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Mitigating Local Causes of Ocean Acidification with Existing Laws

Even as global and national efforts struggle to mitigate CO_2 emissions, local and state governments have policy tools to address "hot spots" of ocean acidification.

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As the level of atmospheric carbon dioxide (CO_2) continues to rise, so too does the amount of CO_2 in the ocean (*1*, *2*), which increases the ocean's acidity. This affects marine ecosystems on a global scale in ways we are only beginning to understand: for example, impairing the ability of organisms to form shells or skeletons, altering food webs, and negatively affecting economies dependent on services ranging from coral reef tourism to shellfish harvests to salmon fisheries (*3*–*5*). Although increasing anthropogenic inputs drive acidification at global scales, local acidification disproportionately affects coastal ecosystems and the communities that rely on them. We describe policy options by which local and state governments—as opposed to federal and international bodies—can reduce these local and regional "hot spots" of ocean acidification.

Several studies document acidification hot spots, patches of ocean water with significantly depressed pH levels relative to historical baselines occurring at spatial scales of tens to hundreds of square kilometers [e.g., (*6*, *7*)]. These coastal hot spots may be due to nonuniform changes in circulation and biological processes (*6*), and precipitation runoff (*4*, *5*, *8*), in concert with globally increased atmospheric CO_2 (*8*) (see the figure). Local studies in the Kennebec River plume in the Gulf of Maine (*9*), the Chesapeake Bay (*10*), and the Manning River estuary in New South Wales, Australia (*11*), illustrate that freshwater inputs, pollutants, and soil erosion can acidify coastal waters at substantially higher rates than atmospheric CO_2 alone.

These nonatmospheric inputs can have particularly large consequences when they coincide with biotic phenomena [e.g., spawning events (*9*)] or abiotic processes, such as upwelling events that bring low-pH water to nearshore areas (*1*, *2*). Additional local phenomena—such as sulfur dioxide precipitation (*12*), hypoxia (*13*), eutrophication (*10*, *14*), and both emissions and runoff from acidic fertilizers (*15*)—can intensify these localized hot spots. These impacts are likely to be magnified when combined with other stressors in the coastal ocean, including overfishing, habitat destruction, temperature increases, and nonacidifying pollution (*16*).

Policy Recommendations

As global and national efforts to mitigate CO_2 emissions struggle to gain traction, smaller-scale actions become increasingly important. In the United States, for example, local and state governments have both the authority and motive to address many stressors that drive or exacerbate acidification conditions. This runs contrary to the widely held perception that acidification cannot be addressed at the scale of local (e.g., municipal and county) or regional (state, multistate, and territorial) jurisdictions [e.g., (*16*, *17*)]. Although we focus here on U.S. policies, similar legal tools exist elsewhere to guard against non-CO_2 acidification drivers.

U.S. federal environmental laws (e.g., Clean Air Act, Clean Water Act, and Coastal Zone Management Act), state laws, and local ordinances provide multiple layers of protection for coastal waters by controlling emissions, runoff, and land-use patterns through zoning and permitting (table S1). Implementing measures that reduce residential and agricultural runoff, for example, can minimize beach and river contamination and algal blooms, while reducing pollutants that acidify the local coastal ocean. Many states have already passed legislation to limit residential runoff, although these are not specifically aimed at mitigating acidification (*18*).

A recent lawsuit and the resulting U.S. Environmental Protection Agency (EPA) memoranda (*19*, *20*) illustrate states' responsibilities to apply federal environmental laws to combat acidification in state waters. In *Center for Biological Diversity* v. *EPA* (*21*), the Center for Biological Diversity (CBD) challenged Washington State's failure to designate coastal waters as "impaired" because of a decline in pH by 0.2 units from baseline levels, as required under the federal Clean Water Act (*22*). Despite the lack of substantive reform of the National Water Quality Standard for marine pH (*19*, *20*) owing to insufficient data, the EPA highlighted the seriousness of acidification's impacts on ocean life and encouraged states to list pH-impaired waters where data are available (*19*). A focus on data collection could lead to future regulatory revisions that allow state governments to better restrict pollutants in coastal waters (*23*). States may also use existing law to develop biological water quality standards for acidification to assess if a water body is impaired on the basis of biological indicators (e.g., negative impacts on coral species) (*24*). Water quality standards and impairment designations, however, are only ecologically meaningful in light of baseline conditions, vulnerability of ecosystems, and thresholds for ecosystem change, which are often undefined.

Four Approaches

Few jurisdictions have taken steps to mitigate acidification, likely because of the combination of low awareness and a sense that the causes are globally diffuse. Four approaches have particular potential for combating locally intensified acidification. First, the Clean Water Act directs state government agencies to ensure that precipitation runoff and associated pollutants (which can increase acidification) are monitored, limited, and consistent with the sustainable functioning of aquatic ecosystems. Stormwater surge prevention (e.g., holding tanks), coastal and riparian buffers (areas of vegetation near land-water intersections), intact wetlands, and improved onsite water treatment facilities are effective measures to address watershed runoff and associated pollutants. In many cases, federal funding is available to help local governments complete these kinds of projects, and local watershed groups provide a grassroots base for ensuring that states and EPA meet their responsibilities.

Second, controlling coastal erosion is a classic function of local and state governments and one that could markedly benefit

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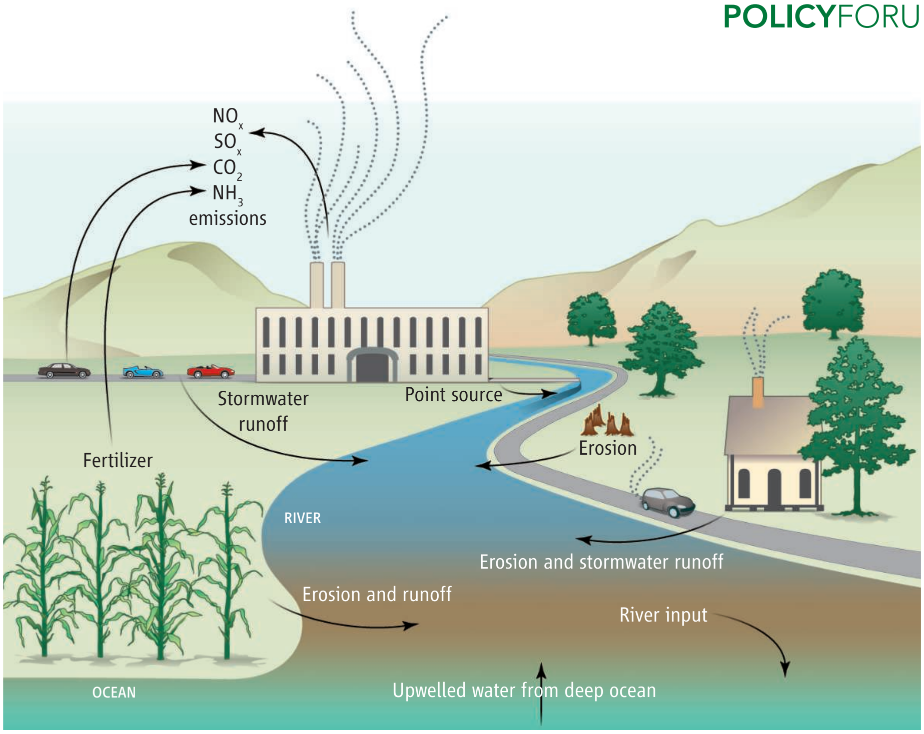
coastal ecosystems by reducing nutrient and sediment loading of water and protecting the physical integrity of the habitat itself. Such coastal inputs may be enriched with fertilizers and, if unchecked, can further increase acidification in estuaries and coastal waterways. Independent local actions, such as increasing vegetation cover, may be effective at small scales, but concerted action among multiple local jurisdictions—as would likely be necessary to address erosion within an entire watershed, for example—may require coordination among state or regional governments, adding a layer of regulatory complexity.

Third, land-use change facilitated through local and regional planning, zoning, and permitting policies can reduce direct and indirect (e.g., deforestation) CO_2 emissions, runoff, and other threats (*25*). Antisprawl land-use plans can help reduce vehicle-miles traveled and impermeable surface cover, limiting both emissions and runoff. At least two state laws [Massachusetts (Global Warming Solutions Act) and California (SB 375)] explicitly link land-use development, transportation, and climate change mitigation. These state-level rules are models for state action, but cities and counties can adopt policies and alter zoning provisions and general plans that could help safeguard their own waters—without waiting for state governments to act (*26*).

Finally, simply enforcing existing federal emissions limits for pollutants such as nitrogen oxide and sulfur oxide (for example, from coal-fired power plants) could help ameliorate local drivers of ocean acidification (*13*). Reductions could have immediate local effects, because these pollutants have short atmospheric residence times, falling out of the atmosphere and into the water and/or land near where they were produced (*12*). Reducing pollutants to benefit local environmental conditions increases the likelihood of responsible stewardship by matching political incentives and environmental remediation at the same spatial scale (*27*).

In addition to regulating inputs to the coastal zone, protecting important ecosystem components (such as shell material) provides another potential mechanism to combat locally intensified acidification. Returning crushed shell material to coastal habitats to approximate densities found in healthy clam populations can substantially increase pH and mitigate localized acidification impacts on clams (*10*, *28*).

Tenaciously enforcing existing limits for sediment runoff, erosion, and emissions may alone improve the health of coastal waters and safeguard coastal economies dependent on calcium carbonate–producing organisms, such as shellfish and corals. In the face of declining conditions, however, it is increasingly critical to establish historical and current pH levels to inform future federal or state regulations aimed at protecting against ocean acidification. The potential biological, ecological, and socioeconomic effects of acidification are likely to affect nearshore environments most severely, affecting the delivery of ecosystem services that over half of the world's population depend on and costing billions of dollars in lost product and income (*5*). Minimizing additional stressors on coastal ecosystems can also help to ameliorate threats to coastal resources, thereby maintaining ecosystem resilience and sustainable economic benefits from the ocean.



Contributors to ocean acidification. In addition to global atmospheric CO_2, this figure depicts the major local (within 100 km) sources contributing to coastal ocean acidification.

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31. The authors thank L. Crowder, N. Baron of Communication Partnership for Science and the Sea (COMPASS), and E. Hartge for helpful comments. Funding was provided by the David and Lucile Packard Foundation. The scientific views, opinions, and conclusions expressed herein are solely those of the authors and do not represent the views, opinions, or conclusions of NOAA, the Department of Commerce, or the EPA.

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www.sciencemag.org/cgi/content/full/332/6033/1036/DC1

10.1126/science.1203815