APPENDIX A

Why West Coast managers should care about ocean acidification

Ocean acidification is already posing a substantial threat, even if it's just beginning to enter the public consciousness.

In the same way that legacy pollutants in the marine environment inspired a generation of environmental activism in the 1970s and 80s, ocean acidification (OA) will define West Coast environmental management in the coming decades. OA endangers not only the biological health of marine organisms but also the numerous economic and societal benefits that stem from the West Coast's dependence on its coastal waters. The Panel unanimously and vigorously affirms that acidification of coastal waters is an undeniable, pervasive issue whose impacts have only begun to be felt.

1. Ocean chemistry is changing at an alarming rate, with no projected end or slowdown in sight.

- **Rapid change:** The fundamental alteration of the ocean's chemistry from continued absorption of atmospheric CO_2 is indisputable. At the current rate of global CO_2 emissions, the average acidity of the surface ocean is expected to double over pre-industrial levels by the end of this century.
- **Consequential change:** Seemingly small changes in ocean pH – which serves as a measure of acidification – are anything but small, as pH is expressed on a logarithmic scale. The 0.1 pH units of change that the ocean has recently experienced is equivalent to a 30% increase in acidity. For some organisms, this can be the difference between being able to grow a shell and having their shell dissolved.

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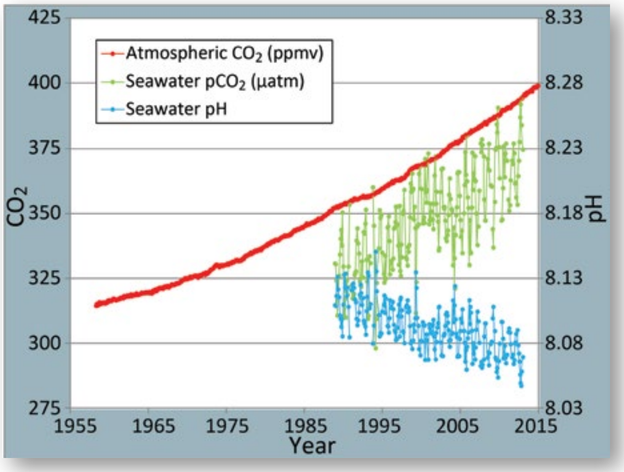
Credit: Modified after R.A. Feely, Bulletin of the Meteorological Society, July 2008.

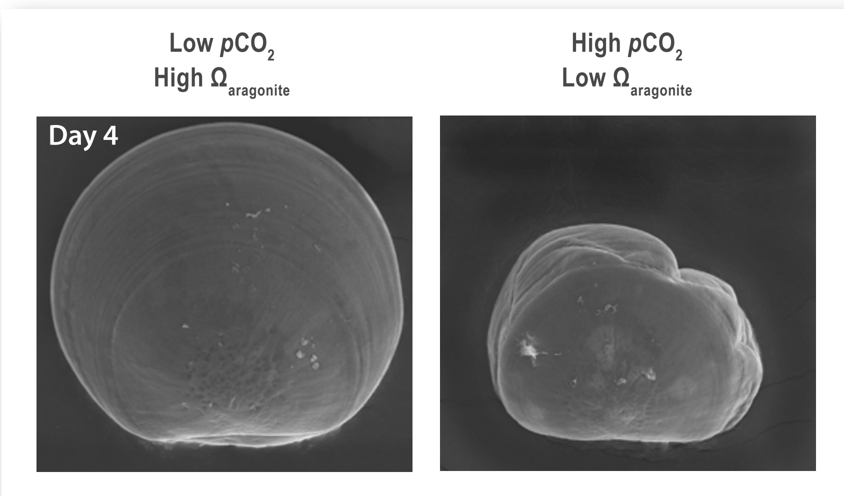


2. West Coast ecosystems are already facing the pervasive impacts of OA.

- **Shell-forming abilities crippled:** Even small increases in acidity of the local water can dramatically reduce the ability of marine organisms to properly grow shell or skeletal structures. Shellfisheries are particularly vulnerable. Oyster hatcheries are seeing high mortality rates during early life stages when shell formation is critical. In 2007, hatchery managers began to experience a severe loss of oyster seed stock as a consequence of OA, which led to acute shortages available to oyster growers up and down the West Coast.
- **Reverberation through food webs:** Microscopic algae and zooplankton that form carbonate structures during their life cycle are at risk, resulting in consequences for marine food webs. For example, swimming sea snails known as pteropods, serve as an important food source for many West Coast fisheries species, including herring, mackerel and salmon. In some locations, more than 50% of these sea snails are already showing signs of shell dissolution. The evidence is compelling, with studies demonstrating that the percentage of pteropods affected by shell dissolution corresponds with local acidity levels.
- **Effects extend beyond shelled organisms:** Rising CO_2 in seawater has been found to disrupt basic neural function and sensitive skeleton structure in marine fishes. These disruptions adversely affect critical behaviors such as orientation, distinguishing predators from prey, finding food, and identifying appropriate habitats. Scientists' understanding of how OA impacts organisms and ecosystems continuously expands, so effects will likely extend beyond those described here.

3. The consequences of OA are affecting ocean industries, with effects projected to worsen over time.

- **Operational disruption:** A West Coast shellfish farmer has relocated his hatchery to Hawaii, where exposure to low-pH marine waters is less than along the West Coast. Other hatcheries have invested in building expensive monitoring and water conditioning systems as necessary to maintain their West Coast operations.
- **Economic loss:** Oyster production in the Pacific Northwest declined 22% between 2005 and 2009 (13% decline in gross sales). In Washington and Oregon alone, two of the three major West Coast oyster seed hatcheries experienced production declines of up to 80% from 2006 to 2009. A Canadian company reported that it lost $10 million during its scallop harvest in 2014 in part due to OA. As the OA trajectory continues, a range of shellfish industries, including those for oysters, mussels and crabs, will be subject to economically devastating losses.
- **Domino effects of job losses:** Washington State's commercial and recreational fishing industries generate $8 billion in sales and 65,000 in jobs annually. In Oregon, the commercial and recreational fishing industries generate $1.5 billion in sales, and 19,000 jobs annually. Lastly, sales generated by the commercial and recreational fishing industries in California are $25.7 billion, and 158,000 jobs generated annually. As these industries endure future increases in acidification, the impacts could set off a domino effect of job losses throughout coastal communities, particularly in places where the fishing industry and coastal tourism provide the economic base.



Even small increases in acidity of the local water can dramatically reduce the ability of marine organisms to properly grow shell or skeletal structures.

Figure. Pacific oyster larvae from the same spawn, raised by the Taylor Shellfish Hatchery in natural waters of Dabob Bay, WA having favorable (left, pCO_2 = 403 ppm, $\Omega_{aragonite}$ = 1.64, and pH (total) = 8.00) and unfavorable (right column, pCO_2 = 1418 ppm, $\Omega_{aragonite}$ = 0.47, and pH (total) = 7.49) carbonate chemistry during the spawning period.
Photo credit: Brunner/Waldbusser.

This report was produced by the West Coast Ocean Acidification and Hypoxia Science Panel (the Panel), working in partnership with the California Ocean Science Trust. The Panel was convened by the Ocean Science Trust at the request of the California Ocean Protection Council in 2013, working in collaboration with ocean management counterparts in Oregon, Washington, and British Columbia. Ocean Science Trust and the Oregon Institute for Natural Resources served as the link between the Panel and government decision-makers. The information provided reflects the best scientific thinking of the Panel. More information on the Panel can be found at www.westcoastOAH.org. Cover image: Robert Couse-Baker / Creative Commons License.