1. Ocean chemistry is changing at an unprecedented rate and magnitude due to human-made carbon dioxide emissions to the atmosphere. The average pH of ocean surface waters has decreased by about 0.1 pH unit—from about 8.2 to 8.1—since the beginning of the industrial revolution, and model projections show an additional 0.2-0.3 drop by the end of the century, even under optimistic scenarios of carbon dioxide emissions.

2. Changes in seawater chemistry are expected to affect marine organisms that use carbonate to build shells or skeletons. For example, decreased concentrations of calcium carbonate make it difficult for organisms such as coral reef-building organisms, and commercially important mollusks like oysters and mussels, to grow or to repair damage. If the ocean continues to acidify, the water could become corrosive to calcium carbonate structures, dissolving coral reefs and even the shells of marine organisms.

3. It is currently not known how various marine organisms will acclimate or adapt to the chemical changes resulting from acidification. Based on current knowledge, it appears likely that there will be ecological winners and losers, leading to shifts in the composition of many marine ecosystems.

4. The committee finds that the federal government has taken positive initial steps by developing a national ocean acidification program. The recommendations in this report provide scientific advice to help guide the program.

5. More information is needed to fully understand and address the threat that ocean acidification may pose to marine ecosystems and the services they provide. Research is needed to assist federal and state agencies in evaluating the potential impacts of ocean acidification, particularly to:
   - understand processes affecting acidification in coastal waters;
   - understand the physiological mechanisms of biological responses;

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Ocean Chemistry
The ocean takes up carbon dioxide from the atmosphere, and as the gas dissolves in seawater it forms carbonic acid. This decreases the concentration of carbonate ions in the water and reduces the availability of calcium carbonate for corals and other calcifying organisms.
• assess the potential for acclimation and adaptation;
• investigate the response of individuals, populations, and communities;
• understand ecosystem-level consequences;
• investigate the interactive effects of multiple stressors;
• understand the implications for biogeochemical cycles; and
• understand the socioeconomic impacts and inform decisions.

6. **The national ocean acidification program will need to adapt in response to new research findings.** Because ocean acidification is a relatively new area of research, the program will need to adapt in response to findings, such as the identification of important biological metrics, analyses of the socioeconomic impact of ocean acidification, and inclusion of concerns from stakeholder communities.

7. **A global network of chemical and biological observations is needed to monitor changes in ocean conditions attributable to acidification.** Existing observation systems were not designed to monitor ocean acidification, and thus do not provide adequate coverage or measurements of carbon parameters, such as total alkalinity, pH, and dissolved inorganic carbon, or biological constituents such as nutrients, oxygen, and chlorophyll. Adding sites in vulnerable carbon, or biological ecosystems such as coral reefs or polar regions, and in areas of high variability, such as coastal regions, would improve the observation system.

8. **International collaboration will be critical to the success of the program.** Ocean acidification is a global problem that requires a multinational research approach. Such collaborations also afford opportunities to share resources, including expensive large-scale facilities for ecosystem-level manipulation, and expertise that may be beyond the capacity of a single nation.

9. **The national ocean acidification program should support the development of standards for measurements and data collection and archiving to ensure that data is accessible and useful to researchers now and in the future.** Steps should be taken to make information available to policy makers and the general public in a timely manner.

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**Tiny open-ocean sea snails, known as pteropods, could lose their calcium carbonate shells in more acidic waters. This could reduce pteropod abundance, affecting an important source of food for fish such as salmon, cod, and herring.**

*Credit: Victoria Fabry*