A study on the impact of ocean water acidification on marine life

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***Abstract:*. Ocean acidification represents a threat to marine species worldwide, and forecasting the ecological impacts of acidification is a high priority for science, management, and policy. As research on the topic expands at an exponential rate, a comprehensive understanding of the variability in organisms' responses and corresponding levels of certainty is necessary to forecast the ecological effects. Here, we perform the most comprehensive meta-analysis to date by synthesizing the results of 228 studies examining biological responses to ocean acidification. The results reveal decreased survival, calcification, growth, development and abundance in response to acidification when the broad range of marine organisms is pooled together. However, the magnitude of these responses varies among taxonomic groups, suggesting there is some predictable trait-based variation in sensitivity, despite the investigation of approximately 100 new species in recent research. The results also reveal an enhanced sensitivity of mollusk larvae, but suggest that an enhanced sensitivity of early life history stages is not universal across all taxonomic groups. In addition, the variability in species' responses is enhanced when they are exposed to acidification in multi-species assemblages, suggesting that it is important to consider indirect effects and exercise caution when forecasting abundance patterns from singlespecies laboratory experiments. Furthermore, the results suggest that other factors, such as nutritional status or source population, could cause substantial variation in organisms' responses. Last, the results highlight a trend towards enhanced sensitivity to acidification when taxa are concurrently exposed to elevated seawater temperature.**

***Keywords:* calcification, carbonate chemistry, climate change, cumulative effects, pH**

I. INTRODUCTION

Many organisms that form the basis for the marine food chain are going to be affected by ocean acidification. It turns out that changing the pH of the ocean is not the only impact from this phenomenon. There is another, equally impactful side effect. When carbon dioxide (CO_2) mixes with water molecule (H_2O) it forms carbonic acid (H_2CO_3) that then breaks down easily into hydrogen ions (H+) and bicarbonate (HCO3-), those available hydrogen ions bond with other carbonate ions to form more bicarbonate. The problem here is that marine organisms possessing shells (many mollusks, crustaceans, corals, coralline algae, foramaniferans) need available carbonate ions to form the calcium carbonate (CaCO3) that comprises their shells. In essence, ocean acidification is robbing these organisms of their necessary building blocks.

There have been scientific experiments focusing on how the projected acidity of the oceans will affect different organisms. Marine pteropods already have thin shells, and these shells literally dissolve over 30 days in seawater with a 7.8 pH. Studies on sea urchins and mollusks show similar results.

There are many resources included in this lesson, and many of them are going to say the same things, but each resource does a good job of explaining a certain part of the ocean acidification story.

Start with the pdf slideshow called Ocean Acidification: effects on marine organisms. It is the best overview and it has informative slides which can be presented or printed. It covers the whole topic and even has some great solution pages.

Ocean Acidification is a short 2-minute video from North Carolina Aquarium that explains how marine organisms build shells from calcium carbonate, and how ocean acidification impedes that process.

NOAA's Ocean Acidification: The Other CO2 Problem video is 4 minutes long and shows the results of acidifying water on marine pteropods, one of the delicate creatures at the bottom of the food chain. NOAA Ocean Acidification Intro and Classroom Demonstrations is a 15-minute video that has some really great hands-on and visual representations of calcium carbonate dissolving in acid, and of CO2 turning water more acidic.

For a more hands-on approach, or if you're interpreting for the classroom or in a lab-like setting, download the Lab Activities pdf. The third experiment "Group Demonstration: I'm Melting! Seashells in Acid" is focysed on the effects of increased acidity on seashells.

Watch the 6-minute Acid Oceans video to get a good feel for how Ocean Acidification will affect sea urchins. There are scientists doing research on the effects of acidity on urchin larval development. Climate Training Activities shows some actual interpretation from Aquarium staff, using props and visuals to show visitors about the impacts of ocean acidification to shellfish and corals.

II. OCEAN WATER ACIDIFICATION

Human activities release CO2 into the atmosphere, which leads to atmospheric warming and climate change, as explained in Causes of climate change. Around a third to a half of the CO2 released by human activities is absorbed into the oceans. While this helps to reduce the rate of atmospheric warming and climate change, it also has a direct, chemical effect on seawater, which we call ocean acidification (Figure 1).

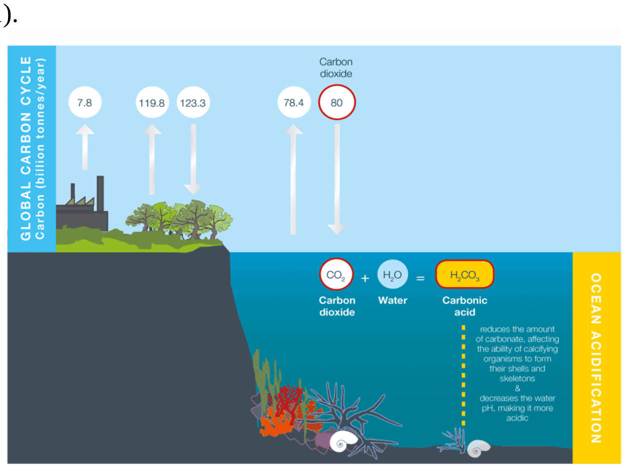

Figure 1

Since around 1850, the oceans have absorbed between a third and a half of the CO2 emitted to the atmosphere. As a result, the average pH of ocean surface waters has fallen by about 0.1 units, from 8.2 to 8.1 (Figure 2). This corresponds to a 26 % increase in ocean acidity, a rate of change roughly 10 times faster than any time in the last 55 million years.

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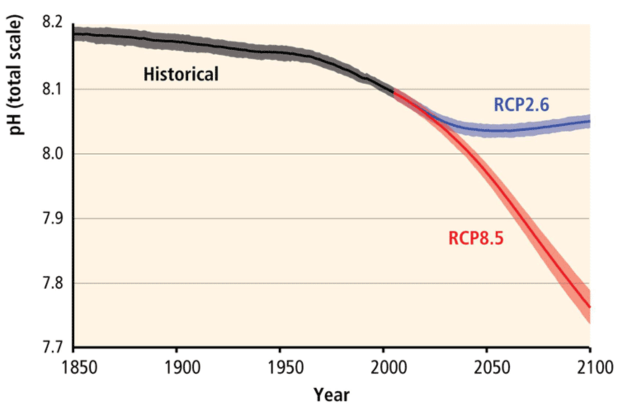

Figure 2

III. EFFECTS OF OCEAN ACIDIFICATION ON MARINE ORGANISMS AND ECOSYSTEMS

Ocean acidification reduces the amount of carbonate, a key building block in seawater. This makes it more difficult for marine organisms, such as coral and some plankton, to form their shells and skeletons, and existing shells may begin to dissolve.

The present-day pH of seawater is highly variable, and a single organism can cope with fluctuations of different pH levels during its lifetime. The problem with ocean acidification is the sustained nature of the change, as the risk comes from the lifetime exposure to lower pH levels. The rapid pace of acidification will influence the extent to which calcifying organisms will be able to adapt.

The impacts of ocean acidification are not uniform across all species. Some algae and seagrass may benefit from higher CO2 concentrations in the ocean, as they may increase their photosynthetic and growth rates. However, a more acidic environment will harm other marine species such as molluscs, corals and some varieties of plankton (Figure 4). The shells and skeletons of these animals may become less dense or strong. In the case of coral reefs this may make them more vulnerable to storm damage and slow the recovery rate.

Marine organisms could also experience changes in growth, development, abundance, and survival in response to ocean acidification (Figure 5). Most species seem to be more vulnerable in their early life stages. Juvenile fish for example, may have trouble locating suitable habitat to live.

Despite the different responses within and between marine groups, positive or negative, research suggests that ocean acidification will be a driver for substantial changes in ocean ecosystems this century. These changes may be made worse by the combined effect with other emerging climate-related hazards, such as the decrease of ocean oxygen levels – a condition known as ocean deoxygenation –that is already affecting marine life in some regions (Long et al. 2016).

Effects on human societies

Changes in marine ecosystems will have consequences for human societies, which depend on the goods and services these ecosystems provide. The implications for society could include substantial revenue declines, loss of employment and livelihoods, and other indirect economic costs.

Socioeconomic impacts associated with the decline of the following ecosystem services are expected:

- Food: Ocean acidification has the potential to affect food security. Commercially and ecologically important marine species will be impacted, although they may respond in different ways. Molluscs such as oysters and mussels are among the most sensitive groups. By 2100, the global annual costs of mollusc loss from ocean acidification could be over US$100 billion for a business-as-usual (RCP8.5) CO2 emissions pathway.
- Coastal protection: Marine ecosystems such as coral reefs protect shorelines from the destructive action of storm surges and cyclones, sheltering the only habitable land for several island nations. This protective function of reefs prevents loss of life, property damage, and erosion, and has been valued at US$9 billion per year.
- Tourism: This industry could be severely affected by the impacts of ocean acidification on marine

ecosystems (e.g. coral reefs). In Australia, the Great Barrier Reef Marine Park attracts about 1.9 million visits each year and generates more than A$5.4 billion to the Australian economy.

- Carbon storage and climate regulation: The capacity of the ocean to absorb CO2 decreases as ocean acidification increases. More acidic oceans are less effective in moderating climate change.

While reducing global greenhouse gas emissions (mitigation) is the ultimate solution to ocean acidification, undertaking some challenging decisions and actions can help us prepare for the adverse effects of ocean acidification. This is the adaptation approach.

Figure 3

At the local level, the following policy and management options can help to minimise the adverse effects of other local stressors and, as a result, help marine ecosystems to cope better with changing environmental conditions.

- Improvements in water quality: Monitoring and regulating localised sources of acidification from runoff and pollutants such as fertilisers.
- Development of sustainable fisheries management practices: Regulating catches to reduce overfishing and creating long-term bycatch[1] reduction plans.
- Implementation of new technologies: Different techniques can be applied depending on the industry. For example, in the aquaculture industry, new forecasting systems have been developed to account for seasonal upwellings that bring low pH seawaters to the ocean surface and cause massive shellfish die-offs.
- Sustainable management of habitats: Increasing coastal protection, reducing sediment loading and applying marine spatial planning.
- Establishment and maintenance of Marine Protected Areas: Protecting highly vulnerable and endangered marine ecosystems.

IV. CONCLUSION

If you live in Kansas or Oklahoma, you may think that ocean acidification doesn't affect you. But it does. Ocean acidification impacts important sectors of the US economy, like fisheries and tourism, it affects food supply, and makes global warming worse by hindering the oceans' ability to absorb CO2. For communities that depend on coastal resources, their way of life and cultural identity are on the line. If CO2 emissions continue unabated, by the end of the century, ocean acidification is expected to reduce harvests of U.S. shellfish. It's estimated that by the end of the century annual supplies of clams could decrease by 35 percent, oysters supplies could fall by 50 percent, and scallops could see a decline of 55 percent. Overall, the shellfish industry could experience cumulative consumer losses of $230 million. In this same scenario, ocean acidification paired with warming could cost $140 billion in today's dollars in lost recreational benefits associated with coral reefs, and the US coral reef recreation industry could decline in value by more than 90 percent by 2100.

The most effective way to limit ocean acidification is to act on climate change, implementing solutions to dramatically reduce the use of fossil fuels. If we dramatically cut our global warming emissions, and we limit future warming, we can significantly reduce the harm to marine ecosystems.

The most recent National Climate Assessment projects that by taking action now we could avoid steep declines in fish catch potential, thus reducing harm to fisheries.

The IPCC report highlights that with significant emissions reductions, 30% of coral reefs would be spared from extinction.

We also need to ensure that resources reach those communities that will be most affected by ocean acidification. At present, taxpayers foot the bill for climate damages and adaptation costs. However, climate change negatively impacts local economies and stymies these communities' ability to adapt.

Courts are beginning to consider holding fossil fuel producers accountable for damage they knew their products were causing because they chose to misinform investors and the public about those risks instead of acting to mitigate them. Making a case for these companies' responsibility, Henry Shue, professor of politics and international relations at the University of Oxford, argues "Companies knowingly violated the most basic moral principle of 'do no harm,' and now they must remedy the harm they caused by paying damages and their proportion of adaptation costs." Scientific findings that show the extent of the damage caused by carbon pollution can inform those efforts.

References

[1]. Abrami PC, Cohen PA, d'Apollonia S (1988) Implementation problems in meta-analysis. Review of Educational Research, 58, 151–179.

[2]. Adams DC, Gurevitch J, Rosenberg MS (1997) Resampling tests for meta-analysis of ecological data. Ecology, 78, 1277–1283.

[3]. Albright R (2011) Reviewing the effects of ocean acidification on sexual reproduction and early life history stages of reef-building corals. Journal of Marine Biology, 2011, Article ID 473615, doi: 10.1155/2011/473615

[4]. Albright R, Langdon C (2011) Ocean acidification impacts multiple early life history processes of the Caribbean coral Porites astreoides. Global Change Biology, 17, 2478–2487.

[5]. Albright R, Mason B, Miller M, Langdon C (2010) Ocean acidification compromises recruitment success of the threatened Caribbean coral Acropora palmata. Proceedings of the National Academy of Sciences of the United States of America, 107, 20400–20404.

[6]. Anthony KRN, Kline DI, Diaz-Pulido G, Dove S, Hoegh-Guldberg O (2008) Ocean acidification causes bleaching and productivity loss in coral reef builders. Proceedings of the National Academy of Sciences of the United States of America, 105, 17442–17446.

[7]. Arnold T, Mealey C, Leahey H, Miller AW, Hall-Spencer J, Milazzo M, Maers K (2012) Ocean acidification and the loss of phenolic substances in marine plants. PLoS ONE, 7, e35017.

[8]. Hurd CL, Hepburn C, Currie KI, Raven JA, Hunter KA (2009) Testing the effects of ocean acidification on algal metabolism: considerations for experimental designs. Journal of Phycology, 45, 1236–1251.

[9]. IPCC (2007) Climate Change 2007: The physical science basis. In: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (ed. Solomon S), pp. 996, Cambridge University Press, Cambridge UK.

[10]. Koch M, Bowes G, Ross C, Zhang X-H (2013) Marine macro-autotrophs and climate change. Global Change Biology, 19, 103–132.

[11]. Kroeker KJ, Kordas RL, Crim RN, Singh GG (2010) Meta-analysis reveals negative yet variable effects of ocean acidification on marine organisms. Ecology Letters, 13, 1419–1434.

[12]. Kroeker KJ, Kordas RL, Crim RN, Singh GG (2011a) Response to technical comment on 'meta-analysis reveals negative yet variable effects of ocean acidification on marine organisms'. Ecology Letters, 14, E1–E2.

[13]. Kroeker KJ, Micheli F, Gambi MC, Martz TR (2011b) Divergent ecosystem responses within a benthic marine community to ocean acidification. Proceedings of the National Academy of Sciences of the United States of America, 108, 14515–14520.

[14]. Langer G, Nehrke G, Probert I, Ly J, Ziveri P (2009) Strain-specific responses of Emiliania huxleyi to changing seawater carbonate chemistry. Biogeosciences, 6, 2637–2646.

[15]. Lischka S, Budenbender J, Boxhammer T, Riebesell U (2011) Impact of ocean acidifi- €cation and elevated temperatures on early juveniles of the polar shelled pteropod Limacina helicina: mortality, shell degradation, and shell growth. Biogeosciences, 8, 919–932.

[16]. Pistevos JCA, Calosi P, Widdicombe S, Bishop JDD (2011) Will variation among genetic individuals influence species responses to global climate change. Oikos, 120, 675–689.

[17]. Portner H (2008) Ecosystem effects of ocean acidification in times of ocean warming: € a physiologist's view. Marine Ecology Progress Series, 373, 203–217.

[18]. Porzio L, Buia MC, Hall-Spencer JM (2011) Effects of ocean acidification on macroalgal communities. Journal of Experimental Marine Biology and Ecology, 400, 278–287.

[19]. Price NN, Martz TR, Brainard RE, Smith JE (2012) Diel variability in seawater pH relates to calcification and benthic community structure on coral reefs. PLoS ONE, 7, e43843.

[20]. Reynaud S, Leclercq N, Romaine-Lioud S, Ferrier-Pages C, Jaubert J, Gattuso J-P (2003) Interacting effects of CO2 partial pressure and temperature on photosynthesis and calcification of a scleractinian coral. Global Change Biology, 9, 1660–1668.

[21]. Ries JB, Cohen AL, McCorkle DC (2009) Marine calcifiers exhibit mixed responses to CO2-induced ocean acidification. Geology, 37, 1131–1134.

[22]. Rodolfo-Metalpa R, Martin S, Ferrier-Pages C, Gattuso J-P (2010) Response of the temperate coral Cladocora caespitosa to mid- and long-term exposure to pCO2 and temperature levels projected for the year 2100 AD. Biogeosciences, 7, 289–300.

[23]. Rodolfo-Metalpa R, Houlbreque F, Tambutte E et al. (2011) Coral and mollusk resistance to ocean acidification adversely affected by warming. Nature Climate Change, 1, 308–312.

[24]. Rosenberg MS, Adams DC, Gurevitch J (2000) MetaWin: Statistical Software for MetaAnalysis Version 2.0. Sinauer Associates, Sunderland.

[25]. Liu J, Weinbauer MG, Maier C, Dai M, Gattuso J-P (2010) Effect of ocean acidification on microbial diversity, and on microbe-driven biogeochemistry and ecosystem functioning. Aquatic Microbial Ecology, 61, 291–305.

[26]. Logan CA (2010) A review of ocean acidification and America's response. BioScience, 60, 819–828.

