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20 FACTS about Ocean Acidification

This document presents the highlights of the *Frequently Asked Questions* about Ocean Acidification (2010, 2012; *www.whoi.edu/OCB-OA/FAQs*), a detailed summary of the state of ocean acidification research and understanding. The *FAQs* and this fact sheet are intended to aid scientists, science communicators, and science policy advisors asked to comment on details about ocean acidification. In all, 63 scientists from 47 institutions and 12 countries participated in writing the FAQ, which was produced by the Ocean Carbon and Biogeochemistry Project (*www.us-ocb.org*), the United Kingdom Ocean Acidification Programme (*www.oceanacidification.org.uk*), and the European Project on Ocean Acidification (EPOCA). More information and contacts can be found at any of these websites or at the Ocean Acidification International Coordination Centre's website (*www.iaea.org/ocean-acidification*). The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report findings on ocean acidification can be viewed at *www.ipcc.ch*.

1 Ocean acidification (OA) is a progressive increase in the acidity of the ocean over an extended period, typically decades or longer, which is caused primarily by uptake of carbon dioxide (CO_2) from the atmosphere. It can also be caused or enhanced by other chemical additions or subtractions from the ocean. Acidification can be more severe in areas where human activities and impacts, such as acid rain and nutrient runoff, further increase acidity.

2 OA has been well documented with global observations conducted over several decades by hundreds of researchers. It has been definitively attributed to human-generated CO_2 in the atmosphere that has been released primarily by fossil fuel combustion and land use changes.

3 Acidity may be thought of as simply the hydrogen ion concentration (H^+) in a liquid, and pH is the logarithmic scale on which this concentration is measured. It is important to note that acidity *increases* as the pH *decreases*.

4 Average global surface ocean pH has already fallen from a pre-industrial value of 8.2 to 8.1, corresponding to an increase in acidity of about 30%. Values of 7.8–7.9 are expected by 2100, representing a doubling of acidity.

5 The pH of the open-ocean surface layer is unlikely to ever become *acidic* (i.e. drop below pH 7.0), because seawater is buffered by dissolved salts. The term "acidification" refers to a pH shift towards the acidic end of the pH scale, similar to the way we describe an increase in temperature from -20°C to 0°C (-4°F to 32°F): it's still cold, but we say it's "warming."

6 OA is also changing seawater carbonate chemistry. The concentrations of dissolved CO_2, hydrogen ions, and bicarbonate ions are *increasing*, and the concentration of carbonate ions is *decreasing*.

7 Changes in pH and carbonate chemistry force marine organisms to spend more energy regulating chemistry in their cells. For some organisms, this may leave less energy for other biological processes like growing, reproducing or responding to other stresses.

Pteropods, also called sea butterflies, are one type of shelled organism at risk from ocean acidification. Photo by Nina Bednarsek (NOAA/PMEL).

8 Many shell-forming marine organisms are very sensitive to changes in pH and carbonate chemistry. Corals, bivalves (such as oysters, clams, and mussels), pteropods (free-swimming snails) and certain phytoplankton species fall into this group. But other marine organisms are also stressed by the higher CO_2 and lower pH and carbonate ion levels associated with ocean acidification.

9 The biological impacts of OA will vary, because different groups of marine organisms have a wide range of sensitivities to changing seawater chemistry.

10 Impacts from OA at any life stage can reduce the ability of a population to grow or to recover from losses due to disturbance or stress, even though news reports have often focused on juvenile forms that are highly vulnerable to acidification (e.g. Pacific oyster larvae).

11 OA will not kill all ocean life. But many scientists think we will see changes in the number and abundance of marine organisms. Many marine ecosystems may be populated by different, and potentially fewer, species in the future. It is unclear whether these biological impacts will be reversible.

12 Areas that could be particularly vulnerable to OA include regions where there is natural upwelling of colder, low pH, deep water onto the continental shelves, such as the west coast of North America; the oceans near the poles, where lower temperatures allow seawater to absorb more CO_2; and coastal regions that receive freshwater discharge.

13 Long-term pH decline could exceed the tolerance limits of marine species that live in coastal waters, even though they may have evolved strategies to deal with fluctuating pH on short timescales typical of coastal environments (where the daily and seasonal changes in seawater pH are much greater than in the open ocean).

14 Evolutionary adaptation to reduced pH has been observed to act quickly when populations are large and robust. Marine populations reduced by other coastal ocean problems have more limited ability to respond evolutionarily to acidification.

15 The current rate of acidification may be unprecedented in Earth's history; it is estimated to be 10 to 100 times faster than any time in the past 50 million years. During an acidification event that occurred 55 million years ago (the Paleocene-Eocene Thermal Maximum), there was a mass extinction of some marine species, especially deep-sea shelled invertebrates.

16 Full recovery of the oceans will require tens to hundreds of millennia. Over decades to centuries, neither weathering of continental rocks, deep ocean mixing, or dissolution of calcium carbonate minerals in marine sediments can occur fast enough to reverse OA over the next two centuries.

17 Geo-engineering proposals that seek just to cool the planet will not address OA, because they do not tackle its cause: excess atmospheric CO_2. Proposals that capture CO_2 and store it away from seawater will mitigate the effects of OA somewhat, but most such proposals are now only cost- or energy-effective on very small scales.

18 Blue carbon is under investigation as a way of locally offsetting CO_2 levels. "Blue carbon" is CO_2 captured from the atmosphere or seawater by salt marshes, mangroves, and seagrass meadows. These environments store it as organic material for decades.

19 Reducing nutrient runoff might offset some of the local changes caused by OA, and could increase the overall health of marine ecosystems. But this would buy only a little time, because the root cause of OA is global atmospheric CO_2 emissions.

20 Ocean acidification represents yet another stress on marine environments that may endanger the flow of goods and services to marine-dependent communities. Humans around the world depend on the ocean for food, water quality, storm buffering, and many other important functions. Disruptions to marine ecosystems can alter these relationships.

All suggestions or comments for improvements to these talking points should be addressed to co-chairs of the U.S. Ocean Carbon and Biogeochemistry Subcommittee on Ocean Acidification: J. Mathis (*jeremy.mathis@noaa.gov*), K. Yates (*kyates@usgs.gov*), and Sarah Cooley (*scooley@whoi.edu*).

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Ocean Acidification International Coordination Centre
iaea.org/ocean-acidification

UK Ocean Acidification Research Programme
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NOAA, Ocean Acidification Program
oceanacidification.noaa.gov

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