Washington Journal of Environmental Law & Policy

Volume 6
Issue 2 *Ocean Acidification: Understanding the Other Climate Crisis*

7-1-2016

Ten Ways States Can Combat Ocean Acidification (and Why They Should)

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TEN WAYS STATES CAN COMBAT OCEAN ACIDIFICATION (AND WHY THEY SHOULD)[▽]

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ABSTRACT: The ocean is becoming more acidic worldwide as a result of increasing atmospheric concentrations of carbon dioxide ("CO_2") and other pollutants. This fundamental change is likely to have substantial ecological and economic consequences globally. In this Article, we provide a toolbox for understanding and addressing the drivers of ocean acidification. We begin with an overview of the relevant science, highlighting known causes of chemical change in the coastal ocean. Because of the difficulties associated with controlling diffuse atmospheric pollutants such as CO_2, we then focus on controlling smaller-scale agents of acidification, discussing ten legal and policy tools that state government agencies can use to mitigate the problem. This bottom-up approach does not solve the global CO_2 problem, but instead offers a more immediate means of addressing the challenges of a rapidly changing ocean. States have ample legal authority to address many of the causes of ocean acidification; what remains is to implement that authority to safeguard our iconic coastal resources.

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† The authors wish to acknowledge valuable input from Debbie Sivas, Michael Thomas, Al Wanger, Karen Worcester, Mark Gold, Brad Warren, Skyli McAfee, Sarah Sikich, Larry Crowder, Matt Armsby, Ashley Erickson, and Melissa Foley. David Weiskopf provided legal research and editing that substantially improved the product.

I. INTRODUCTION

Ocean acidification is known as "the *other* CO_2 problem,"[1]

1. Scott C. Doney et al., *Ocean Acidification: The Other CO_2 Problem*, 1 ANN. REV. MARINE SCI. 169, 170 (2009).

because it has received less attention than climate change but is similarly caused by rising levels of atmospheric carbon dioxide ("CO_2"). Because the ocean absorbs roughly one-third of the CO_2 that humans release into the atmosphere annually,[2] it is significantly more acidic than it was during the preindustrial era.[3] This more acidic ocean has begun to dissolve the shells and other hard parts of marine organisms and threatens to change fundamentally the marine ecosystems on which a large fraction of the world depends for sustenance,[4] recreation, and a host of other services.[5]

This environmental issue has national and international implications, reaching beyond the coastal states whose shores are most directly threatened. One report estimates that "[m]ore than one third of the world's population will be strongly affected by acidification,"[6] and a recent draft strategic research plan from the National Science and Technology Council notes that "ocean acidification has the potential to increase instability in regions of the world where the effects of decreasing pH on marine life will threaten the food supply of over one billion people."[7] These challenges demand governmental action to address acidification in order to mitigate current and impending harms to fisheries, shellfisheries, and the communities that depend upon them.

Ocean acidification is a large-scale environmental problem that arises from a classic externality problem: Rising

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2. *Id*. at 170.

3. ROYAL SOC'Y, OCEAN ACIDIFICATION DUE TO INCREASING CARBON DIOXIDE vi (2005), www.royalsociety.org/uploadedFiles/RoyalSocietyContent/policy/publications/2005/9634.pdf.

4. The people of some countries (including Indonesia, Cambodia, and Bangladesh) depend upon seafood for more than 50% of their protein; many more countries receive at least 15% of their dietary protein from seafood. Sarah R. Cooley et al., *Ocean Acidification's Potential to Alter Global Marine Ecosystem Services*, 22 OCEANOGRAPHY 172, 172–73, 177 (2009) (citing FOOD & AGRIC. ORG. UNITED NATIONS, THE STATE OF FISHERIES AND AQUACULTURE (2008), www.fao.org/docrep/011/i0250e/i0250e00.htm).

5. *Id*. at 172.

6. ELLYCIA HARROULD-KOLIEB ET AL., OCEANA, MAJOR EMITTERS AMONG HARDEST HIT BY OCEAN ACIDIFICATION: AN ANALYSIS OF THE IMPACTS OF ACIDIFICATION ON THE COUNTRIES OF THE WORLD 2 (2009), http://oceana.org/sites/default/files/Acidity_Vulnerability_Risk_report_2.pdf.

7. NAT'L SCI. & TECH. COUNCIL INTERAGENCY WORKING GRP. ON OCEAN ACIDIFICATION, STRATEGIC PLAN FOR FEDERAL RESEARCH AND MONITORING OF OCEAN ACIDIFICATION 70 (2012), www.st.nmfs.noaa.gov/iwgoa/DRAFT_Ocean_Acidification_Strategic_Research_Plan.pdf.

atmospheric CO_2 concentrations cause wholesale changes to ocean chemistry worldwide, but larger CO_2-emitters do not experience greater harm than do lesser emitters.[8] Worse, the problem has been invisible until very recently. Although it has long been known that the ocean absorbs large volumes of atmospheric CO_2,[9] only in the last fifteen years has the resulting change in acidity received significant scientific attention.[10] The past ten years have seen an explosion of primary scientific literature,[11] but little legal analysis or commentary on ocean acidification. As a result, the legal and policy options lag behind the science even as improved understanding of the phenomenon opens up new policy avenues to combat the global change.

Fixing the problem of ocean acidification will ultimately require that we fix the atmospheric CO_2 problem. Humanity must stop pouring tens of billions of metric tons of CO_2 into the air each year. But while the atmospheric CO_2 problem has been the subject of much discussion over the past two decades,[12] a legislative solution is still nowhere on the horizon in the United States. That we have failed to regulate CO_2 domestically is not surprising, given the institutional incentives and vested interests aligned against the change.[13]

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8. That is, emitters as *individuals* do not experience harm in proportion to their emissions. As *nations*, however, the story is quite different: A 2009 Oceana report found that nations with the highest emissions tended to be the most vulnerable to harm from ocean acidification. *See* HARROULD-KOLIEB ET AL., *supra* note 6, at 2. Six of the top ten emitting nations were also among the top twenty-five most vulnerable nations. *Id.* This analysis suggests the existence of direct incentives for these and other nations to minimize their CO_2 emissions. The authors estimated vulnerability using fish consumption per capita, coral reef area as percentage of exclusive economic zone ("EEZ"), total catch within EEZ, and oceanographic parameters. *Id.* at 6.

9. *See* Roger Revelle & Hans E. Suess, *Carbon Dioxide Exchange Between Atmosphere and Ocean and the Question of an Increase of Atmospheric CO_2 During the Past Decades*, 9 TELLUS 18, 19 (1957) (citing SVANTE ARRHENIUS, LEHRBUCH DER KOSMISCHEN PHYSIK (1903)).

10. *See generally* Joan A. Kleypas et al., *Geochemical Consequences of Increased Atmospheric Carbon Dioxide on Coral Reefs*, 284 SCI. 118 (1999).

11. At least 174 scientific papers on ocean acidification were published in 2011 alone. Web-of-Science BIOSIS Previews search for topic ("ocean acidification") and timespan ("2011"), WEBOFKNOWLEDGE.COM (last searched Nov. 28, 2012).

12. *See generally* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: SYNTHESIS REPORT, CONTRIBUTIONS OF WORKING GROUPS I, II, AND III TO THE FOURTH ASSESSMENT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (2007) [hereinafter SYNTHESIS REPORT] and its many citing references.

13. *See, e.g.*, Steven Mufson, *Climate Change Debate Hinges on Economics*, WASH.

Kyoto and hopeful hints from Durban notwithstanding, the prospects for an international accord for regulating greenhouse gases into the future are similarly bleak.[14]

Given this domestic gridlock, it makes sense to focus on smaller units of government as the prime movers on environmental issues. This is not a new idea, and particularly not with respect to CO_2 and climate change. Within the United States, cities, counties, and states have moved towards limiting greenhouse gas emissions in the absence of federal leadership.[15] Regional climate initiatives play similar roles on somewhat larger spatial scales.[16] And while the jury is still out on whether these efforts will curb the stratospheric rise in emissions,[17] such sub-national progress is progress nonetheless and helps demonstrate the efficacy of mechanisms that could be adopted more widely.

What makes ocean acidification particularly amenable to smaller-scale mitigation is that many existing legal tools are available and up to the task. Even if we still lack the fortitude to tackle CO_2 emissions at a large spatial scale, fast-moving science—in significant part funded by the United States federal government—continues to reveal important details about the mechanisms driving changes to the ocean's chemistry. Those details, in turn, suggest new means of

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POST, Jul. 15, 2007, http://www.washingtonpost.com/wp-dyn/content/article/2007/07/14/AR2007071401246.html (discussing the then-current legislative proposals for a cap-and-trade system to limit emissions, and noting that such a system "would alter the calculations of almost every business; hundreds of billions of dollars of energy investments would be redirected").

14. *See, e.g.*, *Climate Change: The Other Greenhouse Gases*, THE ECONOMIST BABBAGE SCI. & TECH. BLOG (Feb. 20, 2012), www.economist.com/blogs/babbage/2012/02/climate-change ("The UN's climate change summit in Durban last December confirmed how far the world is from limiting its emissions of carbon dioxide, the main greenhouse gas. Everyone agrees that this must be done, but not on who, exactly, should do it.").

15. *See, e.g.*, Kirsten H. Engel & Barak Y. Orbach, *Micro-Motives and State and Local Climate Change Initiatives*, 2 HARV. L. & POL'Y REV. 119 (2008); R. B. McKinstry, Jr., *Laboratories for Local Solutions for Global Problems*, 12 PENN ST. ENVTL. L. REV. 15 (2004).

16. *See generally* Kirsten H. Engel, *Mitigating Global Climate Change in the United States: A Regional Approach*, 14 N.Y.U. ENVTL. L.J. 54 (2005).

17. Global emissions in 2010 were the highest on record for the industrial age, and the current atmospheric concentration of CO_2 is the highest in at least 800,000 years. *See Carbon Budget: Atmospheric CO_2 Growth*, GLOBAL CARBON PROJECT, http://www.globalcarbonproject.org/carbon_budget/12/hl-full.htm (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

ameliorating the effects of acidification using tools already in our legal toolbox, in large part by addressing ancillary environmental degradation and thus shoring up shoreline ecosystems' ability to survive despite an acidifying ocean.

In this Article, we briefly review the science of ocean acidification and explain why it poses a fundamental challenge to ocean ecosystems and many of the services those systems provide. We next review federal and international actions in response, finding that most of these focus on research rather than action. To address this shortfall, we then summarize the tools available to state, tribal, and local governments to respond to acidification, discussing ten specific points of action. These points focus primarily on water quality but also include air quality, state environmental impact statutes, common law causes of action, and changes in land use.[18]

Focusing on governance at smaller spatial scales changes the calculus of incentives. Accordingly, we emphasize actions more closely aligned with local benefits, identifying incentives tailored to the appropriate spatial scale. Such a bottom-up strategy does not solve the global CO_2 problem but instead offers a way forward on an otherwise (seemingly) intractable problem. We hope to provide a means of buying time and improving the quality of state waters, to minimize the economic and environmental impacts of acidification in the near term. In the background, of course, is the fact that we cannot solve ocean acidification without solving the global CO_2 emissions problem.

II. THE SCIENCE OF OCEAN ACIDIFICATION

1. Chemistry

Atmospheric CO_2 dissolves in water, making it more acidic;[19] this process is why, for example, carbonated soda water is

18. We note that acidification also threatens the Great Lakes and other freshwater bodies. We concentrate here on marine protection, but many of the approaches to mitigating ocean acidification apply equally well to management of the Great Lakes and similar systems. Furthermore, although the examples in this Article are primarily drawn from California and Washington, both of which are heavily reliant on coastal and marine resources and services, we believe that the suggestions we provide may be readily applied in any coastal state that seeks to combat the effects of ocean acidification.

19. ROYAL SOC'Y, *supra* note 3, at vi.

more acidic than regular tap water. Since the industrial revolution, this phenomenon has played out on a global scale: The oceans have become more acidic as they have absorbed a large portion of the anthropogenic increase in atmospheric carbon dioxide.[20] This change threatens to disrupt large-scale marine ecosystems and the economic and social activities that depend upon them,[21] in part because the shells and other hard parts of marine animals dissolve more readily in more acidic water.[22] Acidified water from the deep ocean is also reaching into shallower depths more than it did in the past,[23] and because the rate at which atmospheric CO_2 is increasing continues to increase, the rate at which we are changing the ocean's chemistry is increasing in kind.[24] These changes are now well documented, and there is a broad scientific consensus that increasing atmospheric CO_2 is the primary mechanism driving the observed change. Deposition of sulfur oxides ("SO_x") and nitrogen oxides ("NO_x")—familiar as the causes of acid rain—could also directly lower ocean pH as these acidifying compounds dissolve in coastal waters.[25]

Indirect drivers of ocean acidification include nutrient

20. Doney et al., *supra* note 1, at 170.

21. *Id*. at 184.

22. *Id*. at 174.

23. This is known as "shoaling" of more corrosive waters. *See, e.g.,* Claudine Hauri et al., *Ocean Acidification in the California Current System*, 22 OCEANOGRAPHY 60, 69 (2009). Note that more acidic water from the deep ocean routinely comes to the surface near the coastal margins as a result of normal upwelling processes, but upwelled water appears to have become more acidic as a result of anthropogenic CO_2 emissions. *See infra* note 32.

24. *See* Ken Caldeira & Michael E. Wickett, *Anthropogenic Carbon and Ocean pH*, 425 NATURE 365, 365 (2003).

25. Scott C. Doney et al., *Impact of Anthropogenic Atmospheric Nitrogen and Sulfur Deposition on Ocean Acidification and the Inorganic Carbon System*, 104 PROC. NAT'L ACAD. SCIENCES 14,580, 14,583 (2007). Note that this deposition is likely to be a more prominent factor on the east coast of the United States, where coal-fired power plants are much more common, than on the west coast. We note also that the effects of SO_x and NO_x deposition on ocean chemistry are still subjects of active research, with at least one publication suggesting these effects are minimal. *See* Keith A. Hunter et al., *Impacts of Anthropogenic SO_x, NO_x and NH_3 on Acidification of Coastal Waters and Shipping Lanes*, 38 GEOPHYSICAL RES. LETTERS, July 2011 (L13602), at 1. Our purpose here is not to declare the importance of these atmospheric acid gases to coastal ocean acidification, but rather to highlight the tools that are available for mitigating these pollutants in the event that they prove to be substantial contributors to the problem. Even where these gases do not contribute to ocean acidification, they nevertheless remain important air pollutants for which emissions reductions are desirable on environmental and public health grounds.

runoff, which plays an important role in altering marine carbonate chemistry.[26] Nutrient pollution causes local acidification through feedback loops involving biological growth, metabolism, and decay, over and above that which would occur in the absence of nutrient input from humans.[27] These processes use more oxygen than they produce, causing oxygen minimum zones ("dead zones"), and resulting in locally acidified waters.[28] More acidic, lower-oxygen waters are likely to undergo both chronic and acute environmental changes, including a decline in biomass productivity, a factor important to fisheries.[29]

The root causes of acidification—including atmospheric CO_2, nutrient runoff, and SO_x and NO_x deposition—interact with oceanography to create a patchwork of coastal effects.[30] In "upwelling zones"—areas along continental margins where colder, more acidic water from the deep ocean is drawn up to regions such as the west coast of the United States—local "hotspots" of ocean acidification develop.[31] Upwelling is a normal oceanographic process, but upwelled water appears to have become more acidic as a result of dissolved anthropogenic CO_2.[32] This more corrosive water is already apparent at the surface in upwelling zones near Cape Mendocino in northern

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26. Nutrient runoff may have an even greater effect on marine carbonate chemistry than increased CO_2 in some cases. *See generally* Alberto V. Borges & Nathalie Gypens, *Carbonate Chemistry in the Coastal Zone Responds More Strongly to Eutrophication than to Ocean Acidification*, 55 LIMNOLOGY & OCEANOGRAPHY 346 (2010) (modeling the relative impacts of nutrient loading and CO_2-driven acidification in the Belgian Coastal Zone, and finding significantly greater effects of nutrient runoff than atmospheric CO_2 on ocean pH).

27. Wei-Jun Cai et al., *Acidification of Subsurface Coastal Waters Enhanced by Eutrophication*, 4 NATURE GEOSCIENCE 766, 766 (2011).

28. *See* Robert J. Diaz & Rutger Rosenberg, *Spreading Dead Zones and Consequences for Marine Ecosystems*, 321 SCI. 926, 926 (2008).

29. *Id*. at 927.

30. Changes to the hydrologic cycle—for example, the changes in freshwater runoff predicted in northern California due to climate change—will also influence the distribution of acidified hotspots in the coastal ocean. *See* Mark A. Snyder & Lisa C. Sloan, *Transient Future Climate Over the Western United States Using a Regional Climate Model*, 9 EARTH INTERACTIONS, July 2005, at 1 (predicting changes in precipitation patterns in northern California toward the end of the twenty-first century).

31. *See* Ryan P. Kelly et al., *Mitigating Local Causes of Ocean Acidification with Existing Laws*, 332 SCI. 1036, 1036 (2011).

32. *See* Richard A. Feely et al., *Evidence for Upwelling of Corrosive "Acidified" Water onto the Continental Shelf*, 320 SCI. 1490, 1490 (2008).

California and is likely present at other prominent rocky headlands along the west coast.[33] Rising atmospheric CO_2 and patchy upwelling along the shore are the baseline to which we add other stressors such as nutrient runoff.

At present, we cannot attribute a particular fraction of the observed change in coastal waters to any given causal factor (e.g., atmospheric CO_2 or nutrient runoff),[34] although in principle this will become possible as more data become available. While CO_2 is the primary driver of the global background change in ocean pH, non-CO_2 inputs may be more influential in specific coastal regions.[35]

Overall, there is a strong consensus that:

1) Coastal acidification is more severe and rapid in some places due to oceanographic features, biological effects, and land-based pollutants;[36]
2) The chemical changes to the coastal ocean are due to a combination of atmospheric CO_2 and other pollutants, including atmospheric deposition of sulfur and nitrogen compounds, and terrestrial nutrient runoff, as well as possible changes in freshwater input and upwelling;[37]

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33. *Id*. at 1490 fig. 1 (showing corrosive waters at several coastal locations).

34. In part, this difficulty stems from the large natural variation in coastal waters. Shallow ocean waters, bays, and estuaries experience fluctuations of pH and related measures over the course of hours and days. These rapid swings are driven by tides, freshwater input, photosynthesis, shell formation, and respiration, among other factors. *See generally* RICHARD E. ZEEBE & DIETER WOLF-GLADROW, CO_2 IN SEAWATER: EQUILIBRIUM, KINETICS, ISOTOPES (2001). For an example of these changes in the intertidal zone on the exposed Washington coast, see Timothy J. Wootton, et al., *Dynamic Patterns and Ecological Impacts of Declining Ocean pH in a High-Resolution Multi-Year Dataset*, 105 PROC. NAT'L ACAD. SCIENCES 18,848 (2008). Daily and monthly variation in pH at a given coastal site may be of larger magnitude than the entire observed change in baseline ocean pH due to anthropogenic CO_2, and such natural variability poses a challenge for discerning the effects of pollution from natural background variation at small scales. *Id*.; *Li-Qing Jiang et al., Carbonate Mineral Saturation States Along the U.S. East Coast*, 55 LIMNOLOGY & OCEANOGRAPHY 2424, 2425 (2010). For example, in upwelling zones, pH can vary between 8.1 and 7.7 within a week. Gretchen Hofmann et al., *High-Frequency Dynamics of Ocean pH: A Multi-Ecosystem Comparison*, 6 PLOS ONE, Dec. 2011 (e28983) at 4. By contrast, it is estimated that the global ocean pH change due to anthropogenic CO_2 input is 0.1 pH units. Feely et al., *supra* note 32, at 1490.

35. *See* Doney et al., *supra* note 25, at 14,583; Richard A. Feely et al., *The Combined Effects of Ocean Acidification, Mixing, and Respiration on pH and Carbonate Saturation in an Urbanized Estuary*, 88 ESTUARINE, COASTAL & SHELF SCI. 442, 442 (2010); Borges & Gypens, *supra* note 26, at 350–52.

36. *See, e.g.,* Kelly, *supra* note 31, at 1036.

37. *See* Snyder & Sloan, *supra* note 30 (showing predicted changes in precipitation,

and

3) Acidification adds yet another stressor to a growing list of threats to ocean health—including overfishing, habitat destruction, and climate change.[38] Acidification could alter marine food webs substantially,[39] which may undermine the nearshore ecosystem's ability to produce goods and services worth billions of dollars annually.

We have already observed changes in marine ecosystems as a result of increasingly acidic waters. More change is inevitable, both because of lag time associated with ocean circulation patterns[40] and because humanity's CO_2 emissions are unlikely to decline suddenly and precipitously. However, mitigating the causes of ocean acidification at present will pay dividends immediately and in the future, safeguarding a public resource that is a critical center of biological diversity, cultural value, and economic benefit to local communities.

2. Ecology and Biology

An ecosystem is the entire set of interactions among species, including humans, and nonliving components of an environment, such as temperature or sunlight.[41] Given the

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and hence freshwater input, in northern California as a result of climate change); Marisol Garcia-Reyes & John L. Largier, *Observations of Increased Wind-Driven Coastal Upwelling Off Central California*, 115 J. GEOPHYSICAL RES., Apr. 2011 (C04011), at 1 (noting that observed increases in coastal upwelling are consistent with model predictions due to climate change; more persistent or more extreme upwelling would also acidify coastal waters).

38. *See, e.g.,* Robin K. Craig & J. B. Ruhl, *Governing for Sustainable Coasts*, 2 SUSTAINABILITY 1361, 1364 (2010).

39. UNITED NATIONS ENV'T PROGRAMME, ENVIRONMENTAL CONSEQUENCES OF OCEAN ACIDIFICATION: A THREAT TO FOOD SECURITY 1 (2010), www.unep.org/dewa/Portals/67/pdf/Ocean_Acidification.pdf.

40. Ocean water absorbs CO_2 from the atmosphere at the surface. After being submerged and transported by deep ocean currents, a particular water molecule may take decades to reach the surface again. Upwelling along the Pacific coast brings water to the surface that was last in contact with the atmosphere perhaps fifty years ago. To some extent, we are now experiencing acidification from the atmospheric CO_2 of the 1960s. This lag time postpones some of the effects of today's emissions, which are much larger than those of decades past. Feely et al., *supra* note 32, at 1492.

41. Arthur Tansley is credited with coining the term "ecosystem" in 1935 to include "not only the organism-complex, but also the whole complex of physical factors forming what we call the environment of the biome—the habitat factors in the widest sense." Arthur G. Tansley, *The Use and Abuse of Vegetational Concepts and Terms*, 16 ECOLOGY 284, 299 (1935). The term has been widely re-defined since, but retains a core meaning of an inclusive concept of the factors that affect living organisms on

complexity of marine ecosystems, it is unsurprising that ecological effects of an acidifying ocean remain poorly understood relative to the chemistry described above. While adding dissolved CO_2 to the ocean has predictable effects on the ocean's chemistry, there is considerably more we need to learn about the effects of the ocean's chemistry on the coastal ecosystem.

One acidification-related metric of great importance for coastal ecosystems is the relative propensity of many marine organisms' hard parts (such as mollusc shells) to dissolve in seawater.[42] As waters acidify, these hard parts have a greater tendency to dissolve. A growing body of research documents the negative impacts of acidified waters on organismal development,[43] suggesting that acidification in the coastal ocean has the potential to disrupt a wide swath of ecosystem functions. Because juveniles belonging to oyster and related species are especially susceptible to acidification, the shellfish industry is facing an imminent threat. Various industry groups have already taken action to understand and combat the changes that face them.[44]

More broadly, we do know that a more acidic ocean is likely to hinder growth in a wide variety of species, to increase the growth rate of some others, and to have little effect on still others.[45] At least under laboratory conditions, acidified

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Earth.

42. The measure of this propensity is known as the saturation state of calcium carbonate, the material of which most species' hard parts are made. It is symbolized by a capital omega (Ω), and differs depending upon the particular form of calcium carbonate to which it refers. The principal forms are aragonite and calcite, written Ω_{arag} and $\Omega_{calcite}$, respectively. Aragonite is more soluble and therefore under greater threat from ocean acidification. Therefore, Ω_{arag} is a primary factor of interest.

43. *See, e.g.*, Victoria J. Fabry et al., *Impacts of Ocean Acidification on Marine Fauna and Ecosystem Processes*, 65 ICES J. MARINE SCI. 414 (2008).

44. *See, e.g.*, Eric Scigliano, *The Great Oyster Crash*, ONEARTH (Aug 17, 2011), www.onearth.org/article/oyster-crash-ocean-acidification; Janet Krenn, *Virginia's Oyster Industry Taking Proactive Steps to Stay on Top*, VA. INST. MARINE SCI. (Nov. 10, 2011), www.vims.edu/newsandevents/topstories/oyster_acid.php (covering a recent ocean acidification workshop at the Virginia Institute of Marine Science).

45. *See* Justin B. Ries et al., *Marine Calcifiers Exhibit Mixed Responses to CO_2-Induced Ocean Acidification*, 37 GEOLOGY 1131, 1131 (2009) (demonstrating developmental response to undersaturated seawater in eighteen species; of these, ten species had decreased calcification rates, seven had increased rates, and one had no response); Stephanie C. Talmage & Christopher J. Gobler, *Effects of Past, Present, and Future Ocean Carbon Dioxide Concentrations on the Growth and Survival of Larval Shellfish*, 107 PROC. NAT'L ACAD. SCIENCES 17,246, 17,246 (2010) (demonstrating

seawater hampers calcification and reproduction in most animal species studied, and has either neutral or positive effects on photosynthesizing species. Species with already marginal survival rates may be at special risk; for example, acidification further threatens the already-imperiled pinto abalone, whose larvae develop less successfully in a high-CO_2 environment.[46]

Changing the chemical environment could alter the ecological interactions that underpin the living ocean we see today by, for example, changing the balance of power in predator-prey relationships and in competition among species.[47] Commercially important effects of this phenomenon include a significant decrease in salmon biomass in waters where a major food source of juvenile salmon is highly susceptible to acidified waters.[48] Direct human health impacts may include amnesic shellfish poisoning as a result of increased frequency and severity of harmful algal blooms, spurred by a high-CO_2 ocean.[49]

In short, while there is little uncertainty surrounding the chemistry of ocean acidification, the biological and ecosystem effects of those chemical changes are not yet as well understood. However, the impacts are potentially grave for both the ecosystems themselves and the human communities that depend on them.[50]

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decreased and slower growth in two bivalve shellfish under modern CO_2 conditions as compared with preindustrial conditions); Fabry et al., *supra* note 43, at 423–24. *See generally* Kristy J. Kroeker et al., *Meta-Analysis Reveals Negative Yet Variable Effects of Ocean Acidification on Marine Organisms*, 13 ECOLOGY LETTERS 1419 (2010).

46. Ryan N. Crim et al., *Elevated Seawater CO_2 Concentrations Impair Larval Development and Reduce Larval Survival in Endangered Northern Abalone* (Haliotis kamtschatkana), 400 J. EXPERIMENTAL MARINE BIOLOGY & ECOLOGY 272, 274 (2011).

47. For example, decreased shell thickness and strength in mussels under acidified conditions may make species more vulnerable to predation and breaking waves. Brian Gaylord et al., *Functional Impacts of Ocean Acidification in an Ecologically Critical Foundation Species*, 214 J. EXPERIMENTAL BIOLOGY 2586, 2592 (2011).

48. *See* Fabry et al, *supra* note 43, at 426.

49. Acidified waters facilitate faster growth rates of harmful algal species, as well as greater concentrations of domoic acid—the toxin that causes amnesic shellfish poisoning in humans—within algal cells. Jun Sun et al., *Effects of Changing pCO_2 and Phosphate Availability on Domoic Acid Production and Physiology of the Marine Harmful Bloom Diatom Pseudo-nitzschia Multiseries*, 56 LIMNOLOGY & OCEANOGRAPHY 829, 829 (2011).

50. Of course, species have the capacity to evolve in response to environmental change, typically over long time horizons. One emerging question is whether and how today's species will evolve in response to ocean acidification. One recent study

III. FEDERAL AND INTERNATIONAL RESPONSE

The United States government has begun to take notice of the acidifying ocean in small but important ways. In 2009, Congress passed legislation focused on ocean acidification,[51] establishing a federal interagency working group on the issue[52] and a research program within the National Oceanic and Atmospheric Administration ("NOAA").[53] The Ocean Acidification Task Force ("OA Task Force"), consisting of a collection of independent scientists and policymakers,[54] was convened to provide advice to the interagency working group.

The National Research Council has also issued a report[55] in response to a Congressional mandate in the 2006 Magnuson-Stevens Fishery Conservation and Management Act.[56] This

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estimates the different evolutionary capacities of two important nearshore species—red sea urchins (*Strongylocentrotus franciscanus*) and mussels (*Mytilus trossulus*)—and concludes the urchin species has a much greater capacity to adapt to acidified conditions. Jennifer M. Sunday et al., *Quantifying Rates of Evolutionary Adaptation in Response to Ocean Acidification*, 6 PLOS ONE, Aug. 2011 (e22881), at 1. This work is the beginning of a larger effort to unravel the evolutionary consequences of acidification, and highlights the ecosystem changes that are inevitable as human pollution creates winners and losers among species in the coastal ocean.

51. Federal Ocean Acidification Research and Monitoring ("FOARAM") Act, 33 U.S.C. §§3701–08 (2009) (authorizing funding, developing interagency plan on ocean acidification, and establishing an acidification program within the National Oceanographic and Atmospheric Administration).

52. *See* INTERAGENCY WORKING GROUP ON OCEAN ACIDIFICATION, www.st.nmfs.noaa.gov/iwgoa/ (last visited Jan. 23, 2013) (on file with the Harvard Law School Library). This working group has now developed a draft strategic plan for research on ocean acidification. *See supra* note 7.

53. *See NOAA OA [Ocean Acidification] Plan*, NOAA, www.pmel.noaa.gov/co2/story/NOAA+OA+Plan (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

54. The OA Task Force operates under the purview of the Ocean Research and Resources Advisory Panel ("ORRAP"), an advisory body that offers "independent advice and recommendations to the heads of federal agencies with ocean-related missions." OCEAN ACIDIFICATION TASK FORCE, SUMMARY OF WORK COMPLETED AND RECOMMENDATIONS FOR ORRAP TO CONVEY TO THE IWGOA 2 (2011), www.nopp.org/wp-content/uploads/2010/03/OATF-REPORT-FINAL-4-21-11.pdf.

55. NAT'L RESEARCH COUNCIL, OCEAN ACIDIFICATION: A NATIONAL STRATEGY TO MEET THE CHALLENGES OF A CHANGING OCEAN (2010), https://download.nap.edu/catalog.php?record_id=12904. *See also* NAT'L SCI. & TECH. COUNCIL JOINT SUBCOMMITTEE ON OCEAN SCI. & TECH., CHARTING THE COURSE FOR OCEAN SCIENCE IN THE UNITED STATES FOR THE NEXT DECADE: AN OCEAN RESEARCH PRIORITIES PLAN AND IMPLEMENTATION STRATEGY (2007), www.whitehouse.gov/sites/default/files/microsites/ostp/nstc-orppis.pdf.

56. P.L. 109–479 § 701.

report is an important marker, consolidating the available scientific information and identifying outstanding uncertainties to guide future research.[57]

Federal research dollars have increasingly gone to support primary research on ocean acidification in the past two years. One metric for this rise is the number of National Science Foundation ("NSF") grants given to ocean acidification research: Of the 177 grants with the phrase "ocean acidification" in the title or abstract of the award, 176 of them (99.5%) have been awarded since 2006.[58] The overall amount of grant money awarded has increased sharply in recent years: Between 2006 and 2008, NSF awarded a total of $ 19.7 million for ocean acidification research, while that number more than tripled between 2009 and 2011, rising to $ 74.4 million.[59] The results of this investment have been immediate and tangible, as the number of publications on ocean acidification has skyrocketed since 2006.[60] Fully one-half of the primary scientific literature on ocean acidification has been published in 2011-12 alone,[61] a sign of tremendous growth in this area of

57. NAT'L RESEARCH COUNCIL, *supra* note 55, at 2. The report also notes that "the federal government has taken initial steps to respond to the nation's long-term needs and . . . the national ocean acidification program currently in development is a positive move toward coordinating these efforts." *Id*. at 6.

58. The increase in per-year awards is also striking: 11 in 2006, 9 in 2007, 14 in 2008, 37 in 2009, 58 in 2010, 48 in 2011, and 50 in 2012. *Awards Advanced Search*, NAT'L SCI. FOUND., www.nsf.gov/awardsearch (advanced search "ocean acidification" by award year) (search performed on Jan. 13, 2013) (results on file with authors).

59. This total does not include a $148 million grant to the University of Alaska, Fairbanks, for shipyard construction costs (award number 939812). *See Award Abstract 939812, Construction and Operation of the Alaska Region Research Vessel: Phase III - Shipyard Construction Costs*, NAT'L SCI. FOUND. (last amended Mar. 7, 2012), http://www.nsf.gov/awardsearch/showAward?AWDID=0939812&HistoricalAwards=false.

60. Google Scholar provides only a rough gauge of the trajectory of this publication boom (due to multiple entries for the same publication, and other problems), but captures a wider spectrum of publications than purely academic search tools (see BIOSIS search, *infra*, note 61). GOOGLE SCHOLAR reports that of 9280 total publications responding to the search term "ocean acidification," 7340 (79%) have been published since 2006. GOOGLE SCHOLAR, www.scholar.google.com (search "ocean acidification") (search performed Dec. 6, 2011) (results on file with authors). 6410 (69%) have come since 2008, and nearly half (3990, 43%) have come since 2010. *Id*.

61. A search of BIOSIS—an authoritative database for scientific publications—finds that 384 of 664 total records for the topic "ocean acidification" were published in 2011 and 2012 (57.8%). Web of Knowledge, www.webofknowledge.com (record search "ocean acidification") (search performed on Jan. 13, 2013) (results on file with authors). Another 119 (17.9%) were published in 2010, and 85 (12.8%) in 2009. *Id*.

research.

Other nations have responded to ocean acidification in a similar fashion to the United States, sponsoring research and collaboration among scientists.[62] Germany's BIOACID program, for example, explores the responses of marine species to an acidifying ocean and to multiple related stressors.[63] China, Japan, and Korea have programs that do likewise.[64] The European Project on Ocean Acidification ("EPOCA"), now completed, was an international collaboration among 27 European member organizations focusing on primary research issues and education.[65]

These national and international actions highlight the importance of ocean acidification and have already proved crucial in generating the research that underpins our understanding of the phenomenon. However, every one of these efforts goes towards documenting and understanding what we already know is a problem; not one affirmatively begins to fix the problem of ocean acidification. In large part, this lack of action is likely due to the daunting mismatch of incentives that has plagued efforts to reduce CO_2 emissions and other pollutants.

Below, we provide some concrete first steps that local and state governments can take now to mitigate the causes and effects of coastal ocean acidification. As we note above, these smaller spatial scales offer an immediate way forward, buying time while work progresses on a global CO_2 solution. We focus on domestic laws of the United States, with a special emphasis on California because of its extensive water quality laws and economically important coastal resources.

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62. *See generally* Heidi R. Lamirande, *From Sea to Carbon Cesspool*, 34 SUFFOLK TRANSNAT'L L. REV. 183, 198–205 (2011) (reviewing foreign jurisdictions' ocean acidification laws, as well as the applicability of international law).

63. *See Biological Impacts of Ocean Acidification*, BIOACID, www.bioacid.de (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

64. Lamirande, *supra* note 62, at 201–02.

65. *See EPOCA Web Site*, EUROPEAN PROJECT ON OCEAN ACIDIFICATION, www.epoca-project.eu (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

IV. INCENTIVES AND RATIONALE FOR SUB-NATIONAL ACTION

Coastal regions are where ecosystems are most productive,[66] where most people live,[67] and, accordingly, where there is the largest nexus of human-environment interaction and dependence. Furthermore, newly available information shows that auxiliary (non-CO_2) drivers can contribute substantially to an acidified condition in some localities, and that these drivers have the most impact in coastal regions. This is (relatively speaking) good news: It means that important problems near shore are the easier ones to fix, because these auxiliary stressors derive from local and identifiable sources, rather than global and diffuse CO_2. Reducing such stressors also contribute to the resilience of coastal ecosystems, bolstering their ability to endure the increasingly acidic ocean environment.[68]

The more we learn about the mechanisms of a particular environmental problem, the more legal hooks we can identify to address it. This relationship is in many ways analogous to the relationship between medical research and drug development: More details on precisely how a disease works yields more points of entry for a potential drug to disrupt the disease's progress. Taking the analogy one step further, it is much cheaper, faster, and easier to use existing drugs to fight off new diseases than it is to develop new drugs. Existing laws function in much the same way. They serve as ready-made tools that, if effective, are valuable means of addressing emerging problems such as ocean acidification.

This analogy demonstrates the importance of new data and reveals that attacking the problem in the nearshore environment makes sense in at least two ways. First, reducing

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66. *See* Francis Chan et al., *Emergence of Anoxia in the California Current Large Marine Ecosystem*, 319 SCI. 920, 920 (2008).

67. For example, more than half of Americans live within fifty miles of the coast. *Ocean Facts*, NOAA, http://oceanservice.noaa.gov/facts/population.html (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

68. *See* Caitlin Mullan Crain et al., *Interactive and Cumulative Effects of Multiple Human Stressors in Marine Systems*, 11 ECOLOGY LETTERS 1304, 1304 (2008) (finding that, in general, combinations of stressors on marine systems tend to harm the ecosystem to a greater extent than the sum of the individual stressors would; this work implies that reducing individual stressors—such as nonpoint source runoff—increases the ability of the system to withstand other stressors such as ocean acidification).

impacts in coastal areas could help ameliorate harm in the sites that most urgently need attention. Second, tackling coastal impacts is a means of mitigating some of acidification's effects while international and national action on CO_2 progresses. As we head toward a profoundly changed world, in which the chemistry of the ocean has seen a wholesale shift, we must minimize the resulting societal and ecological harms in whatever ways we can.

Fortunately, the acidification-mitigating avenues we discuss below dovetail with existing environmental priorities. There is little or no tradeoff between the demands of current statutes and the means of addressing the emerging challenges of ocean acidification. Decreasing water and air pollution has been an important priority for many years; the new information about acidification simply strengthens the imperative for environmental protection of our coasts. Acting to combat the observed and anticipated changes to the coastal ocean therefore represents a responsible path to safeguarding our nearshore ecosystems.

V. INCENTIVES AND OBSTACLES TO ACTION

Focusing on the state and sub-state jurisdictional levels eliminates any federalism concerns, because the states' plenary power means that they certainly have the authority to regulate discharges and other inputs to coastal waters in the interest of public health and safety.[69] So, in general, a state could act to ameliorate acidification by creating a more stringent standard,[70] but why should it want to?

The efforts we discuss below each depend upon the willingness and ability of state administrative agencies to add ocean acidification to the portfolio of issues for which they are responsible. This is not a trivial hurdle. State environmental regulatory agencies have substantial counterincentives to tackling yet another environmental issue. Limited (and shrinking) budgets may be the prime stumbling block in many

69. Federal preemption is generally not a barrier to state action in pollution prevention and remediation. For example, both the Clean Water Act and the Clean Air Act function as floors to (rather than ceilings on) state regulation in these arenas. *See* discussion *infra* Section VI(1).

70. But *see infra* note 74 for a brief discussion of the "no more stringent" laws that exist in some states.

cases, but institutional momentum, a workload full of existing priorities, and the significant political costs associated with any regulation all surely argue against taking on a new issue such as ocean acidification. But if this were the end of the calculation, arguably no environmental law would exist.

A fair treatment of incentives and economic efficiency is well beyond the scope of this article, but we note that in order to tackle ocean acidification on a local scale, a state administrative agency's immediate incentives to do so must outweigh its incentives to the contrary. But even where long-term gains are likely to outweigh the short-term costs by a large margin—such as is the case in acting to avoid environmental harms before they become expensive or impossible to rectify—an agency's immediate incentives often prevent it from acting.

As we discuss various options for state action below, we note economic benefits that are likely to help ease the relevant burdens. These benefits alone are unlikely to drive an agency decision to deal with acidification, especially where infrastructure upgrades are costly (as in the case of publicly owned treatment works) or where the political costs of regulation are particularly high (as in the case of nonpoint source regulation of irrigated agriculture). However, the primary function of state environmental agencies is to maintain and improve the quality of the environment in which their constituents live,[71] and this function provides additional weight to the argument for action, even where economic incentives are insufficient drivers of change. What is more, at the state level, environmental agencies are the only government bodies whose job it is to deal with some of the

71. Washington State's Department of Ecology, for example, describes its mission as "to protect, preserve and enhance Washington's environment, and to promote the wise management of our air, land and water for the benefit of current and future generations." *About Us*, WASH. STATE DEP'T of ECOLOGY, www.ecy.wa.gov/about.html (last visited Jan. 23, 2013) (on file with the Harvard Law School Library). South Carolina's Department of Natural Resources lists its mission as "serving as the principal advocate for and steward of South Carolina's natural resources." *History and Purpose of the Dept. of Natural Resources*, S. C. DEP'T OF NAT. RES., www.dnr.sc.gov/admin/history.html (last visited Jan. 23, 2013) (on file with the Harvard Law School Library). The Massachusetts Department of Environmental Protection's mission is "ensuring clean air and water," among other functions. *About MassDep*, MASS. DEP'T OF ENVTL. PROTECTION, www.mass.gov/dep/about/ (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

causes of ocean acidification, and therefore they may be more likely to address the problem than would be the case if they were merely one among many agencies with overlapping jurisdictions.[72]

Another important driver of action is that the harms associated with ocean acidification, though already being felt, will continue to worsen. Indeed, the most significant impacts are still largely in the future. The next decade will be worse than this decade, on average.[73] As conditions deteriorate, the problem will eventually force its way onto the agendas of coastal resource and environmental agencies.

Perhaps through a combination of internal institutional motivation, economic benefits of harm avoided, and leadership from select jurisdictions with the greatest perceived threats, state and local agencies will begin to address acidification in a way that national and international governments have so far failed to do. Where available, citizen suits could help this effort along.

In addition to the ordinary obstacles that impede regulatory action on emerging environmental problems, one particularly notable obstacle arises where states have bound their own hands by adopting laws that link the stringency of state environmental regulation to the levels set by the federal government. These laws, known as "no more stringent" rules, effectively make federal environmental rules both a regulatory floor (under federal law) and ceiling (under state law), and function as barriers to state efforts to fill federal regulatory gaps.[74] Five coastal states have such laws for water quality.[75]

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72. Anecdotal evidence suggests that this phenomenon does occur. For example, staff members of California's Central Coast Regional Water Quality Control Board took on nonpoint source pollution creating toxic levels of pollutants in drinking water after being reminded that if they failed to act, no one else would. Telephone Interview with Michael Thomas, Deputy Executive Officer, Central Coast Regional Water Quality Control Board (Dec. 7, 2011) (on file with authors).

73. *See generally* James C. Orr et al., *Anthropogenic Ocean Acidification Over the Twenty-First Century and its Impact On Calcifying Organisms*, 437 NATURE 681 (2005).

74. For a discussion of these rules and related state efforts to bolster property rights in ways that hamper environmental regulation, *see generally* Andrew Hecht, *Obstacles to the Devolution of Environmental Regulation: States' Self-Imposed Limitations on Rulemaking*, 15 DUKE ENVTL. L. & POL'Y FORUM 105 (2004); Jerome M. Organ, *Limitations on State Agency Authority to Adopt Environmental Standards More Stringent Than Federal Standards*, 54 MD. L. REV. 1373 (1995). With respect to air quality, twenty-six states have similar "no more stringent" laws or policies. William L.

"No more stringent" laws probably have little practical effect. First, in no case are these laws incorporated into state constitutions.[76] As such, state legislatures may change these statutes—or carve out exceptions to them—by the same procedural means as would be necessary to amend the focal environmental laws themselves.[77] In some states, the laws pose only minor hurdles, merely requiring an administrative justification for proposed rules that would impose stricter pollution controls.[78] In other states, case law has limited the statute's effect by requiring strictly comparable federal and state regulations before weighing the relative stringency of proposed rules.[79] Finally, there remains the fact that even states without "no more stringent" laws rarely impose regulations beyond federal requirements,[80] so as a practical matter, whether a state has or has not expressly limited its own power makes little difference.

The existence of "no more stringent" laws is therefore perhaps more a marker of a state's political attitude towards environmental regulation than an ironclad barrier to rigorous pollution control. Nevertheless, as we discuss below the options for states, tribes, and local governments to combat ocean acidification, we note that a few coastal jurisdictions will also have to surmount their own existing "no more stringent" laws.

Andreen, *Federal Climate Change Legislation and Preemption*, 3 ENVTL. & ENERGY L. & POL'Y J. 261, 302 (2008).

75. As of 2004, a total of seventeen states had general "no more stringent" laws regarding water quality. Of these, only Florida, Maine, Maryland, Mississippi, and Pennsylvania (which has a strong influence on the Delaware and Chesapeake Bays) are coastal. Hecht, *supra* note 74, at 269 n.43. Under Hecht's ranking system, the laws of Maine and Maryland pose only low barriers to heightened water quality requirements, Pennsylvania and Florida have modest barriers, and Mississippi has a significant barrier to more stringent environmental regulation. *Id*. at 132–33.

76. *Id*. at 112.

77. *Id*.

78. Maine, for example, has such a scheme. *Id*. at 122; ME. REV. STAT. ANN. tit. 38, § 341-H(3) (A–B) (2011).

79. A Florida appellate court, for example, limited the application of that state's "no more stringent" statute to instances where state and federal regulations could be easily compared. Fla. Elec. Power Coordinating Grp. v. Askew, 366 So.2d 1186, 1188 (Fla. Dist. Ct. App. 1978) ("The federal standard must be in counterpoise to the state standard."). The court found that while the Clean Air Act provided such a basis for comparison (National Primary and Secondary Ambient Air Quality Standards), the Clean Water Act did not. *Id*.; *see also* Organ, *supra* note 74, at 1400–02 (discussing the Askew case).

80. *See* Andreen, *supra* note 74, at 280.

VI. TEN SUGGESTIONS FOR STATE AND LOCAL ACTION

1. Create More Stringent Technology-Based Clean Water Act Standards for the Most Harmful Point Sources

States and tribes implement the Clean Water Act ("CWA" or "the Act")[81] primarily through two mechanisms: permitting specific levels of pollution from individual point sources (National Pollution Discharge Elimination System or "NPDES" permits)[82] and assessing pollutant levels and allocating tolerable pollutant loads, which, if achieved, will lead to protection of water quality (Total Maximum Daily Loads or "TMDLs").[83] These mechanisms function in tandem to apply the state's adopted water quality standards, which provide the particular targets for legally acceptable levels of water pollution.[84] Where a water body does not meet the applicable water quality standards, the state must list it as impaired and develop TMDLs for the pollutants leading to the impairment.[85] States thus implement the federal Clean Water Act in part by setting water quality standards for water bodies within their jurisdictions.[86]

Water quality standards for a particular water body consist of three major parts: designated uses of the water body (e.g., swimming, shellfish culture, recreation), water quality criteria (numerical or narrative limits for particular pollutants sufficient to maintain the designated uses), and an anti-degradation policy.[87]

However, much of the enforcement power of pollutant-discharge permits arises from federal guidelines that establish technology-based standards for a wide variety of point

81. 33 U.S.C. §§ 1251–1387 (2006).

82. 33 U.S.C. § 1342.

83. 33 U.S.C. § 1313(d)(1)(C).

84. NPDES permit limits take the forms of technology-based limitations and water quality-based limitations. However, water quality-based limitations only apply if the technology-based limits are insufficient to meet the overall water quality standards. 33 U.S.C. § 1313(d)(1)(A).

85. 33 U.S.C. § 1313(d). This is known as the "303(d)" list.

86. 40 C.F.R. §§ 131.2, 131.6 (2012).

87. 33 U.S.C. § 1311(c)(2)(A); 40 C.F.R. § 131.6; *see also* Nat. Res. Def. Council v. EPA, 16 F.3d 1395, 1400 (4th Cir. 1993).

sources.[88] Only when these technology-based standards are insufficient to meet the water quality standards do the quality-based metrics begin to have real effect. Because technology-based standards—rather than water quality-based standards—are a primary means by which the Clean Water Act functions, using state authority to alter or augment them is one of the most direct means of controlling acidifying discharges via the Act.

Although it is not explicit in the Act, states and regional rulemaking bodies have the authority to make these technology standards more stringent than the federal guidelines require.[89] The Act contemplates a lead role for states in setting applicable clean water standards, and case law supports states' power to create more stringent standards. For example, in Shell Oil Co. v. Train[90] the Ninth Circuit noted that:

> Congress sought "to recognize, preserve, and protect the primary responsibilities and rights of States to prevent, reduce, and eliminate pollution." The role envisioned for the states under the 1972 amendments is a major one, encompassing both the opportunity to assume the primary responsibility for the implementation and enforcement of federal effluent discharge limitations and the right to enact requirements which are more stringent than the federal standards . . . . Congress clearly intended that the states would eventually assume the major role in the operation of the NPDES program.[91]

The federal guidelines accordingly operate as a floor for clean water protection, rather than a ceiling, and, in general, states may make the guidelines more stringent than the federal EPA requires.[92]

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88. 33 U.S.C. § 1311(b)(1)(C).

89. California, for example, has regional water boards that issue NPDES permits and which have the authority to create permit limitations. CAL. WATER CODE §§ 13100, 13160.

90. 585 F.2d 408 (9th Cir. 1978).

91. *Id*. at 410 (emphasis added) (citations omitted).

92. Washington State, for example, has altered technology-based effluent standards for combined waste treatment facilities and for municipal water treatment plants. *See* WASH. ADMIN. CODE § 173-220-130(a) (2012). Note that states with "no more stringent" laws face additional hurdles. *See* discussion *supra* notes 77–78 and accompanying text.

To better address the acidifying ocean, states and regional bodies could redefine the existing technology-based discharge standard for a subset of point sources that most strongly contribute to ocean acidification.[93] Those sources generating low pH, high biological oxygen demand,[94] or high nutrient output—such as pulp mills, concentrated animal feeding operations, and sewage outflows—are the most likely to contribute to coastal acidification through their discharges. By augmenting the federal technology-based standards to better control effluent pH of selected categories of point sources, states could therefore exploit a significant opportunity for mitigation.

Developing new technology-based standards is eminently feasible from a scientific standpoint, although political opposition to regulation remains a hurdle. Moreover, such a change would only address point sources, which are subject to technology-based standards, rather than nonpoint sources, which constitute the majority of terrestrial input to the coastal ocean in many regions.[95] Nevertheless, greater scrutiny of the most high-risk point sources would at least partially address coastal acidification and would have the additional benefits of minimizing eutrophication, harmful algal blooms, and dead zones along the coast, thus ameliorating multiple ills with a single regulatory change.

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93. EPA provides guidance for supplementing existing categorical technology-based standards in the case of publicly owned treatment works ("POTWs"). *See* EPA, LOCAL LIMITS DEVELOPMENT GUIDANCE 1–3 (2004), www.epa.gov/npdes/pubs/final_local_limits_guidance.pdf ("EPA's promulgation of categorical standards does not relieve a POTW from its obligation to evaluate the need for and to develop local limits to meet the general and specific prohibitions in the General Pretreatment Regulations.").

94. Biological oxygen demand ("BOD") is a parameter of regulatory interest where human inputs to water bodies cause a lack of oxygen in the water due to respiration. BOD is essentially "food" for bacteria and other microbes, which eat the available organic compounds in the water and, by metabolism, use up the available oxygen. Where there is less food, there is accordingly less oxygen demand. This relates to ocean acidification because the byproduct of that metabolism is CO_2; just as we exhale, so do marine microbes. This exhaled CO_2 contributes to ocean acidification in the same way as does atmospheric CO_2. *See generally* Cai et al., *supra* note 27.

95. *See generally* O. A. Houck, *The Clean Water Act Returns (Again): Part I, TMDLs and the Chesapeake Bay*, 41 ENVTL. L. REP. NEWS & ANALYSIS 10,208 (2011). Michael Thomas, Assistant Executive Director of California's Central Coast Regional Water Quality Control Board, reports that in his region, "the mass pollutant loading from irrigated agriculture [a nonpoint source] dwarfs all other sources." Email from Michael Thomas, Assistant Exec. Director, Cal. Central Coast Regional Water Quality Control Board to Ryan P. Kelly, (Nov. 4, 2011) (on file with authors).

2. Change Water Quality Criteria for Marine pH and Related Parameters

More stringent water quality criteria could better protect coastal ecosystems via implementation under existing NPDES and TMDL programs where technology-based standards are insufficient to safeguard the receiving waters. If enforced, these criteria could help ameliorate the causes of locally intensified ocean acidification. However, water quality standards function mainly as backup rules, reinforcing the technology-based standards that the federal EPA has promulgated for various classes of dischargers. Only where technology-based standards are insufficient to safeguard the designated uses of a water body will a NPDES permit incorporate discharge limits tied to water quality.[96]

In principle, TMDLs limit the overall amount of pollution—not just that portion coming from point sources—entering a particular water body and causing it to fall short of the published water quality standards.[97] In practice, the burden of bringing a water body into compliance falls on the NPDES-permitted point sources rather than on nonpoint sources, because NPDES permits for discharge into impaired waters must be made more stringent to remedy the impairment.[98] Unless states demand otherwise, nonpoint sources run up the

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96. 40 C.F.R. §§ 131.2, 131.6 (2012); *see also* Nat. Res. Def. Council, Inc. v. EPA, 16 F.3d 1395, 1399–40 (4th Cir. 1993); K. M. McGaffey & K. F. Moser, *Water Pollution Control Under the National Pollutant Discharge Elimination System*, *in* CLEAN WATER ACT HANDBOOK 27, 39 (M. A. Ryan ed., 3d ed., 2011).

97. TMDLs for a given pollutant are allocated between point sources and nonpoint sources, 40 C.F.R. § 130.2(i), with a margin of error to account for uncertainty, which EPA may determine on an ad hoc basis. *See* Nat. Res. Def. Council, Inc. v. Muszynski, 268 F.3d 91, 96 (2d Cir. 2001). For a cogent encapsulation of the non-mandatory nature of TMDLs, see City of Arcadia v. EPA, 265 F. Supp. 2d 1142, 1144–45 (N.D. Cal. 2003) (stating that

> TMDLs established under Section 303(d)(1) of the CWA function primarily as planning devices and are not self-executing. A TMDL does not, by itself, prohibit any conduct or require any actions. Instead, each TMDL represents a goal that may be implemented by adjusting pollutant discharge requirements in individual NPDES permits or establishing nonpoint source controls. Thus, a TMDL forms the basis for further administrative actions that may require or prohibit conduct with respect to particularized pollutant discharges and water bodies.)

(emphasis added) (citations omitted).

98. *See* Friends of Pinto Creek v. EPA, 504 F.3d 1007, 1011–15 (9th Cir. 2007) (interpreting the Clean Water Act's TMDL provision and its impacts on point and nonpoint sources); *see also* Houck, *supra* note 95, at 10,210 (discussing the impact of nonpoint regulation on point sources).

bill, and point sources are stuck paying the check.

TMDLs thus have little in the way of mandatory authority over existing nonpoint sources, their prime regulatory targets.[99] States could give them teeth by imposing real limits on nonpoint source pollution. States have the sole authority to regulate nonpoint sources under the Clean Water Act, and therefore have the discretion to implement a TMDL's load allocations as they see fit.[100] If accompanied by enforcement measures, TMDLs could form the basis of nonpoint source regulation that could significantly improve the quality of coastal waters.[101] Of course, this opportunity has been there all along, and the failure of states to create enforceable TMDLs is a well-known problem.[102]

Nevertheless, TMDLs offer some benefits even in the absence of mandatory pollution limits. Most prominent among these is greater protection for already-impaired water bodies, as the TMDL bars new point source permits for discharges that would "cause or contribute to the violation of water quality standards."[103] This provision could be of particular use in impaired coastal areas with increasing urban and industrial density, forcing parties to the table to grapple with how to

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99. *See* Houck, *supra* note 95, at 10,210. However, note that California's Porter-Cologne Act requires even nonpoint source dischargers to file a report of each discharge. *See* CAL. WATER CODE §§ 13260, 13269 (West 2012). Failing to file such a report is a misdemeanor and also punishable by civil fine. CAL. WATER CODE § 13261 (West 2012). Note also that California's regional water boards and the California Coastal Commission accordingly see TMDLs as largely informational, rather than regulatory. For example, California's Nonpoint Source Implementation Plan describes TMDLs as "planning tool[s] that will enhance the State's ability to foster implementation of appropriate [nonpoint source management measures]. By providing watershed-specific information, TMDLs will help target specific sources and corresponding corrective measures and will provide a framework for using more stringent approaches that may be necessary to achieve water quality goals and maintain beneficial uses." STATE WATER RES. CONTROL BD. & CAL. COASTAL COMM'N, NONPOINT SOURCE PROGRAM STRATEGY & IMPLEMENTATION PLAN, 1998–2013 (PROSIP), Vol. I, at ii (2000) [hereinafter PROSIP], www.coastal.ca.gov/nps/prosipv1.pdf.

100. Pronsolino v. Nastri, 291 F.3d 1123, 1140 (9th Cir. 2002).

101. Note that the California Nonpoint Source Implementation Plan sets out sixty-one management measures (akin to best practices) that bear on various sources of nonpoint source pollution. *See* PROSIP, *supra* note 99. These are largely voluntary, with state-provided incentives for participation that include grants under Section 319(h) of the Clean Water Act and also waivers of waste discharge requirements. *Id.*

102. *See* Houck, *supra* note 95, at 10,210.

103. 40 C.F.R. § 122.4(i) (2012). *See also Friends of Pinto Creek*, 504 F.3d at 1011–15.

maintain local water quality and balance its uses appropriately. The TMDL process also generates a level of visibility that could be helpful in the case of ocean acidification, an issue that is still emerging into regulatory consciousness. Finally, because our understanding of coastal acidification has been hindered by a scarcity of reliable monitoring, the data-collection aspect of a TMDL process would also be valuable.

Because of the spatial variability inherent in the coastal ecosystem, making blanket rules for nonpoint source pollution could be an overbroad approach to addressing acidification. Conversely, creating many watershed-specific rules is difficult from a technical standpoint and is labor intensive. A patchwork of regulation would also erode regulatory certainty for landowners and increase their costs of gathering information. If wide swaths of coastline share particular chemical or ecological properties, regional-scale rules could make both permitting and enforcement easier while effectively improving the health of the coastal ocean.

A. TMDLs for Non-Atmospheric Drivers of Acidification

Federal guidelines exist as baseline numerical water quality criteria for pH, dissolved oxygen, nitrates, and phosphates, among other acidification-relevant parameters.[104] As with technology-based standards, states are free to make their criteria more stringent than the federal guidelines, and states are free to establish criteria for pollutants for which federal guidelines do not exist.[105] The criteria are reviewable by

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104. Each of these parameters is directly relevant to ocean acidification: pH measures the acidity directly, dissolved oxygen is inversely correlated with the eutrophication associated with local nutrient plumes, and both nitrates and phosphates are constituent elements of such plumes. Because eutrophication can lead to acidifying bottom waters—particularly in stratified water columns and water bodies with long residence times—it contributes to coastal acidification. In this context, "residence time" refers to the length of time a particular water mass remains within a specified geographic area such as a bay or estuary. Waters with longer residence times therefore have longer periods in which to accumulate CO_2, as the waste products of the resident animals and bacteria build up. *See* WASH. SHELLFISH INITIATIVE BLUE RIBBON PANEL ON OCEAN ACIDIFICATION, SCIENTIFIC SUMMARY OF OCEAN ACIDIFICATION IN WASHINGTON STATE MARINE WATERS 33 (Richard A. Feely et al. eds., 2012).

105. *See, e.g.*, PUD No. 1 of Jefferson Cnty. v. Wash. State Dep't of Ecology, 511 U.S. 700, 712 (1994)

> (The State can only ensure that the project complies with "any applicable effluent limitations and other limitations, under 33 U.S.C. §§ 1311, 1312" or certain other provisions of the Act, "and with any other appropriate requirement of State law."

administrative action rather than legislation, making them easier to adjust to reflect the rapidly developing science of ocean acidification.

Agencies have so far been slow to translate the growing mass of data on ocean acidification into action. In 2008, Washington State declined to include any marine waters on its list of impaired water bodies, resulting in a lawsuit by the Center for Biological Diversity and a subsequent settlement.[106] As a result of that settlement, the federal EPA requested data on the matter and considered altering the national guideline for marine pH.[107] EPA ultimately decided against adjusting its guidance for water quality criteria with respect to pH, citing insufficient information to change the federal standard.[108] No state has yet created a more stringent guideline. Like the federal EPA, California's state water board is also awaiting more data before revising the marine pH criterion,[109] and has accordingly declined to list any marine waters as impaired for pH.[110] Other coastal states appear to be doing the same.

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33 U.S.C. § 1341(d) . . . . As a consequence, state water quality standards adopted pursuant to § 303 are among the "other limitations" with which a State may ensure compliance through the § 401 certification process . . . . [A]t a minimum, limitations imposed pursuant to state water quality standards adopted pursuant to § 303 are "appropriate" requirements of state law.).

106. Ctr. for Biological Diversity v. EPA, No. 2:09-cv-00670-JCC (W.D. Wash. 2009). Note that Washington was not the defendant in this suit; rather, the Center for Biological Diversity sued the federal EPA for approving Washington's list of impaired waters, which had not included any marine waters impaired for pH. Washington has since labeled the acidified Puget Sound as "waters of concern." *See Water*, WASH. DEP'T OF ECOLOGY, www.ecy.wa.gov/water.html (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

107. Notice of Call for Public Comment on 303(d) Program and Ocean Acidification, 75 Fed. Reg. 13,537 (Mar. 22, 2010).

108. *See* Memorandum from Peter S. Silva, Assistant Administrator, EPA, to Center for Biological Diversity, (Apr. 15, 2010), http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/Memorandum-Detailing-EPA-Decision-on-Re-evaluation-and-or-Revision-of-the-Water-Quality-Criterion-for-Marine-pH-for-the-protection-of-Aquatic-Life.pdf.

109. CAL. ENVTL. PROT. AGENCY, STATE WATER RES. CONTROL BD., CALIFORNIA OCEAN PLAN TRIENNIAL REVIEW WORKPLAN 2011-2013 DRAFT 15 (2011), www.swrcb.ca.gov/water_issues/programs/ocean/docs/trirev/wrkpln2011_13.pdf ("[M]ore research, monitoring and assessment should take place, both in California and globally to address and understand decreases of pH (trends and effects) before further changes to the objective or program of implementation is amended.").

110. Memorandum from Alexis Strauss, Director, Water Division, EPA Region IX to Tom Howard, Executive Director, State Water Resources Control Board 29-30 (Oct. 11, 2011), www.waterboards.ca.gov/water_issues/programs/tmdl/records/state board/2011/ref3641.pdf.

More stringent criteria for pH and related parameters would land a greater number of water bodies on the 303(d) list of impaired waters, which would in turn require the state to develop more TMDLs. Although historically this process has been lethargic and resource-intensive,[111] it need not necessarily be so.[112] Where regional water boards develop TMDLs, such as in California, the boards could minimize their individual costs by collaborating to develop marine and estuarine TMDLs.[113] Federal dollars are available to develop TMDLs, although these funds are unlikely to keep pace with a growing list of impaired waters.[114]

However, states have some internal incentives to act. Aiding a locally acidifying ocean by creating a more stringent standard could generate local benefits in the form of healthier state fisheries, shellfish operations, and other coastal activities dependent on water chemistry, and would guard against lawsuits alleging that the present criteria do not adequately safeguard existing beneficial uses. These benefits would mitigate and could surpass the costs of adjusting the criterion.

Precisely what the right criteria might be remains an open question. A technological challenge to setting meaningful water quality criteria is the natural background variation in the chemistry of state waters. For example, the existing water quality criterion for marine pH is +/-0.2 units outside the normally occurring range.[115] Because the natural variability of

111. *See* O. A. HOUCK, THE CLEAN WATER ACT TMDL PROGRAM: LAW, POLICY, AND IMPLEMENTATION 63 (2002) (citing a figure of $ 1 million per TMDL study and ten times that for implementation of each TMDL).

112. *See, e.g.*, CAL. STATE WATER RES. CONTROL BD., WATER QUALITY CONTROL POLICY FOR ADDRESSING IMPAIRED WATERS: REGULATORY STRUCTURE AND OPTIONS, RESOLUTION 2005-0050 8-9 (June 16, 2005), www.waterboards.ca.gov/water issues/ programs/tmdl/docs/iw policy.pdf (describing different options for adopting TMDLs in California, some of which require only a single board action). Of course, this does not accelerate the TMDL development process.

113 One approach to such TMDLs would be to collectively assess the contribution of atmospheric CO_2 input on a range of marine and estuarine resources. Each regional board could then use that assessment as an element of regional and local TMDLs, requiring dischargers to consider such loadings as well as local inputs.

114. 33 U.S.C. § 1329(h).

115. CAL. STATE WATER RES. CONTROL BD., WATER QUALITY CONTROL PLAN: OCEAN WATERS OF CALIFORNIA 6 (2009) [hereinafter OCEAN PLAN], www.swrcb.ca.gov/water issues/programs/ocean/docs/2009copadoptedeffectiveusepa.pdf; *see also* EPA, *National Recommended Water Quality Criteria*, Note P, http://water.epa.gov/scitech/swguidance/ standards/criteria/current/index.cfm (last visited Jan. 23, 2012) (on file with the Harvard Law School Library).

coastal pH is substantially larger than this interval,[116] the existing criterion has little or no real protective effect.[117] However, any human-caused departure from an already-wide natural range has the potential to create an extreme chemical environment that may be fatal to many of the organisms living in the state's waters. In order to effectively mitigate acidification and to protect the existing beneficial uses of coastal waters, revised criteria should be more stringent and tied to an absolute value of pH—or to a hybrid of numeric and narrative criteria with data-backed benchmarks based on ecosystem response[118]—rather than the widely fluctuating natural range. [119] For example, if the vast majority of natural variation in a coastal region occurs within pH range 7.4 to 8.4, it may be that nearshore waters with a pH of less than 7.4 should be designated as impaired.[120]

> According to page 181 of the Red Book [EPA 440/9-76-023, July, 1976]: For open ocean waters where the depth is substantially greater than the euphotic zone, the pH should not be changed more than 0.2 units from the naturally occurring variation or any case outside the range of 6.5 to 8.5. For shallow, highly productive coastal and estuarine areas where naturally occurring pH variations approach the lethal limits of some species, changes in pH should be avoided but in any case should not exceed the limits established for fresh water, i.e., 6.5-9.0.

Id.

116. *See* Hofmann et al., *supra* note 37, at 1 (describing pH variability in different ecosystems); *see also* Jerry C. Blackford & Fiona J. Gilbert, *pH Variability and CO_2 Induced Acidification in the North Sea*, 64 J. of Marine Sys. 229, 234-36 (2007) (finding that the coastal ocean can vary by more than 1 pH unit annually).

117. Given this limitation, current criteria may not protect many of the marine waters' designated beneficial uses, as is required under Porter-Cologne and the Clean Water Act, making them legally insufficient. *See* 40 C.F.R. § 131.5(2); 40 C.F.R. § 131.6(c) (2012) (EPA approval of state water quality criteria is contingent on those criteria being sufficient to protect designated uses).

118. *See, e.g.*, *Nutrient Numeric Endpoints*, S. CAL. COASTAL WATER RES. PROJECT, www.sccwrp.org/ResearchAreas/Nutrients/NutrientCriteriaSupportStudies/BackgroundNutrientNumericEndpoints.aspx (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

119. That is, if the natural pH range of waters in a hypothetical coastal region is pH 7 to 8.5, discharges causing a change of +/-0.2 are likely to have a much more severe environmental impact at the margins of that natural range than in the center of the range. EPA's Red Book guideline implicitly notes as much in setting the absolute outer bounds of permissible pH variation at 6.5 to 8.5 or 6.5 to 9. *See* EPA, QUALITY CRITERIA FOR WATER 337 (1976), http://water.epa.gov/scitech/swguidance/standards/criteria/current/upload/2009 01 13 criteria redbook.pdf (commonly referred to as EPA "Red Book"). However, even for pH-variable waters that sporadically reach an extreme pH of 6.5, inputs that chronically lower the pH by 0.2 would likely jeopardize many beneficial uses. Improved monitoring efforts will continue to increase data quality and availability for pH.

120. With improved monitoring data, calculating a 95% confidence interval for pH of

Criteria more stringent than the current +/-0.2 units would help arm state resource agencies with tools to combat local acidification. Furthermore, narrower criteria face less of a technological hurdle now than in years past because more accurate monitoring technologies now exist, making narrower tolerances more easily enforceable than they would have been when the current water quality criteria were set in the 1970s. Finally, water quality criteria must reflect the most recent scientific knowledge,[121] and a critical mass of information now indicates that the chronic changes in pH that have already taken place can have large and detrimental effects on marine ecosystems.[122] This leaves states vulnerable to citizen suits challenging the existing criteria,[123] and states may prefer to begin revisions than to defend the existing criteria in court.

B. Criteria and TMDLs for Atmospheric Drivers of Acidification

While controlling the total nutrient loadings and other anthropogenic inputs to coastal waters would help mitigate non-atmospheric-driven acidification, developing criteria and TMDLs for $p(CO_2)$[124] and for surface fluxes of NO_x and SO_x could do the same for atmospheric drivers.[125] This action is particularly relevant for coastal waters that are at greater risk as a result of prevailing biological or chemical conditions. For example, atmospheric nitrogen deposition could exacerbate

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particular water bodies would be easily accomplished. This might define the boundaries of probable natural variation, and allow a static water quality standard tied to these boundaries. Note that under such a system, the classification of waters as either impaired or non-impaired would be much more dynamic than is the case at present.

121. 33 U.S.C. § 1314(a)(1) ("The Administrator, after consultation with appropriate Federal and State agencies and other interested persons, shall develop and publish … criteria for water quality accurately reflecting the latest scientific knowledge.")

122. *See, e.g.*, Doney et al., *supra* note 1, at 169; Wootton, *supra* note 34, at 18,849.

123. *See supra* note 106. The large amount of scientific information that has become available since that suit was filed—well over half of the total number of papers published on ocean acidification have been published since 2009—tends to support the proposition that the existing standard fails to incorporate the most recent information.

124. $p(CO_2)$ indicates the partial pressure of carbon dioxide in seawater, an important parameter in the carbonate system.

125. *See generally* Anil J. Antony, *Shotguns, Spray, and Smoke: Regulating Atmospheric Deposition of Pollutants Under the Clean Water Act*, 29 UCLA J. ENVTL. L. & POL'Y 215 (2011) (discussing the view of courts towards such regulation, in the context of several published decisions).

ocean acidification depending upon factors limiting the growth of marine microorganisms locally and upon the timescale of analysis.[126] Where areas of high deposition coincide with upwelling zones—in which colder ocean waters quickly take up CO_2 and therefore acidify more rapidly—TMDLs for atmospheric drivers might be an especially appropriate means of limiting inputs to the coastal ocean, guarding against "hotspots" of acidification.

Deposition of nitrogen and sulfur compounds from the atmosphere could contribute significantly to coastal acidification in some hard-hit areas.[127] Yet, because they are gases, they are not often seen as water pollutants, and agencies have rarely designated water quality criteria for them.[128] The Chesapeake Bay—in which atmospheric nitrogen deposition has historically been greater than nitrogen inputs from fertilizer, manure, or any point source[129]—now has a TMDL for NO_x,[130] demonstrating the feasibility of this regulatory tool. Other coastal regions can follow suit.

3. Create New Water Quality Criteria for Complementary Parameters; Create New Designated Uses

States could make two further changes to water quality standards to improve their ability to address coastal acidification. First, additional criteria for pH-related parts of the carbonate system (e.g., Total Alkalinity, Dissolved Inorganic Carbon)[131] would help monitor acidifying waters

126. *See* Doney et al., *supra* note 25, at 14,580; WASHINGTON SHELLFISH INITIATIVE, *supra* note 104, at 14.

127. *See* Doney et al., *supra* note 25, at 14,580. *But see* Hunter et al., *supra* note 25 , at 1 (suggesting a minimal role for these gases in changing coastal pH).

128. Note that some other airborne pollutants have TMDLs, the primary example being mercury. *See* EPA, *Total Maximum Daily Loads (TMDLs) and Mercury*, http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/mercury/index.cfm.

129. *Appendix L: Setting the Chesapeake Bay Atmospheric Nitrogen Deposition Allocations L-1*, *in* EPA, CHESAPEAKE BAY TMDL (2010) [entire publication hereinafter CHESAPEAKE BAY TMDL], www.epa.gov/reg3wapd/pdf/pdf_chesbay/FinalBayTMDL/AppendixLAtmosNDepositionAllocations_final.pdf.

130. *Executive Summary ES-1, in* CHESAPEAKE BAY TMDL, www.epa.gov/reg3 wapd/pdf/pdf_chesbay/FinalBayTMDL/BayTMDLExecutiveSummaryFINAL122910_final.pdf.

131. Total Alkalinity and Dissolved Inorganic Carbon are measurements used to characterize the overall chemical environment of the ocean with respect to calcium carbonate, the prime ingredient of shells and other hard parts in marine organisms.

more accurately and would be valuable tools for detecting and preventing further degradation.[132] Second, states could define new designated uses for coastal water bodies in such a way as to improve ecological resilience. From a technical standpoint, both steps are feasible means of adapting state Clean Water Act implementations to better fit the emerging threat of ocean acidification, but the latter is perhaps an easier route because it avoids the mathematical modeling and precise threshold-setting that new water quality criteria would entail.

A. Additional Water Quality Criteria to Aid Carbonate Chemistry Monitoring

Data-driven policy requires both that relevant datasets exist and that they meaningfully inform policy decisions. One step that would both generate data and explicitly tie the data to policy action is to develop additional water quality criteria for chemical parameters that are intimately linked to ocean acidification. These parameters, for which existing datasets have been sparse, include Total Alkalinity and Dissolved Inorganic Carbon, two factors in the seawater carbonate system in which pH plays a role.

There are at least two reasons to include these parameters in the repertoire of coastal management tools. First, in comparison with pH, these auxiliary measures are easier to measure accurately and consistently over long periods of time. Second, these measurements give a more accurate understanding of biologically relevant effects such as the rate at which shells and other hard parts dissolve in seawater.[133] Consequently, creating new criteria for and measuring these factors simultaneously with pH would generate a more

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Total Alkalinity reflects the balance of charged molecules in seawater; Dissolved Inorganic Carbon is the sum of carbon atoms contained within a set of defined inorganic molecules. *See* Jean-Pierre Gattuso & Lina Hansson, *Ocean Acidification: Background and History, in* OCEAN ACIDIFICATION 2 (2012), http://fds.oup.com/www.oup.com/pdf/13/9780199591091_chapter1.pdf. Measuring these parameters allows a researcher to calculate the other relevant parameters of the carbonate system.

132. *See* Ryan P. Kelly & Margaret R. Caldwell, *The Limits of Water Quality Criteria*, 29 ENVTL. FORUM 34, 38 (2012).

133. *See supra* note 42, describing Ω_{arag} and $\Omega_{calcite}$. Note that Ω_{arag} would also be a good candidate for regulation under the Clean Water Act, particularly in states such as Washington, where the shellfish industry (and, therefore, shells that dissolve in more corrosive water) is of paramount importance.

complete picture of the chemistry underlying ocean acidification and its attendant biological effects. Moreover, more precise measurements might also allow agencies to trace acidifying plumes to their point or nonpoint sources, helping to limit the spatial extent of regulation to most efficiently address the real sources of the problem.

New water quality criteria for Total Alkalinity and Dissolved Inorganic Carbon would then link explicitly to policy action where particular coastal waters fall short of a state's designated standards for these measures. Such waters would be listed as impaired under CWA § 303(d) and the state would develop TMDLs, as described above. NPDES permits for existing polluters would then require monitoring and discharges appropriate for the new measurements, simultaneously improving water quality and generating a valuable dataset that would not exist otherwise.

This approach broadens the traditional Clean Water Act purview somewhat, by defining water quality standards that serve the dual purposes of information gathering and water quality regulation. Nonetheless, it is consistent with the text of the Act: Both Total Alkalinity and Dissolved Inorganic Carbon constitute "pollution"[134] in the same sense as heat or pH. At present, the federal EPA does not provide guidelines for these chemical water parameters, but states could base water quality criteria on known kinetics of carbonate chemistry in seawater to derive an appropriate range.[135]

B. New Designated Uses for Coastal Waters

As a final use of water quality standards to combat ocean acidification, states could use the Clean Water Act's designated uses provision as a safeguard for especially sensitive areas. As described above, states must designate particular uses for each

134. Note that the Clean Water Act defines "pollutant" and "pollution" in somewhat different terms. 33 U.S.C. § 1362(19) ("The term 'pollution' means the man-made or man-induced alteration of the chemical, physical, biological, and radiological integrity of water."); 33 U.S.C. § 1362(6) ("The term 'pollutant' means dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.").

135. For a discussion of the kinetics of carbonate chemistry, *see* Zeebe & Wolf-Gladrow, *supra* note 34, at 85–139.

water body in their jurisdiction.[136] Where technology-based standards for point sources of pollution are insufficient to safeguard a water body's designated use, NPDES permits will limit discharges in an attempt to meet the appropriate water quality standards. Waters failing to meet these standards are then listed as impaired, as described above.

States are free to designate uses as they see fit, taking into consideration a non-exhaustive list of uses valuable to the public, including "protection and propagation of fish, shellfish and wildlife" and "recreation in and on the water."[137] A state concerned with ocean acidification may define new designated uses for coastal waters in order to protect their ecological resilience and ongoing value as engines of ecosystem services.

For example, Washington could designate a portion of Puget Sound as having the use "to maintain buffering capacity against chemical change" or "to preserve the structure and function of the nearshore ecosystem." These or other new uses would maintain standards appropriate for less stringent uses; that is, the newly designated waters would still be swimmable, but they would also be held to higher standards. Such a change would harmonize the CWA's designated use provision with a more modern understanding of ecosystem function, by explicitly incorporating one or more ecosystem services or processes as "uses" under the act. The change would also set a higher bar for water quality in coastal areas of particular concern. Where water quality is impaired relative to the newly designated use, the state would benefit from the increased monitoring and attention associated with the TMDL process, described above.

4. Use the Clean Air Act to Decrease SO_x/NO_x Deposition Near Coasts

SO_x and NO_x are gases that form acids when dissolved in seawater, and may consequently lower the pH of receiving waters.[138] Because of short residence times in the atmosphere, if these compounds contribute to ocean acidification, their

136. 40 C.F.R. § 131.10(a) (2012).

137. *Id.* States must provide a public hearing before adding or removing a designated use. 40 C.F.R. § 131.10(e) (2012).

138. *See* Doney et al., *supra* note 25, at 14,580. These gases are also the cause of acid rain.

effects would be most acute near locations where the gases are produced as byproducts of human industrial processes.[139] Where acid gases demonstrably contribute to ocean acidification,[140] tighter ambient air quality standards for these compounds would have the greatest impact on ocean acidification near coal-fired power plants or similar heavy industrial sources located near coastlines.

States could use the Clean Water Act to regulate these airborne pollutants, for example, by using technology-based standards and water quality-based standards, including designated uses and water quality criteria, as described above.[141] At least some states do regulate in this way; Maryland, for example, has developed a TMDL for NO_x deposition for waters violating the relevant criteria,[142] demonstrating the practical feasibility of this regulatory tool.

However, the Clean Air Act ("CAA") aims squarely at SO_x and NO_x, both of which are criteria pollutants under that Act.[143] The CAA has functioned for over forty years to limit the ambient concentrations of these pollutants, and has been especially effective with respect to SO_x after the 1990 CAA Amendments established an emissions trading scheme.[144] As

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139. *See id.* at 14,581. Here, "residence time" refers to the length of time the sulfur or nitrogen compound remains in the atmosphere before returning to the Earth's surface (for example, by transport in rainwater).

140. We again stress that the contribution of these compounds to coastal ocean acidification is an open question, with at least one notable paper suggesting they have a negligible effect. *See* Hunter et al., *supra* note 25. As more spatially detailed studies of acidification's causes and effects become available, we expect that the relative importance of acid gases to coastally enhanced acidification will be determined.

141. This assumes that deposition of these compounds meets the statutory definition of a "discharge." *See* 33 U.S.C § 1362(12) (2006) ("The term 'discharge of a pollutant' … means (A) any addition of any pollutant to navigable waters from any point source, (B) any addition of any pollutant to the waters of the contiguous zone or the ocean from any point source other than a vessel or other floating craft.").

142. CHESAPEAKE BAY TMDL, *supra* note 130, at ES-7.

143. *See* 40 C.F.R. §§ 50.4–50.13 (2006) for the National Ambient Air Quality Standards, including those for SO_x and NO_x.

144. The several federal SO_x and NO_x emissions trading programs that have evolved since the Clean Air Act Amendments of 1990 are complex and overlapping. These include the Acid Rain Program, NO_x Trading Program, Clean Air Interstate Rule ("CAIR"), and the recently vacated Cross-State Air Pollution Rule ("CSAPR"); all are implemented under the authority provided by 42 U.S.C. §§ 7651(a)–7651(o) (2012). Note that both the CAIR and CSPAR rules have been vacated; CAIR remains in effect, pending development of a replacement rule. *See* North Carolina v. EPA, 531 F.3d 896 (D.C. Cir. 2008), *vacatur stayed on reh'g* 550 F.3d 1176 (2008); EME Homer City Generation v. EPA, 696 F.3d 7 (D.C. Cir. 2012). What these programs have in common

noted above, states generally are permitted to promulgate more stringent air quality standards than those required federally.[145] However, because SO_x and NO_x are subject to federal trading schemes,[146] federal preemption concerns limit states' ability to regulate these emissions using market-based programs. In Clean Air Markets Group v. Pataki, for example, the Second Circuit held that Title IV of the 1990 Clean Air Act Amendments preempted a New York state law that collected fees for SO_2 emissions allowances traded to out-of-state polluters, and indicated that the state scheme created an "obstacle" to the nationwide trading program.[147] This case highlights a tension between the older command-and-control Clean Air Act rules and the more recent market-based rules. The interaction between these sets of rules remains an area of active legal debate.

If states were to create more stringent SO_x and NO_x standards, they could avoid federal preemption and commerce clause challenges by amending their air quality standards without restricting the transferability of emissions credits. For example, a state could avoid a preemption or commerce clause challenge by lowering its overall cap on acid gas emissions and simultaneously limiting in-state emissions to target levels. Such command-and-control regulation would leave the existing trading schemes unaffected—it would not directly impact other states' regulated entities or the interstate trading of emissions allowances—and would ensure that the clean air benefits accrue to the state with more stringent limits. Virginia provides an example of such regulation, which the Fourth Circuit upheld in 2009.[148]

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is that each regulates SO_x and/or NO_x emissions by setting limits on the emissions (the "cap"), and then allowing regulated entities to trade surplus emissions credits or allowances. For a description of these programs and their relationships to one another, see *Clean Air Markets*, EPA, www.epa.gov/airmarkets/index.html (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

145. *See* 42 U.S.C. § 7416.

146. *See supra* note 144.

147. 338 F.3d 82 (2d Cir. 2003). Note also that the New York law may pose a dormant commerce clause problem; the District Court invalidated the statute's restrictions on trading allowances to out-of-state parties both on commerce clause grounds and on preemption grounds, but the Circuit Court did not reach the commerce clause issue. *Id.* at 89.

148. Mirant Potomac River v. EPA, 577 F.3d 223, 230 (4th Cir. 2009) ("The Nonattainment Provisions, as separate state regulations, do not place any restrictions

SO_x and NO_x deposition can be substantial, especially in the eastern United States, with its high concentration of coal-fired power plants and heavy industry.[149] Where these atmospheric pollutants end up in rivers and streams, they eventually flow to the coastal Atlantic. In some states, coastal waters carry a nitrogen load from atmospheric sources comparable to—or even greater than—that of terrestrial runoff. For example, more of the nitrogen in the Chesapeake Bay comes from atmospheric deposition than from manure and chemical fertilizer runoff from all agricultural lands combined.[150] In these states especially, a non-negligible percentage of coastal ocean acidification may be due to atmospheric pollutants, and the need for increasingly stringent air pollution regulation in these states is correspondingly stronger.

Because SO_x and NO_x have relatively short residence times in the atmosphere, there are improved incentives for state and local governments to regulate them more closely. States with more stringent limits will tend to experience the benefits themselves, as smaller amounts of the pollutants will be deposited within such states. Especially in cases where atmospheric deposition of these pollutants is a significant contributor to coastal acidification, cleaner air could immediately improve the chemical environment of the ocean while paying dividends in local public health benefits.[151]

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on participation in the EPA trading program by any affected power plant. To meet *federal* compliance obligations, any power plant can buy, sell, trade, or use allowances without restriction. To meet *state* compliance obligations, no power plant located in a nonattainment area can exceed its independent state emissions cap without facing state penalties."); *see also* Sonja L. Rodman, *Legal Uncertainties and the Future of U.S. Emissions Trading Programs*, NAT. RES. & ENV'T, Spring 2010, at 7, 10 (discussing this case and other cases relating to the tension between command-and-control and market-based regulations).

149. *See* EPA, OUR NATION'S AIR: ATMOSPHERIC DEPOSITION 35–36 (2010) [hereinafter ATMOSPHERIC DEPOSITION], www.epa.gov/airtrends/2010.

150. *See id*.

151. *See, e.g.*, *Health Effects of Pollution*, EPA REGION 7 AIR PROGRAM, www.epa.gov/region07/air/quality/health.htm (last visited Jan. 23, 2013) (on file with the Harvard Law School Library) (describing human health effects of criteria pollutants). Note that lowering levels of these pollutants could also ease the environmental justice issues associated with the disproportionate concentration of industrial air pollution deposited in poor and minority neighborhoods.

5. Enhance Wastewater Treatment at Publicly Owned Treatment Works

Sewage treatment presents a special problem for water quality regulation, in part because of its absolute volume: Nationwide, wastewater treatment plants process more than thirty-two billion gallons of wastewater daily.[152] Much of this discharge volume flows to the ocean,[153] increasing nutrient loads along the coasts and triggering the acidifying cascade described above. Implementing more stringent technology-based or water quality-based controls through NPDES permits for Publicly Owned Treatment Works ("POTWs") would reduce anthropogenic nutrient loading in the coastal ocean, in turn reducing acidification as well as associated harmful algal blooms and anoxic zones, as described above in Section VI(1).

The federal Clean Water Act singles out POTWs as special point sources with additional NPDES requirements beyond those of ordinary permittees. For example, POTWs are subject to heightened reporting requirements in their permit applications[154] and must limit their discharges to a greater degree than the technology-based standards alone dictate.[155] As a result, a state can require POTWs to minimize discharges by altering the prevailing water quality standards.[156] Where sewage discharge significantly contributes to coastal acidification via nutrient loading, addressing the discharge within the context of the NPDES permitting program would be an attractive way to alleviate this particular stressor.

Changing the prevailing technology-based standard[157] for

152. EPA, CLEAN WATERSHEDS NEEDS SURVEY 1–4 (2008), http://water.epa.gov/scitech/datait/databases/cwns/upload/cwns2008rtc.pdf.

153. For example, California alone discharges 1.35 billion gallons of treated wastewater per day into the Pacific. HEAL THE OCEAN, CALIFORNIA OCEAN WASTEWATER DISCHARGE REPORT AND INVENTORY 5 (2010), http://healtheocean.org/library/detail/california_ocean_waste_water_discharge_inventory_wdi1/.

154. *See* 40 C.F.R. § 122.21(j) (2012).

155. 33 U.S.C. § 1311(b)(1)(C) (2006).

156. *See supra* Section VI(2).

157. While the Clean Water Act does not expressly give states the power to change technology-based standards, the power of states to create more stringent standards is consistent with the Act, which contemplates a lead role for states in setting applicable clean water standards, and with case law. *See, e.g.*, Shell Oil Co. v. Train, 585 F.2d 408, 410 (9th Cir. 1978) ("The role envisioned for the states under the [CWA] is a major one, encompassing … *the right to enact requirements which are more stringent than the federal standards*.") (emphasis added) (citations omitted).

POTWs to require tertiary treatment,[158] including nitrification-denitrification (N-DN),[159] is another means of addressing POTW-related eutrophication. N-DN is the coupled chemical process by which bacteria remove biologically available nitrogen from an environment. Treatment works could use N-DN to lessen the impact of millions of tons of sewage on coastal water quality, directly lowering the eutrophication that can lead to hypoxia and local acidification. N-DN is not a standalone aspect of municipal water treatment, but can be added to improve the quality of already-treated effluent. Nationally, such treatment is now required to be considered on a case-by-case basis; such consideration must involve evaluation of the condition of the receiving water body and the beneficial uses for which it has been designated.[160] States, tribes, and regional bodies could apply this same analysis to the state's coastal POTWs with respect to ocean acidification and related ocean issues.[161] For example, where marine receiving waters are especially vulnerable to acidification or related water quality issues due to upwelling or freshwater input, N-DN might be particularly appropriate.[162]

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158. Note that the term "tertiary treatment" is nonspecific and may be used differently by different authors. This Article uses the term to refer to a process that removes biosolids and nutrients from receiving waters, as well as disinfecting effluent. *See, e.g.*, CHRISTOPHER FORSTER, WASTEWATER TREATMENT & TECHNOLOGY, 183 (2003); NICHOLAS F. GRAY, BIOLOGY OF WASTEWATER TREATMENT 136 (2004).

159. *See* FORSTER, *supra* note 158, at 160–68.

160. *See*, *e.g.*, CHESAPEAKE BAY TMDL, *supra* note 129. For example, New York State requires tertiary treatment of some combined sewer overflows into the Chesapeake River drainage. N.Y. DEP'T ENVTL. CONSERVATION, CHESAPEAKE BAY NITROGEN, PHOSPHORUS AND SEDIMENT TOTAL MAXIMUM DAILY LOADS 29 (2010), www.epa.gov/reg3wapd/pdf/pdf_chesbay/NYDraftPHIWIP.pdf.

161. California's regional water boards have required N-DN for particular facilities in the past. For example, the Central Valley Regional Water Quality Control Board recently required N-DN for the Sacramento Regional Wastewater Treatment Plant. *See* CAL. REG'L WATER QUALITY CONTROL BD., CENT. VALLEY REGION, WASTE DISCHARGE REQUIREMENTS FOR THE SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT SACRAMENTO WASTEWATER TREATMENT PLANT SACRAMENTO COUNTY, ORDER R5-2010-0114 (NPDES No. CA0077682) (2011), www.swrcb.ca.gov/centralvalley/board_decisions/adopted_orders/sacramento/r5-2010-0114-01.pdf. The Los Angeles Region had earlier required N-DN at the D.C. Tillman Water Reclamation Plant. *See* CAL. REG'L WATER QUALITY CONTROL BD., LOS ANGELES REGION, WASTE DISCHARGE REQUIREMENTS FOR CITY OF LOS ANGELES DONALD C. TILLMAN WATER RECLAMATION PLANT DISCHARGE TO LOS ANGELES RIVER VIA DISCHARGE OUTFALLS 6 Order R4-2011-0196 (NPDES No. CA0056227) (2011) (describing facility and its tertiary treatment, including N-DN), www.waterboards.ca.gov/rwqcb4/board_decisions/adopted_orders.

162. State and regional authorities may also implement local effluent limits for

Infrastructure upgrades to treatment works are expensive. And as ever, more stringent regulation will be politically difficult, especially given that costs associated with upgrading facilities would fall to cash-strapped cities and counties.[163] These two facts combine to make the practical feasibility of POTW retrofitting decidedly lower than that of other policy options we discuss here. But the fact that POTW regulations impact government entities rather than private industry means the hurdles to implementation are more likely to be financial than philosophical: Given the financial resources, most cities and counties would probably not object to having cleaner wastewater discharges.

Where the benefits of upgrading accrue to the city or county in such a way as to defray the costs,[164] reform is more likely to happen. One side benefit of more stringent wastewater treatment is improved water recycling for non-potable or indirect potable uses (e.g., recharging groundwater), a benefit probably most attractive to coastal counties in which freshwater is at a premium. Reusing water in this way reduces a municipality's water demand—thus saving money annually—and simultaneously avoids the substantial greenhouse gas emissions associated with moving water from source to tap. In jurisdictions where beach closures are costly,[165] lowering the number of closures would be a further

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POTWs to ensure that they meet the requirements of their NPDES permits. *See* EPA, OFFICE OF WASTEWATER MGMT. 4203, EPA 833-R-04-002A, LOCAL LIMITS DEVELOPMENT GUIDANCE 1–3 (2004), www.epa.gov/npdes/pubs/final_local_limits_guidance.pdf.

163. Marginal costs of N-DN treatment include infrastructure for aeration and raw materials for carbon-limited reaction steps, and may entail tens to hundreds of millions of dollars in expenditures. Low-cost alternatives may be available. *See, e.g.*, Jari P. Y. Jokela et al., *Biological Nitrogen Removal from Municipal Landfill Leachate: Low-Cost Nitrification in Biofilters and Laboratory Scale In-Situ Denitrification*, 36 WATER RESEARCH 4079 (2002); Christian Fux & Hansruedi Siegrist, *Nitrogen Removal From Sludge Digester Liquids by Nitrification/Denitrification or Partial Nitritation/Anammox: Environmental and Economical Considerations*, 50 WATER SCI. & TECH. 10, 15 (2004) (noting environmental costs as well as economic costs of different methods).

164. For example, N-DN plants may have lower operating costs than conventional plants. *See* Diego Rosso & Michael K. Stenstrom, *Energy-Saving Benefits of Denitrification*, 3 ENVTL. ENGINEER: APPLIED RESEARCH & PRAC. 2, 2 (2007).

165. *See generally* PETER C. WILEY ET AL., NOAA, SOUTHERN CALIFORNIA BEACH VALUATION PROJECT: ECONOMIC IMPACT OF BEACH CLOSURES AND CHANGES IN WATER QUALITY FOR BEACHES IN SOUTHERN CALIFORNIA (2006) (modeling economic impacts of thousands to billions of dollars, depending upon the closure scenario and duration). *See also* Sharyl J. M. Rabinovici et al., *Economic and Health Risk Trade-Offs of Swim*

benefit, at least partially offsetting the price of upgrading infrastructure.

6. Leverage CWA § 319(h) Money to Implement Enduring Best Management Practices and Permanent Nutrient-Management Improvements

Motivated in part by the failure of TMDLs to achieve enforceable water quality protection, Congress passed the Coastal Zone Act Reauthorization Amendments ("CZARA") in 1990 to improve nonpoint source pollution control in coastal waters.[166] The Act required states with coastal zone management programs approved under the Coastal Zone Management Act ("CZMA")[167] to develop and implement coastal nonpoint source pollution control plans.[168] As with the CZMA, the federal government provided funds for planning and implementation under CZARA.[169]

The Act provided that the states' plans should be enforceable,[170] on pain of EPA withholding its approval and the consequent loss of funding.[171] However, the actual implementation and enforcement of states' nonpoint source management plans is left to states, and is largely carrot-based: The funds authorized by § 319(h) of the Clean Water Act and § 306 of the CZMA serve as ongoing incentives for states to manage nonpoint source pollution in their coastal zones.

In states lacking the ability or the will to enforce nonpoint source controls, resource agencies can use the CZARA-associated funds as carrots, requiring durable best

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Closures at a Lake Michigan Beach, 38 ENVTL. SCI. & TECH. 2737, 2742 (2004) (estimating net economic loss of up to $ 37,000 per day per swimmer for closure at a particular beach).

166. 16 U.S.C. § 1455b (2006). For a more detailed synopsis of CZARA, see Douglas R. Williams, *When Voluntary, Incentive-Based Controls Fail: Structuring a Regulatory Response to Agricultural Nonpoint Source Water Pollution*, 9 WASH. U. J.L. & POL'Y 21, 92–93 (2002).

167. 16 U.S.C. §§ 1451–60 (2012).

168. 16 U.S.C. § 1455b.

169. 16 U.S.C. § 1455b(f),(h).

170. 16 U.S.C. § 1455b(b)(3) provides that each plan shall contain management measures, the implementation of which are necessary to achieve Clean Water Act standards. 16 U.S.C. § 1455b(c)(2) states "the State *shall* implement the program, including the management measures." (emphasis added).

171. 16 U.S.C. § 1455b(c).

management practices ("BMPs") and permanent nutrient-management improvements. Ideally, these improvements would be more expensive to remove than to implement, such that the state would not have to continue to pay nonpoint source dischargers to maintain them. Federal money would be used to lower barriers to entry for parties who could not (or would not) otherwise adopt cleaner management practices, and the improvements would be maintained after the funds were exhausted and the barrier to entry overcome.

Some state and private actors have had success with collaborative management strategies, pairing with agricultural and other landowners to reduce environmental impacts in ways that generate environmental dividends. In the context of wetlands preservation, The Nature Conservancy has entered into leasing agreements with select farmers in Washington's Skagit Valley, seasonally renting and flooding individual agricultural fields for the use of migrating birds.[172] The birds and other wildlife—visiting just for the season—fertilize the soil with their droppings, reducing the farmers' need to apply additional fertilizer. In the context of nonpoint source pollution, Washington also provides the example of the Nisqually River Council process,[173] in which the threat of regulation led the various agricultural, tribal, and environmental interests to cooperate in order to better manage the Nisqually River for salmon. The implementation of BMPs along the Chehalis and Willapa Rivers[174] offers a similar story.

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172. *See Farming for Wildlife*, THE NATURE CONSERVANCY (June 14, 2012), www.nature.org/ourinitiatives/regions/northamerica/unitedstates/washington/explore/farming-for-wildlife.xml (last visited Jan. 23, 2013) (on file with the Harvard Law School Library). The state of Iowa is implementing a similar program. *See Iowa Conservation Reserve Enhancement Program*, IOWA DEP'T AGRIC. & LAND STEWARDSHIP, www.iowaagriculture.gov/waterresources/CREP.asp (last visited Jan. 23, 2013) (on file with the Harvard Law School Library) (describing a project using financial incentives to encourage landowners to restore wetlands on agricultural lands, administered through a collaboration among various levels of government and private landowners).

173. *Nisqually River Council*, NISQUALLY RIVER COUNCIL, http://nisquallyriver.org/ (last visited Jan. 23, 2013) (on file with the Harvard Law School Library). *See generally* NISQUALLY RIVER TASK FORCE, NISQUALLY RIVER MANAGEMENT PLAN (1987), http://nisquallyriver.org/wp-content/uploads/2010/04/NISQUALLY-RIVER-MANAGEMENT-PLAN.pdf.

174. *Dairy Regulations and Coordinated Approach Help Restore Record Number of Washington Water Bodies*, EPA NONPOINT SOURCE NEWS-NOTES, May 2012, at 14 (explaining

In 2011 the state of Washington reported that 84 impaired water bodies in the

In general, however, an entirely incentive-based system can leave the state in the uncomfortable and unsustainable role of paying its constituents not to pollute.[175] States with more enforceable nonpoint source regulation have the option of wielding either the carrot or the stick. In California, for example, the regional water boards[176] implement the CZARA and Clean Water Act restrictions.[177] The water boards have three tools with which to control nonpoint source pollution outside of the Clean Water Act's TMDL provision: waste discharge requirements ("WDRs"), waivers of WDRs, and basin plan prohibitions.[178] The boards can issue WDRs for general or specific discharges; for example, they may bar discharges that fall outside of a particular pH range or that have a particular nutrient content. Alternatively, boards can agree to waive WDRs in exchange for the discharger's application of best management practices or for other assurances; many of the coastal nonpoint source plan's management measures are administered in this way.[179] WDR violations may trigger abatement, cease-and-desist orders, or civil liability.[180] Fees associated with WDRs[181] defray the costs of implementation and secondarily discourage avoidable discharges.

These seemingly enforceable nonpoint source controls are consistent with an overarching state policy of maintaining

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Chehalis and Willapa watersheds had been restored or partially restored, thanks in large part to widespread non-point source pollution control efforts … . Washington's recipe for success appears to be a combination of regulatory requirements, stakeholder collaboration, targeted implementation and voluntary efforts. Importantly, the success is documented by watershed-wide monitoring.).

175. Discussing a pollution-trading scheme between point and nonpoint source polluters, Oliver Houck recently observed "[o]ne might ask why municipal residents, many of them at the low end of the wage scale, already paying for sewage treatment of their own wastes, should have also to pay farm sources not to pollute. The agriculture sector includes some of the wealthiest (and most heavily subsidized) enterprises in America." Houck, *supra* note 95, at 10,225. Using federal dollars to pay nonpoint sources to maintain BMPs year after year raises the same ethical and practical questions.

176. *See California Water Boards*, CAL. ENVT'L PROT. AGENCY, www.swrcb.ca.gov (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

177. California's Coastal Commission shares authority with the water boards to implement CZARA.

178. CAL. STATE WATER RES. CONTROL BD., RESOLUTION NO. 2004-0030 (2004), 2004 WL 1380112, at *4.

179. *See id.* at *3–*6.

180. See the complete list of enforcement options. PROSIP, *supra* note 99, at 56–61.

181. CAL. WATER CODE § 13260(d) (2011) provides the relevant fee authority.

water quality by using the full power and jurisdiction of the state to do so.[182] However, such measures still rely on identified permittees for implementation, and violations are enforceable only against those same permittees. Rather than water quality-based enforcement, the WDRs and associated rules parallel the technology-or management practices-based measures in NPDES permits. The result is that nonpoint source problems are treated like point source problems, and most pollution is likely to remain unaccounted for.[183]

Solving this problem requires California and states with similar nonpoint source programs to be enterprising in identifying nonpoint source polluters and politically willing to take them on. In states in which a failure to report a discharge or a failure to file for a permit can trigger an enforcement action,[184] agencies can use these state law provisions to bring nonpoint sources into the permitting system. An increase in direct enforcement could curtail nonpoint source runoff from identified sources and could be an effective way of combating a large fraction of the runoff contributing to coastal acidification and degraded water quality. There are no obvious legal barriers here; rather, the feasibility of greater enforcement measures depends entirely on the existence of the political will and funding required to maintain a consistent presence in the field.

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182. *See* RESOLUTION NO. 2004-0030, *supra* note 178 at 3–4 ("(1) The quality of all the waters of the State shall be protected; (2) All activities and factors that could affect the quality of State waters shall be regulated to attain the highest water quality that is reasonable; and (3) The State must be prepared to exercise its full power and jurisdiction to protect the quality of water in the State from degradation.") (citing CAL. WATER CODE § 13000).

183. Note that the advent of pesticide permitting under NPDES—projected to increase the number of permittees by 65%—may bring formerly nonpoint sources into the permitting process and thus allow state, tribal, and regional agencies greater opportunity to impose pollution restrictions beyond those required for pesticides alone. EPA, 2010 NPDES PESTICIDES GENERAL PERMIT FACT SHEET 14–15, www.epa.gov/npdes/pubs/proposed_pgp_fs.pdf.

184. See *infra* Section VI(9) for a discussion of direct enforcement actions. California is one state for which every discharge likely to affect water quality—whether point or nonpoint—requires the discharger to file a report with the state or regional water board. CAL. WATER CODE § 13260.

7. Participate in the National Estuary Program and the National Estuarine Research Reserve System

States can better manage inputs into key coastal sites by enrolling them in the National Estuary Program ("NEP"). This program was created as part of the 1987 amendments to the Clean Water Act[185] and provides federal funds for creating and implementing comprehensive management plans for nationally significant bays and estuaries.[186] The NEP does not set aside estuaries as protected or research areas but rather represents a means of grappling with nonpoint source pollution[187] through a collaborative, watershed-wide process that has been lauded as a model of cooperative governance.[188] Focusing attention on water quality management and ecosystem health through the NEP may avoid some of the expense of developing TMDLs and may be a more effective means of addressing the same core goals.

Twenty-eight bays and estuaries are presently enrolled in the program—representing a total of nineteen states—and state governors can nominate new water bodies for inclusion.[189] Although reliable time-series data are not available, EPA data are available and, on the whole, paint a picture of modest success. Estuaries in the program score equal to or better than U.S. estuaries overall in a series of water-and habitat-quality

185. 33 U.S.C. § 1330. The National Estuary Program is essentially a forum and a source of funds for a kind of collaborative management that moves away from the top-down regulation that may alienate stakeholders to different degrees. In the words of one NEP official, the program focuses on "kumbaya" consensus building and relies on voluntary implementation measures. Telephone interview with anonymous EPA employee familiar with the NEP as it functions in San Francisco Bay (Dec. 16, 2011) (on file with authors).

186. As defined in the National Estuary Program, an estuary is "a part of a river or stream or other body of water that has an unimpaired connection with the open sea and where the sea water is measurably diluted with fresh water derived from land drainage." 33 U.S.C. § 2902(2) (2012). In plain English, an estuary is a coastal site with a mix of fresh and saltwater.

187. *See* LYNN M. GALLAGHER, CLEAN WATER HANDBOOK 129 (3d ed. 2003).

188. *See generally* Mark Lubell, *Resolving Conflict and Building Cooperation in the National Estuary Program*, 33 ENVTL. MGMT 677 (2004); Mark Schneider et al., *Building Consensual Institutions: Networks and the National Estuary Program*, 47 AM. J. POL. SCI. 143 (2003).

189. 33 U.S.C. § 1330. For existing NEP estuaries, see *National Estuary Program Study Areas*, EPA, http://water.epa.gov/type/oceb/nep/upload/NatGeo_24x36_final_revised.pdf (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

measures.[190] The program claims to have protected or restored over 518,000 acres of national estuarine habitat between 2001 and 2005,[191] and a total of 1.3 million acres since 2000.[192] Where states have existing NEP estuaries, they can make use of federal funds to combat acidification in the estuaries' comprehensive management plans.

The National Estuarine Research Reserve System ("NERRS"), by contrast, is not a management program, but a research and monitoring program administered by NOAA that sets aside designated water bodies for long-term protection. A state may request that one of its qualifying water bodies be included in the system, and the federal government provides matching funds for nominee sites. Qualifying sites are those that are "representative estuarine ecosystems suitable for long-term research."[193] After an evaluation process[194] including an environmental impact analysis, sites that are included in the system are "protected for long-term research, water-quality monitoring, education and coastal stewardship," and managed by a state agency or university with technical assistance and funding from NOAA.[195]

States may find the visibility, data collection, and funding that accompany designation as a NERRS site to be helpful for protecting their coasts from acidification and other threats to water and habitat quality. Further, the NERRS program provides matching funds for states to acquire land and waters for inclusion in the system.[196] These matching funds may be particularly attractive for states that allow private ownership

190. EPA, NATIONAL ESTUARY PROGRAM COASTAL CONDITION REPORT, EXECUTIVE SUMMARY ES.9 (2007), http://water.epa.gov/type/oceb/nep/upload/2007_05_09_oceans_nepccr_pdf_nepccr_exec_summ.pdf.

191 EPA, NATIONAL ESTUARY PROGRAM 2004–2006 IMPLEMENTATION REVIEW REPORT 4 (June 19, 2008), http://water.epa.gov/type/oceb/nep/upload_2008_0709_estuaries_pdf_2004-2005_irreportfinal_6_19_08.pdf.

192. *National Estuary Program Habitat Goals*, EPA, www.epa.gov/owow_keep/estuaries/pivot/habitat/progress.htm (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

193. 15 C.F.R. § 921.2(f) (2012).

194. *See Overview*, NAT'L ESTUARINE RES. RESERVE SYS., http://nerrs.noaa.gov/BGDefault.aspx?ID=61 (last visited Jan. 23, 2013) (on file with the Harvard Law School Library) (describing the process leading to designation as NERRS site).

195. *See id*. (describing day-to-day management).

196. 15 C.F.R. § 921.1(f).

of tidelands, such as Washington,[197] and that therefore may have to purchase such lands in order to include them in the federal program.[198]

Both NEP and NERRS are low-risk strategies for collaborative management and research, but both require congressional appropriations in order to maintain operations, and so are vulnerable to changes in economic and political conditions.[199] Congress has consistently appropriated funds for the operation of NEP and NERRS,[200] but at least in the case of NEP, the funding priority is to support existing estuaries rather than to enroll new ones.[201] The last new NEP designation was in 1995 when a congressional appropriation allowed it.[202] Until this changes, states can focus their efforts on mitigating the flow of pollutants into existing NEP estuaries, which occurs in the majority of coastal states.

8. Incorporate Ocean Acidification Impacts into Environmental Review under State NEPA Equivalents

Fifteen states have "little NEPAs," versions of the National Environmental Policy Act ("NEPA").[203] These statutes require

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197. Caminiti v. Boyle, 732 P.2d 989, 993 (Wash. 1987) ("The state of Washington has the power to dispose of, and invest persons with, ownership of tidelands and shorelands subject only to the paramount public right of navigation and the fishery."); Washington v. Longshore, 5 P.3d 1256, 1259 (Wash. 2000) ("Once tidelands are sold to an individual, title to the clams passes to the private property owner.").

198 Note, however, a state need not own lands in fee simple in order to enroll them in NERRS. 15 C.F.R. § 921.30(d).

199. Note: Congress appropriated no funds to a complementary program, the West Coast Estuaries Initiative (Public Law 110-161), in 2011. *See West Coast Estuaries Initiative*, CATALOG FED. DOMESTIC ASSISTANCE [hereinafter CFDA], www.cfda.gov/?s=program&mode=form&tab=step1&id=0d67d410ab169dbba18aa3012dce1007 (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

200. *See NERRS Appropriations FY 2000–2009*, NAT'L ESTUARINE RES. RESERVE SYS., http://nerrs.noaa.gov/BGDefault.aspx?ID=492 (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

201 NEP is program number 66.456, and the funding priority for 2011 was to support the 28 existing NEP estuaries' management plans. *See* CFDA, *supra* note 199.

202. *See Frequently Asked Questions: Estuaries and Coastal Watersheds*, EPA, http://water.epa.gov/type/oceb/nep/questions.cfm (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

203. David Sive & Mark A. Chertok, *"Little NEPAs" and Their Environmental Impact Assessment Processes*, SR045 ALI-ABA 801, 803 (2010). Washington, D.C., and Puerto Rico also have similar statutes. *Id.* at 840. Note also that some cities require similar emissions accounting for development projects. *See, e.g.*, SEATTLE, WASH., ORDINANCE 122574 (Dec. 10, 2007), clerk.ci.seattle.wa.us/archives/Ordinances/Ord_

review of the environmental impact of proposed projects involving at least some government action.[204] States calibrate the stringency of the acts by identifying which kinds of projects require review, which impacts those reviews must assess, and by specifying whether significant impacts must be mitigated.

Case law and the state statutes themselves have largely defined the first and third of these controls, setting a degree of state action (or a degree of potential impact) required in order for a project to trigger environmental review[205] and establishing a degree of necessary mitigation.[206] State environmental agencies generally set the second control—i.e., the impacts that a review must include—by regulation.[207]

Because ocean acidification is a known effect of various byproducts of human development—including at least CO_2 emissions, NO_x and SO_x emissions, and eutrophication from coastal runoff—regulatory agencies can and should include these drivers' contributions to ocean acidification as impacts that environmental reviews must consider. In some states, courts could already require review of acidification impacts under existing statutory language. For example, in California a court could require such analysis under the existing greenhouse gas and water quality provisions of the California Environmental Quality Act ("CEQA") guidelines.[208] Changing these guidelines slightly to expressly require acidification analysis would highlight the growing scientific consensus on the changing ocean chemistry and its importance to the state's

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122574.pdf (last visited June 24, 2016).

204. The acts often refer to "state agencies," "public agencies," or use similar language. Sive & Chertok, *supra* note 203, at 805.

205. *See, e.g.*, No Oil v. City of L.A., 529 P.2d 66 (Cal. 1974); H.O.M.E.S. v. N.Y. State Urban Dev. Corp., 418 N.Y.S.2d 827 (4th Dep't 1979).

206. *See, e.g.*, CAL. PUB. RES. CODE § 21002.1(b) (1994) ("Each public agency shall mitigate or avoid the significant effects on the environment of projects that it carries out or approves whenever it is feasible to do so.").

207. *See, e.g.*, 6 N.Y. COMP. CODES R. & REGS. tit. 6, § 617 (2012); WASH. ADMIN. CODE § 197-11-020 (2012).

208. *See, e.g.*, CAL. CODE REGS. tit. 14, § 15064.4(b) (2012)

> (A lead agency should consider the following factors, among others, when assessing the significance of impacts from greenhouse gas emissions on the environment: … The extent to which the project complies with regulations or requirements adopted to implement a statewide, regional, or local plan for the reduction or mitigation of greenhouse gas emissions …. If there is substantial evidence that the possible effects of a particular project are still cumulatively considerable notwithstanding compliance with the adopted regulations or requirements, an EIR must be prepared for the project.).

economy and coastal ecosystems. It would not be a major regulatory change because California already demands an accounting of greenhouse gas impacts and erosion in environmental review.[209] Massachusetts and Washington also require some form of greenhouse gas accounting in their analogous laws.[210]

Where states lack greenhouse gas accounting requirements in their little NEPAs, courts and environmental agencies can nevertheless require acidification-impact analysis as an aspect of water quality. Again, making this connection more explicit by listing acidification expressly as an impact that project proponents must consider would highlight the issue, but is not essential. Chemical properties (including nutrient loading and pH) are essential measures of water quality, and proposed projects that degrade water quality by changing the pH of receiving waters fall squarely within the ambit of state NEPA equivalents.[211]

Analyzing the contribution of a proposed project to ocean acidification under state NEPA-style laws would be a helpful complement to actions under the Clean Water Act in any effort to deal with nonpoint source pollution more responsibly. Moreover, this shift requires a bare minimum of new law or regulation, and would underscore the growing awareness of the real environmental threat that a fundamentally changed ocean represents.

9. Direct Action to Enforce: Public Nuisance and Criminal Statutes

All states have the power to sue polluters as common law public nuisances, and many jurisdictions also have criminal

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209. *See, e.g.*, CAL. CODE REGS. tit. 14, § 15064.4 (2012) (greenhouse gases); CAL. CODE REGS. tit. 14 art. 20, app. G (2012) (environmental checklist form containing multiple references to erosion and runoff).

210. *See* MASS. EXEC. OFFICE ENERGY & ENVTL. AFFAIRS, REVISED MEPA GREENHOUSE GAS EMISSIONS POLICY AND PROTOCOL (2010), www.env.state.ma.us/mepa/downloads/GHG%20Policy%20FINAL.pdf (last visited June 24, 2016); *SEPA and Climate Change*, WASH. STATE DEP'T OF ECOLOGY, www.ecy.wa.gov/programs/sea/sepa/climatechange/index.htm (last visited .June 24, 2016) (on file with the Harvard Law School Library).

211. *Cf.* WASH. STATE DEP'T OF ECOLOGY, SEPA PROJECT REVIEW FORM: GUIDANCE DOCUMENT 12 (2000), www.ecy.wa.gov/programs/sea/sepa/project/doc/ver5guidance.doc (listing excess nutrient runoff as a condition to be considered when listing impacts).

statutes dealing with water pollution. The federal Clean Water Act does not preempt state common law nuisance claims, expressly leaving states the power to regulate water quality more stringently.[212] Federal courts have upheld state common law claims as viable, despite the preemption of federal common law claims,[213] and these long-established background tools are easily and relatively cheaply deployed to protect water quality.

A public nuisance is an "unreasonable interference with a right common to the general public."[214] In general, citizens lack standing to sue for public nuisances, but where a person is particularly harmed by a public nuisance, he or she has standing to sue.[215] Where degraded water quality jeopardizes a coastal business, for example, the proprietor may seek to abate the cause of that degraded water quality as a public nuisance. State agencies seek the remedy in the absence of a plaintiff claiming special harm. Some instances of water pollution constitute a public nuisance per se,[216] and these are particularly attractive cases for either private or public enforcement because of their predictable outcomes.

Examples of successful nuisance actions for marine pollution abound, arising in a large number of jurisdictions. For instance, commercial fishermen have successfully sued for damages stemming from both land-based[217] and ocean-based[218]

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212. 33 U.S.C. § 1251(b) (2006) ("It is the policy of the Congress to recognize, preserve, and protect the primary responsibilities and rights of States to prevent, reduce, and eliminate pollution, to plan the development and use (including restoration, preservation, and enhancement) of land and water resources.").

213. *See* Milwaukee v. Illinois, 451 U.S. 304, 327-29 (1981); *see also* Int'l Paper Co. v. Ouellette, 479 U.S. 481, 497 (1987) ("Nothing in the [Clean Water Act] bars aggrieved individuals from bringing a nuisance claim pursuant to the law of the source State.").

214. REST. (SECOND) OF TORTS § 821B (1979). Most states have followed this approach to public nuisance. David A. Grossman, *Warming Up to A Not-So-Radical Idea: Tort-Based Climate Change Litigation*, 28 COLUM. J. ENVTL. L. 1, 53 (2003). Note also that California's strong public trust doctrine reinforces the idea that the marine waters are a public good, and as such are amenable to the application of public nuisance doctrine. *See* Nat. Audubon Soc'y v. Super. Ct., 33 Cal.3d 419, 441 (1983).

215. *See, e.g.*, Newhall Land & Farming Co. v. Super. Ct. of Fresno Cnty., 19 Cal. App. 4th 334, 341 (5th Dist. 1993).

216. *Id.* ("Water pollution occurring as a result of treatment or discharge of wastes in violation of Water Code section 13000 et seq. *is a public nuisance per se*.") (emphasis added) (citations omitted).

217. *See, e.g.*, Curd v. Mosaic Fertilizer, LLC, 39 So.3d 1216, 1228 (Fla. 2010) (holding that commercial fishermen may recover from terrestrial fertilizer storage facility for pollution; extensively documenting case law in this area); Leo v. General Electric Co., 145 A.D.2d 291, 292–93 (N.Y. App. Div. 1989). *But see* Holly Ridge

pollution. Nuisance actions place the costs of abatement on polluters,[219] internalizing the cost of future pollution. Further, vicarious nuisance liability may be particularly useful in actions against multi-level corporate entities, such as factory farms.[220]

Many states have clean water statutes, with civil or criminal penalties for polluting parties. In particular, these statutes are likely to focus on drinking water quality.[221] But because drinking water often derives from major sources of surface water, the laws may be more generally applicable to issues of freshwater quality and ultimately coastal water quality. California, for example, has statutes that prohibit the keeping of livestock in a manner that pollutes water used for domestic purposes.[222] Because agricultural nonpoint source runoff is such a substantial source of pollution that often otherwise goes unregulated, these code sections may be particularly valuable enforcement tools for state agencies.

Most states have "right-to-farm" statutes that exempt the agriculture industry from many nuisance actions.[223] Some of these laws are breathtakingly broad: Delaware's, for example, states that "no state or local law-enforcement agency may bring a criminal or civil action against an agricultural

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Associates v. N.C. Dep't of Env't & Nat. Res., 361 N.C. 531, 538 (2007) (finding shellfish growers lacked a direct interest sufficient for intervention as of right, where they had sought to intervene in action over civil penalty assessed against developer by state agency for violation of sediment pollution control act).

218. *See, e.g.*, Louisiana v. M/V Testbank, 524 F. Supp. 1170 (E.D. La. 1981), *aff'd* 767 F.2d 917 (5th Cir. 1985).

219. ENVTL. L. INST., ENFORCEABLE STATE MECHANISMS FOR THE CONTROL OF NONPOINT SOURCE WATER POLLUTION 23 (1997), http://water.epa.gov/polwaste/nps/elistudy_index.cfm. (last visited June 24, 2016).

220. Of particular interest for vicarious liability for nonpoint source pollution is *Assateague Coastkeeper v. Alan & Kristin Hudson Farm*, 727 F. Supp. 2d 433, 442 (D. Md. 2010). There, the district court denied defendant's motion to dismiss for failure to state a claim, on the basis of the corporation's alleged vicarious liability for Clean Water Act violations at a smaller concentrated animal feeding operation ("CAFO"). Although this case arose in the statutory – rather than common law – context, it provides a recent reminder of the power of vicarious liability in the context of environmental law.

221. *See, e.g.*, WASH. REV. CODE § 70.54.010 (West 2011) ("Every person who shall deposit or suffer to be deposited in any spring, well, stream, river or lake, the water of which is or may be used for drinking purposes … any matter or thing whatever, dangerous or deleterious to health … shall be guilty of a gross misdemeanor.).

222. CAL. HEALTH & SAFETY CODE §§ 116990, 116995 (West 2012).

223. *See* ENVTL. L. INST., *supra* note 219, at 25–26, for a review of these statutes.

operation for an activity that is in compliance with all applicable state and federal laws, regulations, and permits."[224] Others, such as New York's, only exempt the agriculture industry from private nuisance suits, leaving the door open to public nuisance actions.[225] California's right-to-farm law leaves intact nuisance actions falling under a broad swath of statutory provisions.[226] Despite the presence of various exceptions,[227] and the right-to-farm statutes' questionable validity under some state constitutions,[228] these statutes somewhat limit states' abilities to abate agricultural nonpoint source pollution.

Using either common law or statutory approaches to abate harmful discharges directly could ameliorate coastal acidification and improve water quality. In some cases, these actions could be the fastest and most effective means of mitigating a particular pollution source. Although it is impossible to estimate the aggregate effect of these actions with any certainty, this approach has the attractive effect of shifting the cost of pollution onto the polluters themselves, encouraging these polluters to minimize future pollution.

Criminal statutes[229] could be of further use for state enforcement efforts. All fifty states have criminal statutes for water pollution, although these vary widely in their penalties and criminal elements.[230] For example, dumping waste matter into water bodies of any kind—or on stream banks or beaches—is a crime in California, and carries a penalty of

224. DEL. CODE ANN. tit. 3, § 1401 (West 2010).

225. N.Y. PUB. HEALTH LAW § 1300-c (McKinney 2012).

226. CAL. CIV. CODE § 3482.5 (West 2012). Note also that this law only exempts agricultural activities from common law nuisance actions when the actions are "due to any changed condition in or about the locality." *Id*. That is, the law is aimed at preserving existing farming activities despite the encroachment of urban areas, rather than exempting the agricultural industry from nuisance law generally.

227. *See* LINDA A. MALONE, ENVT'L REG. OF LAND USE § 6:15 (2011) (citing negligence, trespass, and strict liability as alternative means of abating agricultural runoff).

228. *Id*. (discussing Iowa Supreme Court's finding that the state's right-to-farm statute created a de facto easement, and hence constituted a taking).

229. *See, e.g*., CAL. PENAL CODE § 374.7(a) (West 2012).

230. *See generally* Andrew Franz, *Crimes Against Water: Non-Enforcement of State Water Pollution Laws*, 56 CRIME LAW SOC. CHANGE 27 (2011) (discussing state laws criminalizing water pollution, and the under-enforcement of these laws).

criminal fines.[231] Failing to file for a discharge permit—whether the discharge is from a point or a nonpoint source—is also a misdemeanor under the state's Porter-Cologne Act.[232] Although such dumping is probably not a major driver of coastal water quality problems when compared to more routine point and nonpoint source discharges, enforcing these laws would be a means of deterring illegal pollution while underscoring the seriousness of environmental crimes. Depending upon the criminal fines and the disposition of the revenue from those fines, this money would at least defray the expense of enforcement.

Finally, a rarely invoked example of abatement action is a state agency or municipality suing another agency or municipality for failure to perform a nondiscretionary duty. Where states have waived sovereign immunity with respect to this kind of suit, as is the case in California,[233] a coastal or downstream community would have recourse against inland or upstream government entities that breach an identifiable and nondiscretionary duty to safeguard water quality.[234]

10. Practice Smart Growth and Smart Land Use Changes

Changes in planning and land use can reduce many of the coastal inputs likely to exacerbate local ocean acidification, while simultaneously contributing to a larger-scale effort to minimize the CO_2 emissions that create a background level of ocean acidification worldwide. This approach has the advantage of dealing with both the short term/local and longer term/global drivers of acidification in tandem. We address these non-CO_2 drivers first, and then discuss direct CO_2 management below.

Many states have smart-growth or anti-sprawl guidelines, but ultimately land use decisions are canonical functions of

231. CAL. PENAL CODE § 374.7(a). Oregon has an analogous law. OR. REV. STAT. § 468.946 (2012).

232. CAL. WATER CODE § 13261 (West 2012).

233. CAL. GOV'T CODE § 815.6 (2012) (establishing a mandatory duty of public entity to protect against particular kinds of injuries.).

234. For example, municipalities, counties, and public agencies may sue one another over alleged violations of the California Environmental Quality Act. *See, e.g.*, L.A. Cnty. Sanitation Dist. No. 2 v. Cnty. of Kern, 127 Cal. App. 4th 1544, 1558 (2005).

local government.[235] Hence, local governments have a significant role to play in combating ocean acidification, CO_2 emissions, and poor water quality, and can feasibly do so through a subtle shift in how they make land use decisions.

Local governments can take a number of steps to mitigate nonpoint source runoff that negatively impacts coastal waters by decreasing impermeable surfaces, increasing riparian buffers, and increasing the efficiency of stormwater management. Local governments have already taken a number of steps to achieve these land use goals. For example, every general plan in California requires a transit-friendly circulation element,[236] and requires cities to identify streams and riparian areas that may accommodate floodwaters for purposes of stormwater management.[237] Transit-friendly circulation means greater densities, fewer vehicle miles traveled,[238] and less voracious conversion of habitat to impermeable streets and sidewalks.[239] By safeguarding streams and riparian areas, a local government can ensure better flood accommodation while preserving buffers between the urban street and the waters that flow directly to the ocean.

Other state statutes require that local subdivisions properly provide for erosion control,[240] and some single out special land use classes (such as forestry) for special attention to erosion and pollution control.[241] These and other land use measures

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235. *See generally* Patricia E. Salkin, *Sustainability and Land Use Planning*, 34 WM. & MARY ENVTL. L. & POL'Y REV. 121 (2009) (reviewing land use practices and other sustainability laws in state and local jurisdictions across the United States).

236. CAL. GOV'T CODE § 65302(b)(1) (West 2011).

237. CAL. GOV'T CODE § 65302(d)(3).

238. *See infra* notes 255–68 and accompanying text for a discussion of transit-friendly circulation.

239. Transit plans may be eligible for federal subsidies. *See, e.g.*, *Congestion Mitigation and Air Quality Improvement (CMAQ) Program*, U.S. DEP'T OF TRANSP. FED. HIGHWAY ADMIN., www.fhwa.dot.gov/environment/air_quality/cmaq/ (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

240. *See* CAL. GOV'T. CODE § 65596(f) ("The [subdivision] ordinance shall specifically provide for proper grading and erosion control, including the prevention of sedimentation or damage to offsite property."); *see also id.* § 66646.2 (enabling the San Francisco Bay Conservation and Development Commission to identify areas subject to erosion and inundation due to sea level rise).

241. CAL. PUB. RES. CODE §§ 4581–92. Note in particular that:

> A timber harvesting plan may not be approved if the appropriate regional water quality control board finds … that the timber operations proposed in the plan will result in a discharge into a watercourse that has been classified as impaired due to sediment pursuant to [CWA § 303(d)] …. § 4582.71(a).

that prevent the wastes of urban life from entering surface waters and the coastal ocean ultimately protect nearshore ecosystems and the services they provide.[242] Local land use controls also tend to place the costs of pollution prevention measures on those best equipped to control design and costs, the project developers.

Little NEPAs can be used to effectuate systemic change—because county or city actions to adopt or amend general plans (also called "comprehensive plans"), or to approve tentative subdivision maps, are steps that typically trigger state environmental review statutes.[243] Therefore, a state environmental review statute that requires analysis of ocean acidification impacts would produce broader change in land use regulation simply because it would influence long-term planning.

More than most other states, California has an additional and powerful tool with which to shape land use decisions in favor of coastal protection. The California Coastal Commission can use its broad authority to prevent land use practices that negatively impact the nearshore environment.[244] The Coastal Act authorizes the Commission to maintain and restore marine resources, including coastal water quality and biological

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Id. § 4582.71(a). Given the large number of state water bodies on the 303(d) list, this provision could be especially powerful to minimize sediment and nutrient loadings from forestry activities. *Id.*

242. A good example of such proactive work is Portland, Oregon's "Tabor to the River" watershed-wide restoration effort. This program integrates social and environmental goals to improve water quality and riparian habitat in the Willamette River basin. *See Tabor to the River*, PORTLAND BUREAU ENVTL. SERVS., http://www.portlandoregon.gov/bes/47591 (last visited Jan. 23, 2013) (on file with the Harvard Law School Library). In particular, the program focuses on sewer and stormwater management, as well as tree planting.

243. *See* CAL. CODE REGS. tit. 14 § 15378 (2012); CAL GOV'T CODE, § 65456; Christward Ministry v. Super. Ct., 184 Cal. App. 3d 180, 193–94 (1986); City of Lomita v. City of Torrance, 148 Cal. App. 3d 1062, 1069 (1983). Note that where changes to general plans are done by ballot initiative—rather than by agency approval—those changes are not subject to CEQA review. CAL. CODE REGS. tit. 14 § 15378(b)(3); DeVita v. Cnty. of Napa, 9 Cal. 4th 763, 793–795 (1995). As to subdivision maps, *see* CAL. PUB. RES. CODE § 21080.

244. *See* CAL. PUB. RES. CODE § 30230 ("Marine resources shall be maintained, enhanced, and where feasible, restored."); CAL. PUB. RES. CODE § 30231 ("The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored.").

productivity.[245] Proactively mitigating stressors arising from coastal land uses within the Commission's jurisdiction—which may include nutrient runoff from nonpoint sources, an otherwise difficult issue to tackle—is within the Commission's mandate and is a significant policy tool that is available without any need for change to existing law.[246]

Other coastal states have coastal management agencies with varying degrees of centralization and authority. With the exception of Alaska,[247] every coastal state has an approved coastal management program under the federal Coastal Zone Management Act.[248] New York, for example, has an Office of Communities and Waterfronts[249] that has developed a set of coastal policies[250] guiding some land use decisions along the shore. By contrast, Florida's coastal program weaves together eight state agencies and five water management districts.[251] To the degree that states' CZMA-implementing agencies influence coastal land use planning and decisionmaking, these agencies can minimize inputs into the nearshore environment and ameliorate coastal acidification accordingly.

Efforts to make general plans more responsive to issues in the nearshore environment could be bolstered by the support of local marine industries and residents, all of whom will benefit from a healthier coastline. Politics and tax dollars are more

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245. *See* CAL. PUB. RES. CODE §§ 30230–1.

246. Note that the Coastal Commission shares responsibility with the state and regional Water Boards in implementing the Nonpoint Source Program Strategy and Implementation Plan. PROSIP, *supra* note 99, at v. The Commission's authority is not restricted to implementation of the Plan, but rather by the Coastal Act. *See* CAL. PUB. RES. CODE §§ 30004(b), 30005.5, 30011.

247. Alaska withdrew from the federal coastal zone management program on July 1, 2011. 76 Fed. Reg. 39857 (July 7, 2011).

248. 16 U.S.C. §§ 1451-1466; *see States and Territories Working on Ocean and Coastal Management*, NOAA, http://coastalmanagement.noaa.gov/mystate/welcome.html (last visited Jan. 23, 2013) (on file with the Harvard Law School Library) (showing locations of states and territories with approved issues, and offering details on each).

249. *Office of Communities and Waterfronts*, N.Y. DEP'T OF STATE, www.dos.ny.gov/communitieswaterfronts/ (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

250. *State Coastal Policies*, N.Y. DEP'T OF STATE COASTAL MGMT. PROGRAM, www.dos.ny.gov/communitieswaterfronts/pdfs/coastalpolicies.pdf (last visited Jan. 23, 2013) (on file with the Harvard Law School Library).

251. FLA. DEP'T OF ENVTL. PROT., FLORIDA COASTAL MANAGEMENT PROGRAM GUIDE 11 (2011), www.dep.state.fl.us/cmp/publications/fcmp_guide.pdf.

likely to favor changes where coastal industries affected by ocean acidification, such as shellfish fisheries, finfish fisheries, and tourism, significantly influence the local economy. Similarly, where urban redevelopment funds and other anti-sprawl incentives are available, municipalities should find it easier to budget for actions to combat ocean acidification locally.

VII. DIRECT CO_2 MANAGEMENT

Despite its critical importance, we did not include direct CO_2 management among the ten points above because of the extensive existing literature on the subject,[252] and because of the relatively unfavorable alignment of incentives for state, tribal, and local governments to bear the cost of reducing emissions in exchange for a diffuse, global benefit. Nevertheless, we cannot conclude this paper without at least briefly discussing the role of subnational governments in reducing CO_2 directly.

Government entities may act to manage CO_2 directly either by regulation (e.g., via the Clean Air Act), or by using governmental spending power (e.g., greener purchasing, renewable energy portfolios, etc.). Coastal states account for a substantial portion of the nation's carbon emissions,[253] and these emissions are generated in large part by the states' transportation and energy sectors.[254] And of course, the national emissions of the United States constitute a substantial fraction of the world's emissions.[255] While state or

252. *See, e.g.*, Robert N. Stavins, *A Meaningful U.S. Cap-and-Trade System to Address Climate Change*, 32 HARV. ENVTL. L. REV. 293 (2008); Jonathan S. Masur & Eric A. Posner, *Climate Regulation and the Limits of Cost-Benefit Analysis*, 99 CAL. L. REV. 1557 (2011).

253. California, Florida, Louisiana, and New York were among the top ten emitting states in 2010, according to EPA data. *See* EPA, STATE CO_2 EMISSIONS FROM FOSSIL FUELS COMBUSTION, 1990–2010 DATA, www.epa.gov/statelocalclimate/resources/state_energyco2inv.html.

254. *Id.*

255. The United States accounted for approximately 16.4% of the world's emissions in 2010. See *Preliminary CO_2 Emissions 2010*, CARBON DIOXIDE INFO. ANALYSIS CTR., http://cdiac.ornl.gov/ftp/trends/co2_emis/Preliminary_CO2_emissions 2010.xlsx (last visited Jan. 23, 2013) (on file with the Harvard Law School Library) (listing total U.S. emissions in 2010 as 1497864.583 thousand metric tons of carbon and world total as 9138791.143 thousand metric tons of carbon; U.S. emissions divided by world total equals 0.1639, or 16.4%). California's per capita emissions are greater than those for

local emissions reductions will not in themselves be globally significant, reducing the total amount of anthropogenic CO_2 that a given state adds to the atmosphere is an absolutely essential step towards mitigating the primary driver of global ocean acidification.[256]

But where the incentives to reduce emissions are so far small or nonexistent, jurisdictions are unlikely to act unless they experience some more immediate and tangible benefit. This immediate and tangible benefit is most likely to arise in the context of local land use changes, which will pay local dividends over short time horizons while diminishing emissions. For example, increasing urban density to reduce vehicle miles traveled is likely to be an especially effective step to reduce CO_2 emissions[257] and has many positive side benefits for cities. Greater population density can increase municipal tax revenues and pay cultural dividends, all while reducing emissions from vehicle miles traveled.[258] Going beyond incentives for denser development and greener building codes—both of which largely impact future infrastructure—to reach existing infrastructure would provide large energy and emissions savings for many cities, particularly since these programs can be extremely cost effective.[259]

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many large nations, including Germany, Japan, Italy, France, Mexico, Brazil, and Argentina. *See* CAL. ENERGY COMM'N, INVENTORY OF CALIFORNIA GREENHOUSE GAS EMISSIONS AND SINKS: 1990 TO 2004 20 (Figure 11) (2006), www.energy.ca.gov/2006publications/CEC-600-2006-013/CEC-600-2006-013-SF.pdf. In 2004, California emitted a total of approximately 363.8 million metric tons of carbon dioxide equivalents ("mmtCO_2-eq"), of which 188 mmtCO_2-eq (51.7%) was from the transportation sector. *Id.* at 25.

256. Some reductions may also be required under state law. *See, e.g.,* CAL. HEALTH & SAFETY CODE § 38550 (West 2012) (requiring 1990 emissions levels in California by 2020).

257. For example, California's Senate Bill 375 (Steinberg), chaptered Sept. 30, 2008, provides modest incentives for denser and more transit-friendly development in California. S.B. 375, 2007–2008 Leg. Sess. (Cal. 2008); *see also* KING CNTY., WASH., PROPOSED MOTION No. 2011-0208.1 7 [hereinafter CLIMATE MOTION] (2011), http://your.kingcounty.gov/dnrp/climate/documents/2011_Climate_Motion.pdf (similar).

258. *Id.*

259. *See* FED. ENERGY MGMT. PROGRAM, OPERATIONS & MAINTENANCE BEST PRACTICES: A GUIDE TO ACHIEVING OPERATIONAL EFFICIENCY (RELEASE 2.0) 2.3 (2004), www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf ("It has been estimated that [operations and maintenance] programs targeting energy efficiency can save 5% to 20% on energy bills without a significant capital investment."); *see also* LEVIN NOCK & CLINT WHEELOCK, PIKE RESEARCH, ENERGY EFFICIENCY RETROFITS FOR COMMERCIAL AND PUBLIC BUILDINGS EXECUTIVE SUMMARY 1 (2010), www.srmnetwork.com/pdf/whitepapers/Energy_Efficiency_Retrofits_Jul10.pdf (estimating average payback time

State and local governments can also save substantial amounts of money by moving to greener sources for government acquisitions.[260] Small examples of more emissions-friendly purchasing policies include many cities' and states' ban on government-purchased bottled water[261] and San Francisco's vehicle fleet reduction.[262] Cities and counties can also change their energy portfolios toward increasing renewables, as King County, Washington has done.[263]

Finally, state and local governments can avoid increasing their emissions by obtaining water in an energy efficient manner. Desalination projects, under consideration in a variety of states, will have enormous CO_2 footprints,[264] and the relevant governmental agencies must carefully weigh the value of these and other coastal industries against the impacts of CO_2 on their ocean. Water recycling and conservation is likely to be much cheaper than desalination, and comes with large emissions reductions.[265] These and other CO_2 management

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of slightly over one year for energy efficiency projects). Corning, a major manufacturer of glass and ceramics, has reported striking returns on investment (80–100%) from energy efficiency projects, including combined heat-and-power plants. *See* PETER GARFORTH ET AL., CHANGING CORPORATE ENERGY CULTURE: THE CORNING, INC. AND NYSERDA PARTNERSHIP, 3–86 (2007), www.eceee.org/conference–proceedings/ACEEE_industry/2007/Panel_3/p37/ (thanks to Brad Warren of the Sustainable Fisheries Partnership for providing this reference).

260. *See, e.g.*, KING CNTY., 2010 ANNUAL GREEN REPORT 2 (2010), http://your.kingcounty.gov/dnrp/library/dnrp-directors-office/climate/2010-annual-green-report.pdf (reporting a county savings of $ 1 million in 2010 alone for buying "environmentally preferable products").

261. *See, e.g.*, *Bottled Water Banned*, CITY OF MILL VALLEY, www.cityofmillvalley.org/index.aspx?recordid=231&page=34 (last visited Jan. 23, 2013) (on file with the Harvard Law School Library); Timothy B. Wheeler, *Maryland State Offices Going off the Bottle*, BALT. SUN, Sept. 30, 2011; Sharon P. Chan, *Seattle Giving Bottled Water the Boot*, SEATTLE TIMES, Mar. 14, 2008.

262. San Francisco Office of the Mayor, Exec. Directive No. 09-01 (Jan. 12, 2009).

263. King County will implement its 2010 Energy Plan to achieve 50% of its energy needs from renewables by 2015. CLIMATE MOTION, *supra* note 257, at 11.

264. Depending upon the desalination process used, plants use between 4–12 kWh of thermal energy and 1.5–7 kWh of electric energy to desalinate a single cubic meter of water. *See* Sabine Lattemann & Thomas Hopner, *Environmental Impact and Impact Assessment of Seawater Desalination*, 220 DESALINATION, MAR. 2008, at 1, 10. The authors note a mid-sized desalination plant uses as much energy annually as 10,300 four-person households. *Id*. Emerging technologies may lower the energy demand of desalination. *See, e.g.*, M. Busch & W. E. Mickols, *Reducing Energy Consumption in Seawater Desalination*, 165 DESALINATION, AUG. 2004, at 299. However, carbon emissions from desalination efforts in the United States are likely to remain a serious environmental cost of the process for years to come.

265. Seawater desalination is roughly nine times as energy intensive as surface

efforts are the beginnings of the broader policy changes necessary to combat global ocean acidification.

VIII. CONCLUSION

Ocean acidification sits at the intersection of water and air quality issues. Although the primary driver of worldwide acidification is atmospheric CO_2, other atmospheric (SO_x/NO_x) and non-atmospheric (e.g., nutrient) inputs may contribute to large chemical changes in some coastal regions. Consequently, state, tribal, and local governments can mitigate a significant portion of acidification's harms through smaller-scale actions as we work toward global CO_2 solutions. That they can do so without serious environmental tradeoffs, in ways consistent with existing environmental priorities, is especially fortunate.

These government entities have no shortage of tools at their disposal. In this Article, we have provided a short list as a starting point for action, but the list could have been much longer. New and better laws are of course welcome to help tackle this emerging environmental issue, but more valuable in actually solving the problem will be a more favorable alignment of costs and benefits as the contours of the threat become clearer.

It is difficult to persuade a local, state, or tribal government to spend money out of its very limited budget to mitigate an environmental problem, when the precise harm is uncertain and lies largely in the future. Ocean acidification is not yet a priority for many jurisdictions,[266] and that is hardly surprising given the list of challenges facing all levels of government. Although there are significant benefits to mitigating acidification sooner rather than later—especially given the possible nonlinear impacts of environmental change—the main benefits are in the form of future harm reduction. This kind of

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water desalination. *See* BEVAN GRIFFITHS-SATTENSPIEL & WENDY WILSON, THE RIVER NETWORK, THE CARBON FOOTPRINT OF WATER 15 (2009), www.rivernetwork.org/sites/default/files/The%20 Carbon%20Footprint%20of%20Water-River%20Network-2009.pdf (stating that desalination is seven times as energy intensive as groundwater, which in turn is 30% more intensive than surface water).

266. A notable exception is Washington State, where the aligned interests of treaty tribes and the shellfish industry led the governor to announce the formation of a blue ribbon panel on ocean acidification. Press Release, Wash. Dep't of Ecology, Gov. Gregoire Announces New Initiative to Create Jobs, Restore Puget Sound, (Dec. 9, 2011), www.ecy.wa.gov/news/2011/gov_20111209.html.

benefit is routinely and systematically undervalued.[267]

There are good reasons to believe that ocean acidification will become a higher priority in the future. First, the direct harm to ecosystems and industries dependent upon them is likely to get worse as the ocean becomes more acidic. As economic harms increase, we expect efforts to mitigate these harms to increase proportionately. Conversely, the benefits of combating ocean acidification will become both clearer and nearer in time as the cost of inaction grows. More certain and more immediate benefits tend to be valued more highly, and therefore benefit from greater incentives for government action. Third, a wider spectrum of interests will likely find common cause as the threats of acidification become more tangible and widespread. The resulting political pressure should be a substantial incentive for governments to act.

Whether these changes will come to pass in time for coastal management to influence the environmental outcome is an open question. At present, the ocean appears to be acidifying at a rate faster than at any other time in the geologic record.[268] We are already in a no-analog future.[269] We hope that this Article provides a useful set of measures for those government entities that want to combat ocean acidification now, as well as a prompt to those governments who do not yet realize the value of doing so.

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267. *See, e.g.*, David M. Driesen, *The Societal Cost of Environmental Regulation*, 24 ECOLOGY L. Q. 545, 587–88 (1997).

268. *See* Richard E. Zeebe, *History of Seawater Carbonate Chemistry, Atmospheric CO_2, and Ocean Acidification*, 40 ANN. REVS. EARTH & PLANETARY SCI. 141, 160 (2012); Barbel Honisch et al., *The Geological Record of Acidification*, 335 SCI. 1058, 1058 (2012); *see also* Kump et al., *supra* note 30, at 105–06:

> ([M]uch of humanity is, in effect, engaged in a collective and deliberate effort to transfer carbon from geological reservoirs to the atmosphere as CO_2. The resulting rate of environmental change very likely far exceeds that associated with past greenhouse transient events, and will have been exceeded in the geological record only by bolide impacts of the sort that caused the K/T extinction [i.e., of the dinosaurs, among many, many other species] 66 million years ago. Lesser events in the geologic past have left an indelible imprint on the geologic and biotic record. "Business as usual" combustion of fossil fuels, unless accompanied by an aggressive and successful program of carbon capture and storage, is likely to leave a legacy of the [present] as one of the most notable, if not cataclysmic, events in the history of our planet.).

269. *See generally* Douglas Fox, *Back to the No-Analog Future?*, 316 SCI. 823 (2007); J. B. Ruhl, *Climate Change and the Endangered Species Act: Building Bridges to the No-Analog Future*, 88 B.U. L. REV. 1 (2008).