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Looking Ahead: Ocean Acidification

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4.4 Ocean Acidification

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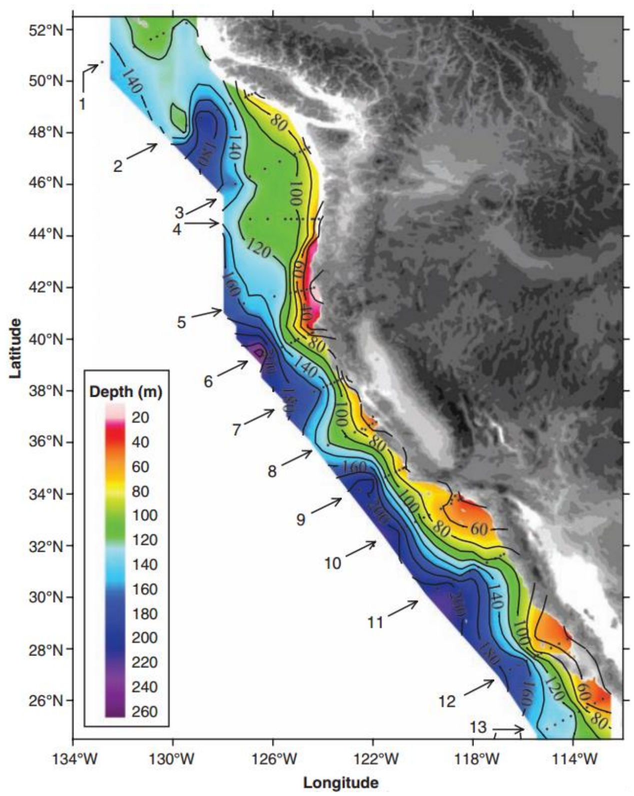
Ocean acidification is often referred to as 'the other CO_2 problem' after global climate change (Doney et al. 2009). Since the beginning of the industrial revolution in the early 1800s, the burning of fossil fuels and changing land use has released billions of tons of carbon dioxide (CO_2) and other greenhouse gases into the atmosphere. Prior to industrialization, the concentration of CO_2 in the atmosphere was ~280 parts per million (ppm). Now, that number is approaching 400 ppm and the increase is accelerating. Scientists now know that about half of this anthropogenic, or man-made, CO_2 has been absorbed over time by the oceans (Sabine et al. 2004). When molecules of CO_2 interact with water (H_2O) they create carbonic acid (H_2CO_3), which lowers the pH of the ocean. By the end of this century, the sea surface is predicted to decrease by 0.3 to 0.5 pH units. This may not seem like a high amount, but pH units are measured on a logarithmic scale, and this rate of change is faster than any time in the past 300 million years (Bijma et al. 2013).

Figure 4.4-1. Depth of "corrosive" water (pH < 7.75) along the U.S. Pacific Coast. The depth of this layer is an estimated 50m shallower due to human generated CO_2 in the atmosphere. On transect line 5, the corrosive water reaches all the way to the surface in the inshore waters near the coast. The black dots represent station locations. *Source: Feely et al. 2008.*



Upwelling zones, like off the Pacific coast of the United States, are particularly susceptible to impacts from increased CO_2 in the atmosphere. In addition to direct acidification, increased temperatures on land could lead to greater winds due to higher coastal pressure gradients, which in turn may intensify upwelling of deep, low pH water (Snyder et al. 2003). An increasing number of studies are documenting the progression of ocean acidification and already observing the effects (Figure 4.4-1). Models predict that much of the nearshore California Current System will experience 'corrosive' waters all summer long in the upper 60 meters within the next 30 years (Gruber et al. 2012). Localized impacts can also have an additive effect, as human inputs of nutrients into coastal waters can lead to the excessive production of algae, a process known as eutrophication.

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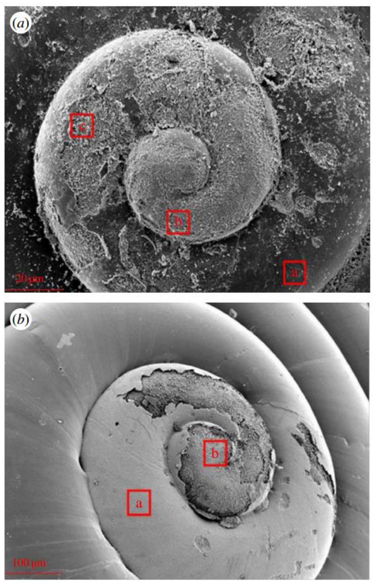
Microbial consumption of this organic matter lowers oxygen, as carbon dioxide production increases through respiration, which lowers pH (Cai et al. 2011).

Figure 4.4-2. Images of sea butterfly (pteropod) shells from a nearshore station showing severe shell dissolution (a), and an offshore station with minor shell dissolution (b). *Source: Bednaršek et al. 2014.*



Ocean acidification can affect many marine organisms, but especially "marine calcifiers" that build their shells and skeletons from calcium carbonate, such as corals, clams, oysters, snails, mussels, urchins, and many phytoplankton and zooplankton, the tiny plants and animals that form the base of the marine food web. Changes to the primary producer community, from phytoplankton to giant kelp, could lead to cascading effects up the food web, influencing marine herbivores and detritivores, and delaying access to recycled trace nutrients (Swanson and Fox 2007).

Marine calcifiers face potential challenges, both from their carbonate shells and skeletons dissolving in the corrosive water and also during the formation of their shells, as the chemical building blocks they need (calcium carbonate) are less biologically available (Orr et al. 2005). The ability of many marine animals, most importantly pteropods, foraminifera, and some benthic invertebrates, to produce calcareous skeletal structures is directly affected by seawater CO_2 chemistry (Fabry et al. 2008). Pteropods (see image) are a type of pelagic marine snail often called sea butterflies and an important prey group for ecologically and economically important fishes (such as salmon), birds, and whales (Armstrong et al. 2005). Significant decalcification of pteropod shells in recently acidified waters off the United States Pacific Coast has been documented (Bednaršek et al. 2014, Figure 4.4-2).

Many local taxa such as sea urchins, corals, mussels, coralline algae, and calcareous planktons have shown signs of vulnerability (Hauri et al. 2009). Larvae of marine calcifying organisms are particularly at risk, especially in upwelling regions. This includes the commercially important red sea urchin (*Mesocentrotus franciscanus*, formerly *Strongylocentrotus franciscanus*) and all seven species of wild abalone, whose populations are already severely depleted due to a combination of fishing pressure, disease, and severe El Niños. Though the physiological research is limited, a few studies have shown some responses to changing pH levels, ranging from abnormal larval shell development under mild ocean acidification conditions (Byrne et al. 2011; Crim, Sunday, and Harley 2011), and some shell decalcification but no decrease in weight gain (White 2011), to no effect on gene expression (Zippay and Hofmann 2010). More research, both *in situ* and in the laboratory, are necessary to determine the long-term impact on these sensitive species.

California's seven abalone species are: black (*Haliotis cracherodii*, endangered), white (*H. sorenseni*, endangered), pink (*H. corrugata, species of concern*), green (*H. fulgens, ,species of concern*), red (*H. rufescens*), pinto (*H. kamtschatkana, species of conern*), and flat (*H. walallensis*).

Economic Impact of Ocean Acidification

Beginning in 2005, production at some Pacific Northwest oyster hatcheries began declining at an alarming rate, posing a severe economic threat. Oyster production represents $84 million of the West Coast shellfish industry (60% of the total revenue), which supports more than 3,000 jobs (NOAA). Marine researchers have definitively linked the collapse of oyster seed production at a commercial oyster hatchery in Oregon to an increase in OA (Barton et al. 2012).

While acidification is persistent, its impact in these areas is seasonal, being exacerbated in the spring with the onset of upwelling of cold, deep, acidic water. As waters acidify, however, the survival of many calcifying coastal species may depend on the timing and duration of low pH events. For example, if major spawning events occur at the same time as sustained periods of upwelling, some animals may see a reduction in their numbers or size. The acidity of the water being upwelled is slowly intensifying as the ocean absorbs more CO_2 in naturally cold subduction zones. This water is then transported by deep ocean currents to coastal upwelling regions where it resurfaces, a process that can take decades. We are just starting to feel the effects of high atmospheric CO_2 from 50 years ago, and higher levels are “in the pipeline” (Feely et al. 2008).

Currently, the science is limited by the precision of the available sensors. Given that ocean acidification occurs in small increments over long periods of time, it will be critical to have precise instruments to detect when important biological thresholds are breached. The California Current Acidification Network (C-CAN), is an interdisciplinary collaboration dedicated to advancing the understanding of ocean acidification and its effects on biological resources along the U.S. West Coast. C-CAN is currently working to standardize ocean acidification monitoring and data management practices to ensure data comparability and quick public access. One of C-CAN’s partners, the Southern California Coastal Water Research Project (SCCWRP), is also collaborating with the Wendy Schmidt Ocean Health XPRIZE to develop accurate, affordable, and robust ocean pH sensors. The cooperative of Southern California publically-owned treatment works marine monitoring programs will be the test bed for the newly designed sensors.

Live sea butterfly, pteropod. *Image from Russ Hopcroft, UAF (http://funwithkrill.blogspot.com/2011/08/pity-pteropods.html)*

Not all species are susceptible to ocean acidification; some species even seem to grow better in these conditions (Ries, Cohen, and McCorkle 2009). It is difficult to predict who will be the winners or losers, but what is clear is that the impact of ocean acidification is already being felt and food web changes are accelerating. It is critically important to monitor coastal waters, ecosystems, and economically important fisheries as ocean acidification intensifies, while putting pressure on governments and industries to reduce carbon dioxide pollution.

References

Armstrong, J.L., J.L. Boldt, A.D. Cross, J.H. Moss, N.D. Davis, K.W. Myers, R.V. Walker, et al. (2005). "Distribution, size, and interannual, seasonal and diel food habits of Northern Gulf of Alaska juvenile pink salmon, Oncorhynchus Gorbuscha." Deep-Sea Research Part II: Topical Studies in Oceanography 52(1-2 SPEC. ISS.):247–65. doi:10.1016/j.dsr2.2004.09.019.

Barton, A., B. Hales, G.G. Waldbusser, C. Langdon, and R.A. Feely (2012). "The Pacific oyster, Crassostrea Gigas, Shows negative correlation to naturally elevated carbon dioxide levels: Implications for near-term ocean acidification effects." Limnology and Oceanography. DOI:10.4319/lo.2012.57.3.0698.

Bednaršek, N., R.A. Feely, J.C.P Reum, B. Peterson, J. Menkel, S.R. Alin, and B. Hales (2014). "Limacina Helicina shell dissolution as an indicator of declining habitat suitability owing to ocean acidification in the California Current ecosystem." Proceedings. Biological Sciences / The Royal Society 281(1785): 20140123. DOI:10.1098/rspb.2014.0123.

Bijma, J., H-O Pörtner, C. Yesson, and A.D. Rogers (2013). "Climate change and the oceans--What does the future hold?" Marine Pollution Bulletin 74(2):495–505. DOI:10.1016/j.marpolbul.2013.07.022.

Byrne, M., M. Ho, E. Wong, N.A. Soars, P. Selvakumaraswamy, H. Shepard-Brennand, S.A. Dworjanyn, and A.R. Davis (2011). "Unshelled abalone and corrupted urchins: Development of marine calcifiers in a changing ocean." Proceedings. Biological Sciences / The Royal Society 278(1716):2376–83. DOI:10.1098/rspb.2010.2404.

Cai, W-J, X. Hu, W-J Huang, M.C. Murrell, J.C. Lehrter, S.E. Lohrenz, W-C Chou, et al. (2011). "Acidification of subsurface coastal waters enhanced by eutrophication." Nature Geoscience. DOI:10.1038/ngeo1297.

Crim, R.N., J.M. Sunday, and C.D.G. Harley (2011). "Elevated seawater CO2 concentrations impair larval development and reduce larval survival in endangered northern abalone (Haliotis Kamtschatkana)." Journal of Experimental Marine Biology and Ecology 400(1-2):272–77. DOI:10.1016/j.jembe.2011.02.002.

Doney, S.C., V.J. Fabry, R.A. Feely, and J.A. Kleypas (2009)." Ocean acidification: The other CO2 problem." Annual Review of Marine Science 1:169–92. DOI:10.1146/annurev.marine.010908.163834.

Fabry, V.J., B.A. Seibel, R.A. Feely & J.C. Orr (2008). "Impacts of ocean Acidification on marine fauna and ecosystem processes." ICES Journal of Marine Science, 65:414–32. DOI:10.1093/icesjms/fsn048.

Feely, R.A., C.L. Sabine, J.M. Hernandez-Ayon, D. Ianson, and B. Hales (2008). "Evidence for upwelling of corrosive 'acidified' water onto the continental shelf." Science 320(5882):1490–92. DOI:10.1126/science.1155676.

Gruber, N., C. Hauri, Z. Lachkar, D. Loher, T.L. Frölicher, and G-K Plattner (2012). "Rapid progression of ocean acidification in the California Current system." Science 337(6091):220–23. DOI:10.1126/science.1216773.

Hauri, C., N. Gruber, G-K Plattner, S. Alin, R.A. Feely, B. Hales, and P. Wheeler (2009). "Ocean acidification in the California Current system." Oceanography. DOI:10.5670/oceanog.2009.97.

Orr, J.C, V.J. Fabry, O. Aumont, L. Bopp, S.C. Doney, R.A. Feely, A. Gnanadesikan, et al. (2005). "Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms." Nature 437(7059):681–86. DOI:10.1038/nature04095.

Ries, J.B., A.L. Cohen, and D.C. McCorkle (2009). "Marine calcifiers exhibit mixed responses to CO2-induced ocean acidification." Geology 37(12):1131–34. DOI:10.1130/G30210A.1.

Sabine, C.L, R.A. Feely, N. Gruber, R.M. Key, K. Lee, J.L. Bullister, R. Wanninkhof, et al. (2004). "The oceanic sink for anthropogenic CO2." Science 305(5682):367–71. DOI:10.1126/science.1097403.

Snyder, M.A., L.C. Sloan, N.S. Diffenbaugh, and J.L. Bell (2003). "Future climate change and upwelling in the California Current." Geophysical Research Letters 30(15):1823. DOI:10.1029/2003gl017647.

Swanson, A.K. and C.H. Fox (2007). "Altered kelp (laminariales) phlorotannins and growth under elevated carbon dioxide and ultraviolet-b treatments can influence associated intertidal food webs." Global Change Biology 13(8):1696–1709. DOI:10.1111/j.1365-2486.2007.01384.x.

White, L. (2011). The effect of ocean acidification and upwelling conditions on the growth and calcification of the red abalone. California State University San Marcos.

Zippay, M. L. and G.E. Hofmann (2010). "Effect of Ph on gene expression and thermotolerance of early life history stages of red abalone (Haliotis Rufescens)." Journal of Shellfish Research 29:429–39. <http://dx.doi.org/10.2983/035.029.0220>.