

OCB-OA: OA and Calcification

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Why does adding CO₂ plus CaCO₃ benefit corals in saltwater aquaria, but not those in the ocean?

Basic: Adding CO₂ to an aquarium adjusts the chemistry of the saltwater only when calcium carbonate is also added. But it would be too difficult to use this method to solve ocean acidification due to the vast amounts of calcium carbonate that would be needed.

Intermediate: In saltwater aquaria, corals and fish require a narrowly balanced pH and owners often add carbonate “hardeners” to increase the water's alkalinity and maintain the pH between 8.0 and 8.4. Devices called “calcium reactors” bubble CO₂ gas through crushed calcium carbonate (usually crushed coral), which releases calcium and carbonate ions into the salt water, providing the high-alkalinity, calcium-rich waters that aquarium corals and other calcifying organisms need to continue healthy growth. Unfortunately, these types of devices cannot be used to solve ocean acidification on a global scale, because of the vast amounts of crushed calcium carbonate that would be required to carry out the process in the world's oceans. It has been suggested that buffering the global ocean with calcium carbonate would require an annual application of at least 30 times as much limestone as is mined by humans today (largely for cement production)- and this would have to be somehow distributed more or less evenly across all of the ocean basins. — H. Findlay, J. Kleypas, M. Holcomb, D. Hutchins

Why does ocean acidification affect shell building in marine organisms?

Basic: Ocean acidification alters water chemistry in many ways. These changes force marine organisms to spend more energy building shells. Organisms have a limited supply of energy and so if they spend more energy on building their shells they may have less energy available for other important biological processes like growing, reproducing or responding to stress.

Intermediate: Dissolving CO₂ in seawater causes a suite of changes in the carbonate system in seawater: the concentrations of dissolved CO₂, total dissolved inorganic carbon, and the bicarbonate ion increase, while pH, carbonate ion concentration, and calcium carbonate saturation state decrease. One or several of these changes may affect shell building in marine organisms. The formation of skeletons or shells in most marine organisms is an internal process where most organisms appear to convert bicarbonate to carbonate to form calcium carbonate. But because this conversion creates protons (hydrogen ions), the organisms must exert energy to transport the hydrogen ions into the external environment (seawater). One hypothesis as to why ocean acidification can cause slower calcification rates (and there are several) is that as seawater pH decreases (leading to protons building up in the external environment), the organisms must exert more energy to rid themselves of the protons produced internally by calcification --- they are simply working against a steeper proton gradient. It takes energy to pump ions against their concentration gradients. This explains why many calcifying organisms have lower calcification rates when they are physiologically taxed by other stresses (e.g. lack of food); that is, the added stress leaves the organisms with less energy for calcification. Ocean acidification can also indirectly affect shell formation through physiological impacts, such as changes in an organism's respiration rate and aerobic metabolism, which can impact energy budgets and thus alter the organism's ability to produce shell material. While some organisms may grow their shells at normal rates under ocean acidification, the exposed parts of the shell may dissolve more quickly, so that the organism may need to spend more energy in shell maintenance, and less in reproduction or other important life activities like growth and stress tolerance. — H. Findlay, A. Cohen, J. Kleypas

Do crustaceans suffer from ocean acidification also?

Basic/Intermediate: Crustaceans form a very large group, which includes such familiar animals as copepods, crabs, lobsters, crayfish, shrimp, krill and barnacles. Compared to other marine calcifiers, crustaceans appear to be relatively tolerant to near-future ocean acidification. However, some direct negative effects, including changes in health, growth, reproduction, and survival have been documented in several key species. Other species experience indirect negative effects when their food supplies are altered.

Advanced: Because ocean acidification alters the pH, carbonate mineral balance, and CO₂ concentration in seawater, organisms may experience effects related to regulation of acid-base balance within their bodies, respiration, and other processes beyond shell and skeleton building. Other effects may be associated with indirect effects, or effects on prey species or habitat. Studying all of these effects on crustaceans is challenging given their wide variety and distinctly different developmental forms. Crustaceans form a very large group, which includes such familiar animals as copepods, crabs, lobsters, crayfish, shrimp, krill and barnacles. Compared to other marine calcifiers, crustaceans appear to be relatively tolerant to near-future ocean acidification.

Copepods constitute the most abundant animal group on earth. They comprise 80% of the zooplankton biomass and constitute the primary food source for larvae of more than 90% of all fish species in the ocean, including almost all commercial species. Moderate levels of OA have relatively small effects on copepods. However, a recent study demonstrates that copepod reproduction and growth can be

negatively impacted through indirect effects on ocean acidification on their food (Rossoll et al. 2012).

-Considerable information on the impact of ocean acidification on decapods is available suggesting that this group is relatively tolerant to near-future levels. However, it was shown that long-term exposure to ocean acidification can increase the mortality in the shrimp *Palaemon pacificus* (Kurihara et al. 2008). Sublethal effects were also documented such as changes in carapace mineralogy in European lobsters (Arnold et al. 2009) and a narrowing of the thermal window in the spider crab *Hyas araneus* (Walther et al. 2009).

- Barnacles are sessile crustaceans covered by calcium-carbonate shells. Impact of ocean acidification on barnacles is variable, ranging from positive to negative depending on species, life-history and distribution. For example, an increased mortality in *Semibalanus balanoides* was described (Findlay et al. 2009) while ocean acidification had no negative effect in *Balanus amphitrite* (McDonald et al. 2009).

Larger, mobile crustaceans like crabs have generally showed a good capacity for acid-base regulation of their internal fluids, except for deep-sea crabs, which show a high degree of vulnerability. As this regulation implies energetically costly mechanisms, the energy available for other processes such as growth, reproduction, and even feeding is likely to decrease. Growth is particularly at risk in crustaceans, because they moult and need to re-calcify thereafter. The process of calcification is either not impacted by OA or enhanced. However, in some species, the time between two moulting events under ocean acidification is longer, thus reducing growth. Finally, even though crabs can resist OA, when the latter is coupled to other environmental factors it may become detrimental. For instance, it was shown in several species, that the thermal tolerance window is reduced when they are exposed to increased pCO₂, leading to possible mass mortality in the environment if they face extreme temperatures.—S. Dupont, M. Collard

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