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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 is the concentration of hydrogen ions ($H^+$) 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 (which provide chemical building blocks for marine organisms' shells and skeletons) is *decreasing*.

**7 Decreases in the availability of carbonate ions force marine organisms to spend more energy** building and maintaining their shells or skeletons. For some organisms, spending more energy on shell formation 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 ion concentrations; conditions predicted for the coming decades may prove very stressful to these organisms. Corals, bivalves (such as oysters, clams, and mussels), pteropods (free-swimming snails) and certain phytoplankton species fall into this group.

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 will likely be particularly vulnerable to OA** include regions where there is natural upwelling of 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 **Evolutionary adaptation is a slow process, requiring many generations, and OA is occurring at a rapid pace** compared to the speed of reproduction of some organisms. However, organisms have demonstrated an incredible ability to adapt to a wide range of environmental conditions, including reduced pH; the role of evolution in OA responses is being studied.

14 **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).

15 **The current rate of acidification may be unprecedented in Earth's history**; it is estimated to be 10 to 100 times faster than anytime in the past 50 million years. During a much slower 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 prevent OA.

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. For example, buffering the global ocean with mined calcium carbonate would require an annual application of at least 30 times as much limestone as is mined by humans today.

18 **Blue carbon is under investigation as a way of locally offsetting $CO_2$ levels**. $CO_2$ from the atmosphere or seawater can be captured in salt marshes, mangroves, and seagrass meadows as organic material that can be stored for decades. This is called "blue carbon."

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: S. Cooley (*scooley@whoi.edu*), J. Mathis (*jeremy.mathis@noaa.gov*), and K. Yates (*kyates@usgs.gov*).

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Ocean Acidification International Coordination Centre
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UK Ocean Acidification Research Programme
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NOAA, Ocean Acidification Program
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