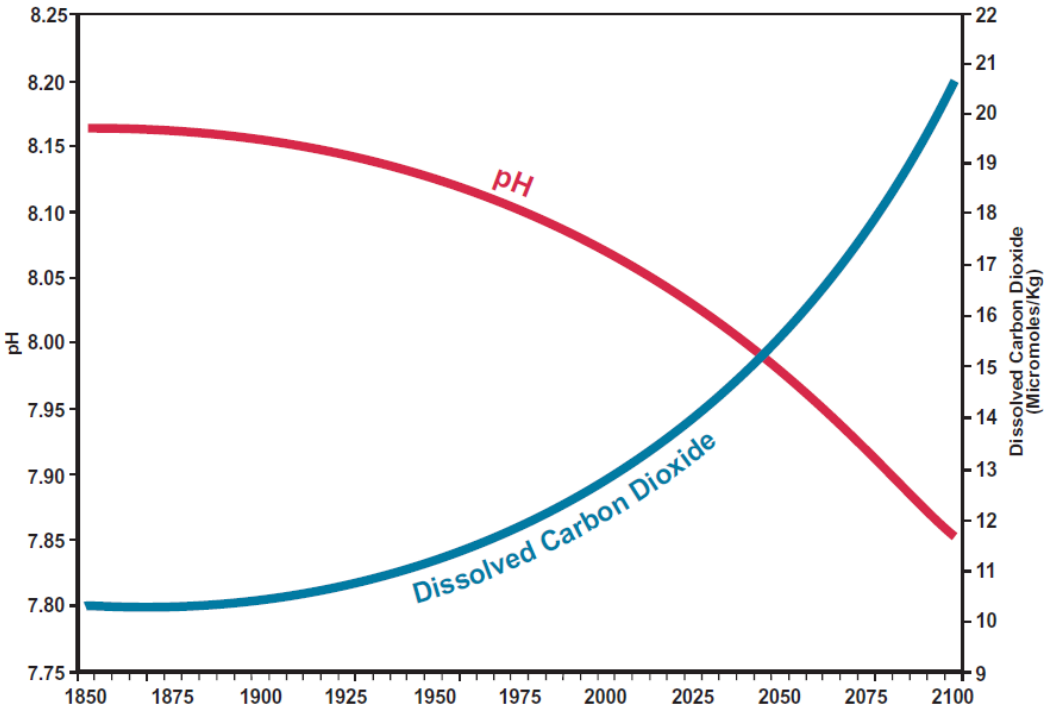

Figure 6. Historical and projected pH and dissolved CO_2. Note that the scale on the left is pH, the right scale shows dissolved carbon dioxide, and each mark on the date axis represents five years. *Credit:* Feely, R.A., C.L. Sabine, and V.J. Fabry. 2006. Carbon dioxide and our ocean legacy. National Environmental Trust, Washington, D.C. <https://www.pmel.noaa.gov/pubs/PDF/feel2899/feel2899.pdf>

Question 7: Use Figure 6 to complete the following table.

Year	*1875*	*1925*	*1975*	*2000*	*2025*	*2050*	*2075*
pH value							
CO_2							

Question 8: Describe the relationship between the values by circling the correct word.

(a) What has been happening to pH values since 1850? increase decrease

(b) What has been happening to the amount of dissolved CO_2? increase decrease

Question 9: Complete the paragraph to help explain how pH has changed over time.

The pH level of the ocean has _____over time. Since atmospheric _____ is _____, the amount of CO_2 that the water takes in _____ as well. When there is more CO_2 in ocean water, this changes ocean chemistry. The ending chemical reaction in the ocean results in an increase in _____ ions, which will result in a pH decrease, thus causing the ocean to become more _____.

Question 10: If humans continue to emit CO_2 at the amount we do right now, what does that mean for the future?

Brandy: Wow, I don't know about you, but I'm completely in shock about all of this! Ocean acidification has been happening for a long time. I wonder how we change it?

Ashley: I agree, but how can we help since billions of people contribute to this problem?

Brandy: Well, from I've read online, every human leaves a carbon footprint. This means that depending on what we do and for how long we do something, it all adds up and is included in the overall CO_2 emission of humans. We just have to figure out how to lower it.

Question 11: What are some things that you can do to decrease your carbon footprint and help decrease the overall emission of CO_2?

Part III – Ocean Acidification and Marine Snails

Brandy and Ashley finally landed at the airport in Miami and headed to their hotel. They were starting to feel hungry and decided to eat at a seafood buffet. They had the following discussion while waiting in line.

Brandy: Hey, you know what I was thinking? If we're a big reason why the ocean is changing, do you think that we're also harming the animals in it?

Ashley: I didn't even think about that possibility. Let me see what I can find on marine animals and ocean acidification. Give me a minute while I check online... . Oh look, Brandy! There's something called a sea butterfly and it can really be affected when the water is more acidic than it should be.

Read the article: "Acidification Eating Away at Tiny Sea Snails" by Craig Welch, *The Seattle Times*, April 30, 2014. <http://apps.seattletimes.com/reports/sea-change/2014/apr/30/pteropod-shells-dissolving/>

Question 1: Why is this marine snail called a sea butterfly? (*Hint:* search online for an answer.)

Question 2: Contrast a healthy pteropod shell with a shell damaged by ocean acidification. (*Hint:* refer to the diagram in the article.)

Question 3: Identify two ways damaged shells can affect the biology of a pteropod.

Question 4: What would likely happen if the sea butterfly population were to decrease dramatically?

Question 5: What are the broader impacts of increased ocean acidification on marine organisms, the ocean ecosystem, and humans?

Brandy: This is much bigger than we thought; a lot of marine animals are being affected.

Ashley: Yes, and if we don't change our ways, soon fishermen won't be able to catch larger animals.

Brandy: Oh no! That means fishermen will be put out of business and less fish and seafood will be served at restaurants.

Ashely: Well, now I won't be taking it for granted anymore that the ocean is an infinite natural resource.