DEALING WITH OCEAN ACIDIFICATION: THE PROBLEM, THE CLEAN WATER ACT, AND STATE AND REGIONAL APPROACHES[▽]

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ABSTRACT: Ocean acidification is often referred to as climate change's "evil twin." As the global ocean continually absorbs much of the anthropogenic carbon dioxide produced through the burning of fossil fuels, its pH is dropping, causing a plethora of chemical, biological, and ecological impacts. These impacts immediately threaten local and regional fisheries and marine aquaculture; over the long term, they pose the risk of a global mass extinction event. As with climate change itself, the ultimate solution to ocean acidification is a worldwide reduction in carbon dioxide emissions. In the interim, however, environmental groups such as the Center for Biological Diversity have worked to apply the federal Clean Water Act to ocean acidification, while states and coastal regions are increasingly pursuing more broadly focused responses to ocean acidification's local and regional impacts. This Article provides a first assessment of these relatively nascent legal efforts to address ocean acidification. It concludes first that ocean acidification should prompt renewed Clean Water Act attention to stormwater runoff and nutrient pollution. However, this Article also demonstrates that improved implementation of the Clean Water Act will not be enough. The realities of ocean acidification require more comprehensive legal and policy innovations so that coastal states and regions can adapt to its impacts now and into the future.

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I. INTRODUCTION

Ocean acidification is often referred to as climate change's "evil twin."[1] As a natural part of the Earth's carbon dioxide (CO_2) cycle, the world's ocean[2] has been absorbing much of the "extra" carbon dioxide that humans have been producing, especially since humans began burning fossil fuels on a large scale as a result of the Industrial Revolution.[3] However, once absorbed into the ocean, carbon dioxide chemically reacts with water to form carbonic acid[4]—essentially the same reaction that both gives sodas their fizz and contributes to their ability to dissolve tooth enamel.[5] This acid-forming reaction is lowering the ocean's pH.[6]

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1. *E.g.*, ARC Ctr. of Excellence in Coral Reef Studies, *Ocean Acidification: 'Evil Twin' Threatens World's Oceans, Scientists Warn*, SCIENCEDAILY (Apr. 1, 2010), http://www.sciencedaily.com/releases/2010/03/100330092821.htm.

2. While both laypeople and scientists commonly divide the world's ocean into five geographic regions—the Pacific Ocean, the Atlantic Ocean, the Indian Ocean, the Arctic Ocean, and the Southern Ocean—it is increasingly recognized that all of the world's marine realms are physically, chemically, and biologically interconnected. For example, the National Ocean Service of the National Oceanic and Atmospheric Administration (NOAA) declares that "[t]here is only one global ocean." Nat'l Ocean Service, *How Many Oceans Are There?*, NOAA, http://oceanservice.noaa.gov/facts/howmanyoceans.html (last visited Oct. 13, 2015) (emphasis in original). To emphasize this interconnectedness, this Article purposely refers to the world's "ocean" in the singular unless specific research results are restricted to particular geographic regions of that ocean.

3. Peter M. Cox et al., *Acceleration of Global Warming Due to Carbon-Cycle Feedbacks in a Coupled Climate Model*, 408 NATURE 184, 184 (2000).

4. *Ocean Acidification*, NAT'L GEOGRAPHIC, http://ocean.nationalgeographic.com/ocean/critical-issues-ocean-acidification/ (last visited Oct. 13, 2015).

5. Matthew Lee, *Soda's Effects on Tooth Erosion*, SFGATE, http://healthyeating.

The result, potentially, is worldwide marine ecological havoc.[7] Most life on Earth is sensitive to small changes in pH. In humans, for example, a change in blood pH outside of a very narrow healthy range (7.35 to 7.45)[8] leads to disease—acidiosis[9] when blood pH falls below 7.4, and alkalosis[10] when it rises above 7.45.[11] If the levels of pH change projected for the ocean—0.3 to 0.4 pH units on average by the end of the century[12]—were applied to human blood chemistry, humans would die.[13]

Ocean life is similarly sensitive to changes in pH—even the external changes that ocean acidification is causing.[14] This sensitivity is particularly acute in shelled marine invertebrates that directly interact with ambient chemical conditions in the oceans for their basic life processes.[15] Moreover, ocean acidification's impacts can be exacerbated in some areas because the pH change is not uniform—certain places are ocean acidification "hot spots."[16] Indeed, ocean acidification is

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sfgate.com/sodas-effects-tooth-erosion-3825.html (last visited Oct. 27, 2015).

6. *See* discussion *infra* Part I.A.

7. *See* discussion *infra* Part I.C.

8. *Definition of Blood pH*, MEDICINENET.COM, http://www.medicinenet.com/script/main/art.asp?articlekey=10001 (last visited Oct. 13, 2015).

9. "Acidosis is a condition in which there is too much acid in the body fluids." Nat'l Inst. of Health, U.S. Nat'l Library of Med., *Acidosis*, MEDLINEPLUS, http://www.nlm.nih.gov/medlineplus/ency/article/001181.htm (last visited Oct. 13, 2015).

10. "Alkalosis is a condition in which the body fluids have excess base (alkali)." Nat'l Inst. of Health, U.S. Nat'l Library of Med., *Alkalosis*, MEDLINEPLUS, http://www.nlm.nih.gov/medlineplus/ency/article/001183.htm (last visited Oct. 13, 2015).

11. *Blood pH*, HARPER C., http://www.harpercollege.edu/tm-ps/chm/100/dgodambe/thedisk/bloodbuf/zback.htm (last visited Oct. 13, 2015).

12. *Ocean Portal: Ocean Acidification*, SMITHSONIAN NAT'L MUSEUM NAT. HIST., http://ocean.si.edu/ocean-acidification (last visited Oct. 23, 2015).

13. *Id.*; *see also Blood pH*, *supra* note 11.

14. For example, in the lab, "a decrease of 0.2 to 0.3 units in seawater pH inhibits or slows calcification in many marine organisms, including corals, foraminifera, and some calcareous plankton." Richard E. Zeebe et al., *Carbon Emissions and Acidification*, 321 SCIENCE 51, 52 (2008) (citations omitted).

15. *What Is Ocean Acidification?*, NAT'L OCEANIC & ATMOSPHERIC ADMIN. PMEL CARBON PROGRAM, http://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F (last visited Oct. 14, 2015).

16. For example, "[t]he largest relative changes are in the high latitudes where waters are coldest and absorb most of the CO_2 from the atmosphere." Jelle Bijma et al., *Climate Change and the Oceans—What Does the Future Hold?*, 74 MARINE POLLUTION BULLETIN 495, 498 (2013) (published as part of the 2013 IPSO STATE OF THE OCEANS REPORT, http://www.stateoftheocean.org/wp-content/uploads/2015/10/State-of-the-Ocean-2013-report.pdf).

already a problem for commercial fishing and shellfish aquaculture enterprises around the world, including the state of Maine and the west coast of the United States.[17]

What can the Clean Water Act[18]—the most significant domestic federal law that deals with water pollution—do to address ocean acidification? The problem in trying to apply the Act—which focuses on polluters who dispose of waste directly into *water*—is that most of the cause of ocean acidification is emissions of anthropogenic carbon dioxide into the *air*.[19] Moreover, like climate change itself, ocean acidification occurs in response to carbon dioxide emissions from all over the world.[20] Ultimately, therefore, the long-term solution to ocean acidification is largely the same as the solution to climate change: a worldwide reduction in anthropogenic carbon dioxide emissions.[21]

Nevertheless, as has been documented by scientists, politicians, and legal scholars, nations have thus far made little progress in reducing either global carbon dioxide emissions or atmospheric carbon dioxide concentrations.[22] Although many governments (including the United States) negotiated and ratified the United Nations Framework Convention on Climate Change in 1992 (in force 1994),[23] that treaty is fairly general and does not commit nations to specific carbon reduction goals.[24] The Kyoto Protocol,[25] negotiated in

17. *See infra* Part III.

18. 33 U.S.C. §§ 1251–1388 (2012).

19. Monika Rhein et al., *Observations: Ocean*, *in* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS 255, 294 (Howard Feeland et al. eds., 2013) [hereinafter IPCC 2013 REPORT], http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf.

20. *Id*.

21. Notably, however, climate change is a response to an increasing concentration of a *variety* of greenhouse gases in the atmosphere, including methane and water vapor. Ocean acidification, in contrast, is driven almost entirely by increasing concentrations of carbon dioxide.

22. As the IPCC noted in its latest climate change assessment report, anthropogenic greenhouse gas emissions of carbon dioxide and other greenhouse gases have only continued to increase, as have global atmospheric concentrations of greenhouse gases. Lisa V. Alexander et al., *Summary for Policymakers*, *in* IPCC 2013 REPORT, *supra* note 19, at 3, 4–6 (T.F. Stocker et al. eds.).

23. United Nations Framework Convention on Climate Change, May 9, 1992, 1771 U.N.T.S. 107.

24. As international climate law scholar Daniel Bodansky noted in 1993:

To many, the Convention was a disappointment. Despite early hopes that it would

1997 and in force as of 2005, set more specific goals, but the United States, one of the world's two largest emitters of carbon dioxide,[26] never ratified it.[27] Moreover, many nations that did ratify the Protocol have failed to meet their commitments.[28] The Protocol would have expired on its own terms in 2012, but the parties negotiated a second commitment period lasting until 2020 in the 2012 Doha Amendment.[29] What happens beyond 2020 is an open question, despite several more Conferences of the Parties.[30] As this Article goes to press, the world is engaging in the next round of climate negotiations, set for Paris, France, in November and December 2015.[31]

> seek to stabilize or even reduce emissions of greenhouse gases by developed countries, the Convention contains only the vaguest of commitments regarding stabilization and no commitment at all on reductions. It fails to include innovative proposals to establish a financial and technology clearinghouse or an insurance fund, or to use market mechanisms such as tradeable emissions rights. Furthermore, it not only contains significant qualifications on the obligations of developing countries, but gives special consideration to the situation of fossil-fuel producing states.

Daniel Bodansky, *The United Nations Framework Convention on Climate Change: A Commentary*, 18 YALE J. INT'L L. 451, 454 (1993).

25. Kyoto Protocol to the United Nations Framework Convention on Climate Change art. 28, Dec. 10, 1997, 37 I.L.M. 22. For a helpful contemporary overview of the Kyoto Protocol, see Ved P. Nanda, *The Kyoto Protocol on Climate Change and Challenges to Its Implementation: A Commentary*, 10 COLO. J. INT'L ENVTL. L. & POL'Y 319, 327–30 (1999) (describing in detail the carbon dioxide reduction goals of the Kyoto Protocol and how they were set).

26. Based on 2011 data, China emits the greatest amount of carbon dioxide overall (the United States is second), but the United States emits considerably more carbon dioxide per capita than China. *Each Country's Share of CO_2 Emissions*, UNION CONCERNED SCIENTISTS, http://www.ucsusa.org/global_warming/science_and_impacts/science/each-countrys-share-of-co2.html#.Vi_jDYTJdUR (last visited Oct. 27 2015).

27. *Status of Ratification of the Kyoto Protocol*, UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, http://unfccc.int/kyoto_protocol/status_of_ratification/items/2613.php (last visited Oct. 14, 2015).

28. Based on the United Nation's own evaluations, *The Guardian* reported in 2008 that while "16 [industrialized nations] [were] on target to meet their Kyoto obligations, including France, the UK, Greece and Hungary," about twenty other industrialized nations were already "off-course, including Canada, Germany, Ireland, Italy, Japan, New Zealand and Spain." David Adam, *Analysis: Has the Kyoto Protocol Worked?*, THE GUARDIAN (Dec. 7, 2008), http://www.theguardian.com/environment/2008/dec/08/kyoto-poznan-environment-emissions-carbon.

29. *UN and Climate Change: Towards a Climate Agreement*, UNITED NATIONS, http://www.un.org/climatechange/towards-a-climate-agreement/ (last visited Oct. 20, 2015).

30. *See id.*

31. *Meetings: Paris Climate Change Conference—November 2015*, UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, http://unfccc.int/meetings/paris_nov_2015/meeting/8926.php (last visited Oct. 14, 2015).

Nevertheless, both global carbon dioxide emissions[32] and atmospheric concentrations of carbon dioxide continue to increase, with average global atmospheric concentrations of carbon dioxide surpassing four hundred parts per million at least by March 2015, and perhaps as early as April 2012.[33] Ocean acidification thus remains a real threat. As the world continues to wait for an effective global treaty to reduce anthropogenic carbon dioxide, coastal states and environmental organizations are pursuing local, regional, and national legal means of addressing ocean acidification. The goal of this Article is to describe and begin to assess those emerging legal approaches. The Article begins in Part I by more thoroughly describing ocean acidification itself, concentrating on the basics of the carbon cycle, the chemistry of ocean acidification, its biological and ecological impacts, projections for the future, and its current impacts on marine fisheries and aquaculture. Part II then examines the Center for Biological Diversity's (CBD's) pursuit of national and state action regarding ocean acidification through the Clean Water Act, focusing on the Act's Section 304 national recommended (reference) marine pH water quality criterion and the Section 303 programs for water quality standards, identification and listing of impaired waters, and total maximum daily loads, or TMDLs. Part III, in turn, examines nascent state and regional responses to ocean acidification, focusing on the states of Washington and Maine and the growing collection of regional ocean acidification programs along the West Coast.

This Article concludes that ocean acidification should spur renewed Clean Water Act interest in stormwater runoff and

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32. While carbon dioxide emissions in the energy sector remained steady in 2014, *see Global Energy-Related Emissions of Carbon Dioxide Stalled in 2014*, INT'L ENERGY AGENCY (Mar. 13. 2015), http://www.iea.org/newsroomandevents/news/2015/march/global-energy-related-emissions-of-carbon-dioxide-stalled-in-2014.html, overall global carbon dioxide emissions increased 2.5% in 2014 over 2013 levels, *see* Becky Oskin, *Global Carbon Emissions Reach New Record High*, LIVESCIENCE (Sept. 21, 2014, 1:00 PM), http://www.livescience.com/47929-global-carbon-emissions-2014-record.html.

33. *See* Adam Vaughan, *Global Carbon Dioxide Levels Break 400ppm Milestone*, THE GUARDIAN (May 6, 2015), http://www.theguardian.com/environment/2015/may/06/global-carbon-dioxide-levels-break-400ppm-milestone; *Earth's CO_2 Home Page*, CO2.EARTH, http://www.co2.earth (last visited Oct. 14, 2015). Many scientists and environmentalists argue that atmospheric concentrations above 350 parts per million are unacceptable. *See, e.g.*, James Hansen et al., *Target Atmospheric CO_2: Where Should Humanity Aim?*, 2 OPEN ATMOSPHERIC SCI. J. 217 (2008).

nutrient pollution control, particularly along the East Coast and Gulf of Mexico. These sources of water pollution exacerbate ocean acidification in many areas of the country, and strengthening the Clean Water Act's regulation of these sources would improve other recognized water quality problems, like eutrophication and marine "dead zones," as well. However, the Clean Water Act's regulatory programs cannot currently reach the primary cause of ocean acidification—namely, the numerous sources of carbon dioxide emissions into the air—nor can it address certain exacerbating factors like climate change-induced alterations in ocean currents and upwelling patterns. Moreover, scientists estimate that it will take approximately 1000 years to cycle excess carbon dioxide back out of the oceans. For all of these reasons, improved implementation of the Clean Water Act is at best an incomplete response to ocean acidification. As a result, this Article also argues that ocean acidification demands new and creative ocean adaptation law and policy, the ocean acidification equivalent of climate change adaptation efforts. Nevertheless, while several states and some coastal regions are starting to identify and implement these new approaches, much remains to be learned and tried before a comprehensive adaptation response is possible.

II. OCEAN ACIDIFICATION, CLIMATE CHANGE, MARINE ECOSYSTEMS, AND MARINE AQUACULTURE

To understand the legal importance of ocean acidification, it is necessary first to understand what ocean acidification is and why it matters to marine environments (and human uses of those environments). This Part begins by explaining what role the ocean plays in the global carbon cycle and how fossil fuel burning is affecting the ocean's role as a carbon sink. It then examines the chemistry of ocean acidification before translating that chemistry into biological and ecological consequences for marine ecosystems, both short term and long term.

While much of the science is technical, the resulting impacts of the ocean's absorption of carbon dioxide are fairly straightforward. As the following sections discuss, when the

ocean absorbs carbon dioxide, its pH lowers.[34] All life is sensitive to changes in pH. As a result, the ocean is already experiencing a wide range of biological and ecological impacts as a result of ocean acidification, and these impacts—while admittedly still being studied—are only expected to worsen.[35] Indeed, the pH changes already in progress are coming close to matching those of paleological mass extinction events and could eventually produce the same extinction results, giving the ocean a decidedly uncertain long term future.[36]

In the shorter term, the chemistry of ocean acidification most directly interferes with marine organisms that grow shells—mussels, clams, oysters, crabs, lobsters, coral reefs, and important plankton at the bottom of marine food chains.[37] This interference with shell growth is affecting shellfish aquaculture, wild marine organisms, and coral reef ecosystems and could begin to disrupt the food supplies of fish and marine mammals—and humans.[38] It is to these shorter-term changes that states and regions are responding, and hence they are worth exploring in detail.

A. The Earth's Carbon Cycle, the Oceans, and Absorption of Carbon Dioxide

Much of the problem of ocean acidification ultimately derives from the ocean's role in planetary cycles as a carbon sink—that is, as a depository for excess carbon dioxide in the atmosphere. In fact, the ocean is the world's largest carbon sink for carbon dioxide gas.[39] However, the ocean is also part of the Earth's larger carbon cycle, different components of which operate on a variety of time scales.[40] Fast components of this cycle move carbon biologically through life forms and ecosystems, while the slowest components take millions to tens of millions of years to cycle carbon through rocks and the planetary crust

34. *See infra* Part I.A.

35. *See infra* Part I.B–C.

36. *See infra* notes 91–94 and accompanying text.

37. *See infra* Part I.C.

38. *See infra* Part I.C–D.

39. FRED PEARCE, WITH SPEED AND VIOLENCE: WHY SCIENTISTS FEAR TIPPING POINTS IN CLIMATE CHANGE 86 (2007).

40. Holli Riebeek, *The Carbon Cycle*, NASA EARTH OBSERVATORY (June 16, 2011), http://earthobservatory.nasa.gov/Features/CarbonCycle/.

and then into volcanoes, which return the carbon to the atmosphere as carbon dioxide.[41] The ocean's gas exchange with the atmosphere at the ocean's surface and its absorption of carbon dioxide is one of the faster elements of the slow carbon cycle.[42]

Rocks, the ocean, and the atmosphere are all carbon reservoirs, balancing the location and reactivity of carbon on Earth at any given time. Importantly, removing carbon (including carbon dioxide) from one reservoir simply shifts it to a different reservoir. Viewed from this global earth science perspective, humans using fossil fuels actively disrupt the normal balance of carbon cycle components, accelerating the return of carbon to the atmosphere from oil and coal deposits through the very fast processes of mining, drilling, and burning, compared to the very slow geological processes that would normally govern those deposits.[43]

In terms of anthropogenic climate change, therefore, the ocean is important because it absorbs the carbon dioxide that humans "prematurely" returned to the atmosphere and sequesters it in slower carbon cycle component processes. As the National Aeronautics and Space Administration (NASA) has explained, since the Industrial Revolution, the ocean now absorbs more carbon dioxide from the atmosphere than it releases to the atmosphere.[44] "Over millennia, the ocean will absorb up to 85 percent of the extra carbon people have put into the atmosphere by burning fossil fuels."[45] Currently, however, winds, currents, and ocean temperatures limit how fast the ocean can take carbon dioxide out of the atmosphere.[46] At the beginning of the 21st century, the ocean and land ecosystems (mostly plants) were absorbing about half of the anthropogenic emissions of carbon dioxide[47]—roughly 25% by land plants and 25% by the ocean.[48] In 2006, oceanographers at

41. *Id*.

42. *Id*.

43. *See* Cox et al., *supra* note 3, at 184–87 (explaining this acceleration).

44. Riebeek, *supra* note 40.

45. *Id*.

46. *Id*.

47. *See* Cox et al., *supra* note 3, at 184.

48. *The Ocean Carbon Cycle*, HARVARD MAG., Nov.–Dec. 2002, http://harvard magazine.com/2002/11/the-ocean-carbon-cycle.html. Some scientists, however, conclude that the ocean's absorption contribution is even greater: "Over the past two

the National Oceanic and Atmospheric Administration (NOAA) estimated that "[o]ver the past 200 years the oceans have absorbed 525 billion tons of carbon dioxide from the atmosphere, or nearly half of the fossil fuel carbon emissions over this period."[49] The ocean continues to uptake about 22 million tons of carbon dioxide per day.[50]

However, because of continuing and increasing climate change impacts, the ocean appears to be losing its immediate ability to act as a carbon sink. As a general matter, the cold water at ocean depths can sequester more carbon dioxide than warmer waters at the surface.[51] As a result, any process that circulates cold water to the surface reduces the ocean's ability to act as a carbon sink. Research published in 2009 indicates that, as a result of climate change, the Southern Indian Ocean is being subjected to stronger winds.[52] The winds, in turn, mix the ocean waters, bringing up carbon dioxide from the depths and preventing the ocean from absorbing more carbon dioxide from the atmosphere.[53] For similar reasons, "the CO_2 sink diminished by 50% between 1996 and 2005 in the North Atlantic."[54] Overall, "the open ocean is projected to absorb a decreasing fraction of anthropogenic CO_2 emissions as those emissions increase," leaving 30% to 69% of 21st century carbon dioxide emissions in the atmosphere, depending on future emissions scenarios.[55]

The loss of the ocean's full capacity as a carbon sink, at least in the short term, could have significant implications for the progress of climate change everywhere. If the ocean reaches its

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hundred years, the oceans have taken up ~40% of the anthropogenic CO_2 emissions." Zeebe et al., *supra* note 14, at 52. The most recent summary report published in *Science* declares that the global ocean has "captured 28% of anthropogenic CO_2 emissions since 1750, leading to ocean acidification." J.-P. Gattuso et al., *Contrasting Futures for Ocean and Society from Different Anthropogenic CO_2 Emissions Scenarios*, 349 SCIENCE 45, 46 (2015).

49. RICHARD A. FEELY ET AL., CARBON DIOXIDE AND OUR OCEAN LEGACY 1 (2006), http://www.pmel.noaa.gov/pubs/PDF/feel2899/feel2899.pdf.

50. *Id*.

51. *The Ocean Carbon Cycle*, *supra* note 48.

52. CNRS, *Ocean Less Effective at Absorbing Carbon Dioxide Emitted by Human Activity*, SCIENCEDAILY (Feb. 23, 2009), http://www.sciencedaily.com/releases/2009/02/090216092937.htm.

53. *Id*.

54. *Id*.

55. Gattuso et al., *supra* note 48, at 50.

immediate capacity as a carbon reservoir, carbon dioxide will accumulate more quickly in the atmosphere over the next decades, potentially accelerating the process of climate change.

B. The Chemistry of Ocean Acidification

While important to the progress of climate change generally, the ocean's absorption of anthropogenic carbon dioxide—its role as a carbon sink—comes at a price: Absorbed carbon dioxide changes the ocean's chemistry, a process known colloquially as "ocean acidification." The absorbed carbon dioxide undergoes a series of complex chemical reactions in ocean waters, essentially becoming carbonic acid.[56] Initially, the carbon dioxide reacts with water molecules to form hydrogen ions, which makes the ocean more acidic.[57] The hydrogen then reacts with carbonate molecules from rocks to make bicarbonate.[58] Three chemical results of these reactions are critically important to ocean acidification's ability to disrupt organisms and ecosystems: (1) the ocean's pH drops; (2) the concentration of carbonate ions in seawater drops; and (3) saturation states of calcium carbonate minerals, such as calcite and aragonite, which are critical to marine organisms' shell formation, are reduced.[59]

The ocean is naturally basic, with an average pH of about 8.16, and that pH level has been remarkably stable over geological time.[60] However, since the Industrial Revolution, the average ocean surface water pH has dropped by 0.1 unit;[61] the largest changes in pH, according to the Intergovernmental Panel on Climate Change (IPCC) in 2013, have been in the

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56. *Ocean Acidification*, *supra* note 4. More specifically, as the IPCC Report explains, "[d]issolved CO_2 forms a weak acid (H_2CO_3) and, as CO_2 in seawater increases, the pH, carbonate ion (CO_3^{2-}), and calcium carbonate ($CaCO_3$) saturation state of seawater decrease while bicarbonate ion (HCO_3^-) increases." Rhein et al., *supra* note 19, at 293.

57. Riebeek, *supra* note 40.

58. *Id*.

59. *What Is Ocean Acidification?*, *supra* note 15.

60. European Sci. Found., *Ocean Acidification: Another Undesired Side Effect of Fossil Fuel-burning*, SCIENCEDAILY (May 24, 2008), http://www.sciencedaily.com/releases/2008/05/080521105251.htm. However, pH does vary from location to location. According to the IPCC, for example, "the mean pH (total scale) of surface waters [currently] ranges between 7.8 and 8.4 in the open ocean." Rhein et al., *supra* note 19, at 293.

61. *What Is Ocean Acidification?*, *supra* note 15.

northern North Atlantic Ocean, while the smallest have been in the subtropical South Pacific Ocean.[62] While this change may seem small, the pH scale is logarithmic, so that a pH decrease of 0.1 units means that the oceans have become 26% more acidic in the last 250 years.[63] The problem is likely to only become worse over time. The IPCC reported in 2014 that the ocean's average pH is expected to drop by 0.13 to 0.42 pH units by the end of the century, depending on emissions scenario.[64] Similarly, NOAA estimates that by the end of this century, under a "business as usual" scenario, ocean surface waters "could be nearly 150 percent more acidic [than the normal average of 8.16], resulting in a pH that the oceans haven't experienced for more than 20 million years."[65]

The ocean, therefore, is approaching a chemical state that is unprecedented in human experience—and it is changing *quickly*. According to NOAA scientists, "[a]t present, ocean chemistry is changing at least 100 times more rapidly than it has changed during the 650,000 years preceding our industrial era."[66] Moreover, this altered chemical state is likely to be of long duration—at least from a human and ecological perspective. As reported in *Science*, "[i]t takes the ocean about 1000 years to flush carbon dioxide added to surface waters into the deep sea where sediments can eventually neutralize the added acid."[67] As a result, coastal states and nations are likely to be dealing with ocean acidification for quite some time, regardless of any efforts to reduce carbon dioxide emissions, making ocean acidification adaptation efforts critical to future marine law and management.

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62. Rhein et al., *supra* note 19, at 294.

63. *Id*.

64. Hans-O. Pörtner et al., *Ocean Systems*, *in* CLIMATE CHANGE 2014: IMPACTS, ADAPTATION, AND VULNERABILITY 411, 418 (Kenneth F. Drinkwater & Alexander Polonsky, eds. 2014), https://ipcc-wg2.gov/AR5/report/full-report/.

65. *What Is Ocean Acidification?*, *supra* note 15.

66. FEELY ET AL., *supra* note 49, at 2; *see also* Richard A. Kerr, *Ocean Acidification Unprecedented, Unsettling*, 328 SCIENCE 1500, 1500 (2010) (emphasizing the speed of current ocean acidification).

67. Kerr, *supra* note 66, at 1500–01.

C. Biological and Ecological Impacts from Ocean Acidification

Such unprecedented changes in ocean chemistry, especially when combined with the other impacts on the ocean from climate change like rising water temperatures, have significant negative implications for marine life, biodiversity, and ecosystems. Of course, not every species will react to ocean acidification the same way. Ocean plants, for example, need carbon dioxide the same way that land plants do, and hence they are likely to benefit from increased carbon dioxide levels in seawater.[68] In contrast, the chemical reactions of carbon dioxide absorption put shelled marine organisms at risk, which in turn puts marine food webs—and the people who depend on fish and other ocean protein—also at risk.[69]

There are also considerable uncertainties regarding how marine life will respond to ocean acidification,[70] exacerbated by a continuing lack of research regarding the effects of ocean acidification on particular species, marine life communities, and ocean ecosystems.[71] Nevertheless, even under low-emissions scenarios, and taking into account all of the impacts of climate change, scientists have concluded that "warm-water corals and mid-latitude bivalves [two-shelled shellfish like clams and oysters] will be at high risk by 2100."[72] Moreover, a variety of marine organisms have already been affected by the combination of ocean acidification and warming ocean waters, including warm-water corals, mid-latitude seagrass, high-latitude pteropods, high-latitude krill, mid-latitude bivalves, and fin fishes.[73]

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68. *What Is Ocean Acidification?*, *supra* note 15.

69. *Id*.

70. Roger Harrabin, *Shortages: Fish on the Slide*, BBC (June 18, 2012), http://www.bbc.com/news/science-environment-18353964; *see also* INT'L PROGRAMME ON THE STATE OF THE OCEAN, THE STATE OF THE OCEAN 2013: PERILS, PROGNOSES AND PROPOSALS 3 (2013) [hereinafter IPSO, PERILS, PROGNOSES AND PROPOSALS] ("Biological impacts are already being observed as acidification is a direct threat to all marine organisms that build their skeletons out of calcium carbonate, including reef-forming corals, crustaceans, molluscs and other planktonic species that are at the lower levels of pelagic food webs.").

71. Gattuso et al., *supra* note 48, at 50.

72. *Id*. at 45.

73. *Id*.

Scientific research regarding the impacts of ocean acidification tends to concentrate on various kinds of shell-forming animals, especially pteropods, shellfish, and coral reefs. These animals build their shells from calcium carbonate and hence are directly impacted by the chemical effects of ocean acidification, particularly in terms of reduced saturation of calcium carbonate minerals in seawater.[74] Specifically, decreasing pH is projected to reduce the availability of calcium carbonate by about 60% by the end of the century.[75]

As one example of the biological impacts of reduced calcium carbonate, pteropods (also known as sea butterflies) are small (pea-sized) shelled sea creatures that serve as a food source for everything from krill to North Pacific juvenile salmon to mighty whales.[76] In laboratory experiments, pteropods dissolved when subjected to seawater at the pH levels projected for the ocean by the end of the 21st century.[77] Field studies, in turn, have revealed "dissolution of live pteropod shells in the California Current system and Southern Ocean, both areas that experience significant anthropogenic acidification."[78] Pteropods are important base components of ocean food webs, and hence ocean acidification's effects on them could reduce populations of important human food fish like salmon, herring, mackerel, and cod.[79]

Shellfish, especially bivalves like clams and oysters, are experiencing similar impacts from under-saturation of calcium carbonate minerals, and these effects have been documented in the wild.[80] Lab testing indicates that a number of other marine organisms such as snails, sea urchins, and certain types of microscopic plants and animals (calcareous phytoplankton and zooplankton, respectively) cannot survive well in water at pH levels equal to the projected decreases in the oceans.[81]

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74. *What Is Ocean Acidification?*, *supra* note 15.

75. IPSO, PERILS, PROGNOSES AND PROPOSALS, *supra* note 70, at 3.

76. *Id*.

77. *Id*.

78. Gattuso et al., *supra* note 48, at 50.

79. *See supra* note 70 (citing sources).

80. *What Is Ocean Acidification?*, *supra* note 15.

81. *How Will Marine Organisms Respond?*, OCEAN ACIDIFICATION (Mar. 20, 2014), http://ocean-acidification.net/2014/03/20/marine-organisms/.

Coral reefs and the highly productive ecosystems that they support are at particularly high risk.[82] "Coral reefs occupy a small part of the world's oceans yet harbor a hugely disproportionate amount of its biodiversity."[83] They suffer particularly acutely in this climate change era because of past abuses and a sensitivity to rising sea temperatures, but tropical corals are also shell-forming organisms harmed by decreasing concentrations of carbonate ions.[84] As a result of these combined impacts, "within decades, rates of reef erosion will exceed rates of reef accretion across much of the tropics and subtropics."[85] In short, ocean acidification in combination with other stressors will soon be destroying coral reefs faster than they can grow. Some coral species may surprise scientists with their abilities to adapt to these changing conditions,[86] but as marine biologists summarized in a 2011 *Science* article, "[t]he most pessimistic projection is for global-scale losses of coral reefs resulting from annual mass bleaching events."[87] To stave off this grim future, both the corals' own adaptation abilities and "aggressive emissions reduction" will be necessary.[88] Nevertheless, many corals appear to be losing the battle.[89]

As the connections to marine food production noted above suggest, the impacts of ocean acidification on marine ecosystems—and human well-being—are likely to be much broader than just the effects on shell-forming organisms. Recent scientific studies have begun to document broader responses to ocean acidification in phytoplanktonic, bacterial, seagrass, and algal communities—i.e., responses that affect multi-species interactions, potentially building to ecosystem-level responses.[90] At the biological level, ocean acidification can

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82. IPSO, PERILS, PROGNOSES, AND PROPOSALS, *supra* note 70, at 3–4; Joan A. Kleypas & Kimberly K. Yates, *Coral Reefs and Ocean Acidification*, OCEANOGRAPHY, Dec. 2009, at 108, 109.

83. John M. Pandolfi et al., *Projecting Coral Reef Futures Under Global Warming and Ocean Acidification*, 333 SCIENCE 418, 418 (2011).

84. *Id*. at 418–19.

85. *Id*. at 418.

86. *Id*. at 420.

87. *Id*. at 421.

88. *Id*.

89. Gattuso et al., *supra* note 48, at 50.

90. *Id*.

cause acidosis, the buildup of carbonic acid in organisms' bodily fluids, which in turn can cause a host of other problems for organisms such as fish.[91] At the level of marine biochemistry, "the pH gradient across cell membranes is coupled to numerous critical physiological/biochemical reactions within marine organisms, ranging from such diverse processes as photosynthesis, to nutrient transport, to respiratory metabolism."[92] At the physical level, decreasing pH levels decrease the ocean's ability to absorb sound, and the resulting increased noise in the ocean may detrimentally affect acoustically sensitive whales and dolphins, potentially disrupting their abilities to navigate and find food.[93] In addition, decreasing concentrations of calcium carbonate minerals allow more light to penetrate deeper into the ocean, raising substantial uncertainties regarding impacts on species adapted to the ocean's generally low light levels.[94]

Given emerging marine community responses to ocean acidification and its multitude of ancillary impacts, the marine ecosystem impacts from ocean acidification could be tremendous, resulting in loss of commercially and locally important fisheries and coastal protection from storms.[95] The economic and cultural costs for humans, especially those in developing nations or coastal countries, could be enormous.[96] In addition, as with coral reefs, ocean acidification is likely to interact synergistically with climate change's impacts on the ocean to multiply harms to marine ecosystems.

Thus, ocean acidification affects marine organisms' abilities to grow, reproduce, and protect themselves. It alters their internal chemistry and can even affect their abilities to move and communicate. Given all of these impacts, it is entirely possible that ocean acidification could also cause—or at least contribute significantly to—the next global mass extinction

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91. *Ocean Portal: Ocean Acidification*, *supra* note 12.

92. Scott C. Doney et al., *Ocean Acidification: A Critical Emerging Problem for the Ocean Sciences*, OCEANOGRAPHY, Dec. 2009, at 16, 16.

93. *Id*.

94. *Id*.

95. *Id*.; *see also* Sarah R. Cooley et al., *Ocean Acidification's Potential to Alter Global Marine Ecosystem Services*, OCEANOGRAPHY, Dec. 2009, at 172, 172–76 (detailing these ecosystem impacts); Gattuso et al., *supra* note 48, at 45 (same).

96. *See* Cooley et al., *supra* note 95, at 172–76 (detailing the value of marine ecosystem services that could be impacted by ocean acidification).

event. As reported in *Science*, current ocean acidification most closely resembles conditions that existed 55.8 million years ago, during the last major mass species extinction event known as the Paleocene-Eocene Thermal Maximum (PETM).[97] The International Programme for the State of the Ocean (IPSO) made the same connection in its 2013 *State of the Ocean* report, emphasizing that "the scale and rate of the present day carbon perturbation, and resulting ocean acidification, is unprecedented in Earth's known history."[98] Carbon dioxide is entering the atmosphere at a rate that is actually ten times greater than was occurring during the PETM extinction event, and Earth has not experienced current ocean acidification levels for at least 300 million years.[99] "We are entering an unknown territory of marine ecosystem change, and exposing organisms to intolerable evolutionary pressure. The next mass extinction event may have already begun."[100]

D. Ocean Acidification, Marine Food Supply, and Marine Aquaculture

While a global mass extinction event remains ocean acidification's ultimate threat, it is ocean acidification's more immediate impacts on marine life that are driving interest in developing more creative legal approaches to the problem. In particular, ocean acidification immediately threatens marine food supplies, in terms both of natural stocks and marine aquaculture. In addition, acidification "hot spots" like Puget Sound magnify these impacts, requiring some coastal regions to adapt sooner and faster than others.

As noted, researchers have already documented the effects of ocean acidification on shell-forming organisms like bivalves and coral reefs.[101] In 2012, environmental NGO Oceana published a report on how ocean acidification and climate change are impacting global food security as a result of the impacts on marine organisms. It noted that ocean acidification poses a direct food security threat to many coastal and island

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97. Kerr, *supra* note 66, at 1500.

98. IPSO, PERILS, PROGNOSES, AND PROPOSALS, *supra* note 70, at 3.

99. *Id*.

100. *Id*.

101. *See supra* notes 68–81 and accompanying text.

nations that depend on fish and other seafood for their food supply, including some wealthy industrialized nations, like Japan.[102] Again, impacts to coral reefs are particularly troublesome, because "[a]bout a quarter of all marine fish species live on coral reefs and about 30 million people around the world depend heavily on these fish as a stable source of protein."[103] Similarly, the shellfish that are especially vulnerable to ocean acidification provide 50% or more of available food protein to residents of many island nations, and those shellfish also support jobs and significant economic activity in many parts of the world.[104]

However, ocean acidification impacts on fisheries and food supply do not need to rise to the level of existential vulnerability for nations to notice them. As the United Nations Environment Programme observed in 2010, many important global fish stocks have already suffered from overfishing and habitat destruction, and ocean acidification poses one more global threat to world food supply and the economics of global fishing.[105] The relative importance of these three impacts on fisheries varies by fish species and location—but, notably, ocean acidification poses a new threat to some fish stocks that have previously been considered relatively healthy and sustainable. For example, in the United States, Alaska fisheries, "which accounted for 50% of the United States' total catch in 2009," have become vulnerable to ocean acidification.[106] Alaska fisheries have traditionally benefitted from upwelling currents that bring nutrients to the surface

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102. Matthew Huelsenbeck, Oceana, *Ocean-Based Food Security Threatened in a High CO_2 World: A Ranking of Nations' Vulnerability to Climate Change and Ocean Acidification* 3 (2012) (citations omitted), http://oceana.org/sites/default/files/reports/Ocean-Based_Food_Security_Threatened_in_a_High_CO2_World.pdf.

103. *Id.* at 6 (citations omitted).

104. *Id.* (citations omitted). Oceana concluded that the ten nations most threatened by ocean acidification are the Cook Islands (South Pacific Ocean), New Caledonia (Southwest Pacific Ocean), Turks and Caicos Islands (Caribbean), Comoros (Indian Ocean), Kiribati (Central Tropical Pacific Ocean), Aruba (southern Caribbean), Faroe Islands (North Atlantic Ocean), Pakistan (Arabian Sea), Eritrea (Red Sea), and Madagascar (Indian Ocean). *Id.* at 8 tbl.3.

105. UNITED NATIONS ENV'T PROGRAMME, ENVIRONMENTAL CONSEQUENCES OF OCEAN ACIDIFICATION: A THREAT TO FOOD SECURITY 4 (2010), http://www.unep.org/dewa/Portals/67/pdf/Ocean_Acidification.pdf.

106. Xochitl Rojas-Rocha, *Worsening Ocean Acidification Threatens Alaska Fisheries*, SCIENCEMAG.ORG (July 29, 2014, 11:00 AM), http://news.sciencemag.org/climate/2014/07/worsening-ocean-acidification-threatens-alaska-fisheries.

and increase food supplies (one reason that many species of whales summer in Alaskan waters). However, these currents accelerate the process of ocean acidification, because their colder waters absorb more carbon dioxide than warmer surface waters, and hence the upwelling carries more acidic waters to the surface.[107]

Importantly, the combination of standard ocean acidification and acidic upwelling is already affecting commercially important marine species in Alaska, such as by stunting the growth of red king crabs and tanner crabs.[108] A recent NOAA study concluded that economic losses to the crabbing industry could run into the hundreds of millions of dollars, while loss of seafood resources would directly affect the roughly 20% of Alaska's population that relies heavily on marine species for food.[109]

On the East Coast, land-based nutrient runoff is accelerating ocean acidification. As one example, the Chesapeake Bay has well-documented nutrient runoff issues and "is acidifying three times faster than the rest of the world's oceans."[110] Rapid acidification has been observed in other eastern coastal waters that are similarly subject to significant nutrient runoff problems, such as Long Island Sound, Narragansett Bay, and the Gulf of Mexico.[111] This long term acidification may be contributing to the drop in oyster harvests from the coastal Atlantic Ocean.[112] In addition, mudflats in Maine have become acidic enough in some spots to kill young clams.[113]

Ocean acidification "hot spots" are also proving troublesome to shellfish aquaculture. In the Pacific Northwest, for example, "Puget Sound has some of the world's most corrosive waters. Scientists are finding that marine waters in the Northwest have become so corrosive that they are eating away at oyster

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107. *Id.*

108. Reid Wilson, *Marine Industries at Risk on Both Coasts as Oceans Acidify*, WASH. POST (July 30, 2014), http://www.washingtonpost.com/blogs/govbeat/wp/2014/07/30/marine-industries-at-risk-on-both-coasts-as-oceans-acidify/.

109. *Id.*

110. *Id.*

111. *Id.*

112. *Id.*

113. NATURAL RES. DEF. COUNCIL, GULF OF MAINE: OCEAN ACIDIFICATION 1, http://www.nrdc.org/oceans/acidification/files/ocean-acidification-maine.pdf.

shells before they can form."[114] As in Alaska, moreover, natural upwelling patterns in this region exacerbate the ocean acidification occurring both in Puget Sound and off the coast of Oregon.[115] Beginning in 2008, oyster aquaculture facilities in Puget Sound and off the coast of Oregon began experiencing huge drops in larvae production, with die-offs reaching eighty percent of the larvae at some facilities.[116] The *Seattle Times* reported in 2013 that one family of oyster aquaculturists moved their facilities to Hawai'i because young Pacific oysters in Washington simply "stopped growing."[117]

E. From Science to Law

To summarize ocean acidification science: Despite the many remaining uncertainties regarding ocean acidification's broader and long-term impacts, multiple scientific studies conclude that ocean acidification both is currently debilitating marine ecological health with respect to several marine species and poses a long term threat to marine and human life. Ocean acidification hotpots, moreover, exacerbate current impacts in specific locations, particularly when upwelling currents and nutrient runoff contribute to acidification problems at local and regional scales. As a result, different localities will need geographically specific responses to ocean acidification tailored to address their particular ocean acidification causes and

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114. *Acidifying Water Takes Toll on Northwest Shellfish*, NAT'L OCEANIC & ATMOSPHERIC ADMIN. PMEL CARBON PROGRAM, http://www.pmel.noaa.gov/co2/story/Acidifying+Water+Takes+Toll+On+Northwest+Shellfish (last visited Oct. 14, 2015).

115. Specifically:

> Regional marine processes including coastal upwelling exacerbate the acidifying effects of global carbon dioxide emissions. Coastal upwelling brings deep ocean water, which is rich in carbon dioxide and low in pH, up into the coastal zone. This upwelled water has spent decades circulating deep in the ocean, out of contact with the atmosphere for 30 to 50 years. This means that the waters currently upwelled onto the coast of the Pacific Northwest reflect the atmospheric carbon dioxide concentrations of the 1970s and 1980s.

Ocean Acidification: What Is Ocean Acidification?, NORTHWEST ASS'N NETWORKED OCEAN OBSERVING SYSTEMS, http://www.nanoos.org/education/learning_tools/oa/ocean_acidification.php (last visited Oct. 14, 2015).

116. *See id.*; Craig Welch, *Oysters in Deep Trouble: Is Pacific Ocean's Chemistry Killing Sea Life?*, SEATTLE TIMES (June 14, 2009), http://www.seattletimes.com/seattle-news/oysters-in-deep-trouble-is-pacific-oceans-chemistry-killing-sea-life/; Craig Welch, *Sea Change: Oysters Dying as Coast Is Hit Hard*, SEATTLE TIMES (Sept. 12, 2013), http://apps.seattletimes.com/reports/sea-change/2013/sep/11/oysters-hit-hard/ [hereinafter *Sea Change*].

117. *Sea Change*, *supra* note 116.

impacts. Nevertheless, the primary cause of ocean acidification remains anthropogenic emissions of carbon dioxide.[118] This causation reality means that the problem of ocean acidification (as well as climate change) warrants a much stronger global commitment to reducing anthropogenic emissions of carbon dioxide.[119] Moreover, and especially in conjunction with exacerbating problems like upwelling, the connection between ocean acidification and carbon dioxide emissions means that a response to ocean acidification that focuses solely on water quality regulation will be insufficient.

Until an effective global legal commitment to reduce carbon dioxide is in place, however, the nations affected by ocean acidification must respond to it and its impacts with domestic law. At the national level in the United States, the primary question has been what role the federal Clean Water Act can and should play in addressing ocean acidification. It is to those issues that Part II will turn.

III. THE CLEAN WATER ACT & OCEAN ACIDIFICATION

In the United States, ocean acidification poses a bit of a quandary for agencies and lawyers trying to apply existing federal environmental laws to reduce its impacts. For the most part, these statutes regulate pollution problems largely on the basis of the medium into which a source emits, discharges, or otherwise releases pollutants. Thus, the Clean Air Act[120] regulates sources like power plants that emit pollutants into the *air*;[121] the Clean Water Act regulates sources that discharge pollutants into *water*;[122] and the Resource Conservation and Recovery Act (RCRA)[123] regulates sources that can contaminate *land* with their wastes.[124] An

118. Rhein et al., *supra* note 19, at 294.

119. *See, e.g.*, Gattuso et al., *supra* note 48, at 45.

120. 42 U.S.C. §§ 7401–7671q (2012).

121. *See, e.g.*, *id.* § 7479(1) (defining "major emitting facilities" as "stationary sources of air pollutants which emit, or have the potential to emit, one hundred tons per year or more of any air pollutant" from specific kinds of facilities).

122. *See, e.g.*, 33 U.S.C. § 1362(12) (2012) (defining "discharge of a pollutant" to be "any addition of any pollutant to navigable waters" or "any addition of any pollutant to the waters of the contiguous zone or the ocean").

123. 42 U.S.C. §§ 6901–6987.

124. *See, e.g.*, *id.* §§ 6903(27), 6944 (defining "solid waste" to exclude domestic sewage and water pollution regulated under the Clean Water Act and providing

increasingly recognized problem with these statutes is that they do not adequately address sources that emit pollutants into one medium—say, air—but cause actual pollution problems in a different medium—say, water. For example, neither the Clean Air Act nor the Clean Water Act squarely addresses the atmospheric deposition of mercury, the well-documented phenomenon where air emissions of mercury from sources like coal-fired power plants settle into waterways, causing both mercury pollution of the water column and mercury contamination of the fish and other organisms that live there.[125] As a result, many governments now warn consumers, especially pregnant women and young children, to avoid several species of mercury-contaminated fish, like shark, swordfish, king mackerel, and albacore tuna.[126]

Ocean acidification poses the same kind of regulatory quandary that mercury deposition does. Because ocean acidification is largely the result of emissions of carbon dioxide into the *air*, the United States' medium-based approach to pollution regulation suggests a domestic need to use the Clean Air Act to address ocean acidification. As such, the United States Environmental Protection Agency's (EPA's) increasing efforts to address greenhouse gas emissions through the Clean Air Act may eventually help to address the ocean acidification problem. Indeed, many of the EPA's recent greenhouse gas regulations and proposed regulations explicitly mention ocean

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criteria for sanitary landfills, respectively).

125. *See* Memorandum from Craig Hooks, Dir., Office of Wetlands, Oceans, & Watersheds, U.S. EPA, to Water Div. Dirs., Regions 1–10 (Mar. 8, 2007), http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/2007_03_08_tmdl_mercury5m_Merury5m.pdf (directing a voluntary approach under the Clean Water Act for dealing with waters impaired by atmospheric deposition of mercury). *See generally* U.S. GOV'T ACCOUNTABILITY OFFICE, GAO–13–39, WATER QUALITY: EPA FACES CHALLENGES IN ADDRESSING DAMAGE CAUSED BY AIRBORNE POLLUTANTS ii (2013), http://www.gao.gov/assets/660/651522.pdf ("EPA has also sought to address atmospheric deposition through Clean Air Act (CAA) regulations but faces challenges in doing so . . . . Even with reduced emissions, NO_x, SO_2, and mercury continue to pollute the nation's waterbodies.").

126. *What You Need to Know About Mercury in Fish and Shellfish*, U.S. FOOD & DRUG ADMIN. (Mar. 2004), http://www.fda.gov/Food/FoodborneIllnessContaminants/Metals/ucm351781.htm; *see also Fish: What Pregnant Women and Parents Should Know: Draft Updated Advice by FDA and EPA*, U.S. FDA (June 2014), http://www.fda.gov/Food/FoodborneIllnessContaminants/Metals/ucm393070.htm.

acidification as one reason for imposing increased emissions controls.[127]

Nevertheless, there is no disputing the fact that the *effects* of ocean acidification occur *in the water*, meaning that ocean acidification can be fairly characterized as a water pollution problem. Moreover, as noted in Part I, in some places other forms of water pollution, such as nutrient runoff, can exacerbate ocean acidification. Thus, the federal Clean Water Act would also seem to be relevant—particularly in light of the fact that the Act's water quality standards provisions directly address ambient water quality regardless of the source of water pollution.[128] Indeed, the Center for Biological Diversity (CBD) has been spearheading petitions and litigation to bring the Clean Water Act to bear on the United States' increasing ocean acidification problems,[129] focusing on these water quality standards provisions. Specifically, on December 18, 2007, the CBD formally petitioned the EPA to strengthen the federal national recommended (or reference) water quality criterion under the Clean Water Act for ocean pH and to provide guidance to the states regarding ocean acidification and water quality.[130]

The question, of course, is what the Clean Water Act's water quality standards provisions can actually contribute to any resolution of the ocean acidification problem. This Part begins by providing an overview of the Clean Water Act's regulatory provisions, emphasizing the role of water quality standards and the EPA's reference water quality criteria in the Act's

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127. *See, e.g.*, Carbon Pollution Standards for Modified and Reconstructed Stationary Sources: Electric Utility Generating Units, 79 Fed. Reg. 34,960, 34,967 (June 18, 2014) (referencing the National Research Council's 2010 report, "Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean"); Standards of Performance for Greenhouse Gas Emissions from New Stationary Sources: Electric Utility Generating Units, 79 Fed. Reg. 1430, 1439 (Jan. 8, 2014) (noting that ocean acidification is one reason for pursuing reductions in carbon dioxide emissions and climate stabilization).

128. 33 U.S.C. § 1313 (2012).

129. Letter from Benjamin H. Grumbles, Assistant Adm'r, U.S. EPA, to Ms. Miyoko Sakashita, Attorney, Ctr. for Biological Diversity (Jan. 16, 2009), http://www.biologicaldiversity.org/campaigns/ocean_acidification/pdfs/EPA_Response_to_CBD_Ocean_Acidification_Petition.pdf.

130. Press Release, Ctr. for Biological Diversity, Lax Standard Fails to Prevent Souring Seas; Group Petitions EPA to Address the Threat of Ocean Acidification (Dec. 18, 2007), http://www.biologicaldiversity.org/news/press_releases/ocean-acidification-12-18-2007.html.

overall scheme. It then examines the history of the CBD's efforts to force the EPA and the states to use the Clean Water Act to address ocean acidification, the subsequent administrative responses to ocean acidification, and the ocean acidification litigation that has occurred in the United States. This Article emphasizes the latest example of this litigation: the 2015 federal district court decision denying the CBD's challenge to the EPA's approval of Washington's and Oregon's 2010 impaired waters lists.[131] It concludes that, while the Clean Water Act has yet to seriously address the ocean acidification problem, Washington and Oregon may soon have to declare large sections of their coasts to be "impaired waters" because of decreases in pH. If the Clean Water Act does force states to legally recognize their coastal ocean acidification problems, it may thus provide states with increased motivation to address ocean acidification through other kinds of state and regional programs. In addition, if states increasingly recognize that ocean acidification has legally impaired their coastal water quality, those recognitions should inspire both federal and state governments to extend their use of the Clean Water Act to address nutrient runoff and stormwater, as Part III will explore in more detail.

A. An Overview of the Clean Water Act's Regulatory Regime

Ocean acidification underscores the important differences between the Clean Water Act's two most important mechanisms for protecting and improving water quality: its regulatory programs for individual polluters and its "backstop" programs that govern ambient water quality. Because the primary cause of ocean acidification is carbon dioxide emissions *into the air*, the Clean Water Act's programs for regulating individual polluters do not apply.[132] However, pH has always been an important parameter of overall water quality, and hence the Clean Water Act's programs to protect and improve ambient water quality *are* relevant to ocean acidification, as the CBD has argued. This section will discuss both key provisions of the Clean Water Act and their applications to ocean acidification.

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131. Ctr. for Biological Diversity v. U.S. EPA, 90 F. Supp. 3d 1177, 1182 (W.D. Wash. 2015).

132. *See* discussion *infra* Part II.A.1.

1. Regulation of Individual Polluters Under the Clean Water Act

The Clean Water Act's regulatory programs for individual polluters derive from the statute's declaration that, except as in compliance with the Act itself, "the discharge of any pollutant by any person shall be unlawful."[133] Under the Act's definitions, a "discharge of a pollutant" is "(A) any addition of any pollutant to navigable waters from any point source, [and] (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."[134] Thus, for Clean Water Act jurisdiction to exist for federal agencies to regulate individual polluters, there must be: (1) an addition; (2) of a pollutant; (3) to jurisdictional waters; (4) from a point source. Moreover, if all these requirements are met, the discharger must operate in compliance with one of the Act's two permit programs, either the Section 402 National Pollutant Discharge Elimination System (NPDES) permit program[135] or the Section 404 "dredged or fill material" permit program.[136]

With regard to ocean acidification and jurisdictional waters (element 3), the Clean Water Act clearly seeks to protect the oceans as well as fresh waters. As the Act's definition of "discharge of a pollutant," quoted above, makes clear, the relevant waters for Clean Water Act jurisdiction are the "navigable waters," the "contiguous zone," and the ocean.[137] Together, these three terms cover the entirety of marine waters under U.S. jurisdiction. According to the Act's definitions, the "navigable waters" are the "waters of the United States, including the territorial sea,"[138] and the "territorial sea" is the first three miles of ocean.[139] The "contiguous zone" references an international law definition that extends the Act's jurisdiction out to twelve nautical miles from the coast,[140] while the "ocean" refers to any area beyond

133. 33 U.S.C. § 1311(a).

134. *Id.* § 1362(12).

135. *Id.* § 1342.

136. *Id.* § 1344.

137. *Id.* § 1362(12).

138. *Id.* § 1362(7).

139. *Id.* § 1362(8).

140. *Id.* § 1362(9) (referencing article 24 of the U.N. Convention on the Territorial

the contiguous zone;[141] under current law, the United States claims jurisdiction out to 200 nautical miles from shore.[142] Thus, the Clean Water Act clearly covers ocean water quality.

However, federal Clean Water Act jurisdiction also requires the "addition" of a "pollutant" from a "point source" in order for its regulatory permit programs to apply,[143] and the Act's definitions of each of these terms indicate that carbon dioxide emitters cannot be directly and individually regulated under the Act. For example, a "point source" is "any discernible, confined and discrete conveyance," like a pipe,[144] but the phrase has also been broadly interpreted to apply to most human-controlled conveyances of pollutants to waterways.[145] However, both runoff and, most relevant here, atmospheric deposition of pollutants do not qualify as point source pollution but rather are nonpoint source pollution, which the states are supposed to regulate through means other than the Act's permit programs.[146] Thus, because the carbon dioxide that causes ocean acidification is first emitted *into the air*, it does not qualify as point source pollution subject to the Act's two permitting programs.

Moreover, because industries do not directly discharge carbon dioxide into water, the carbon dioxide that causes ocean acidification probably does not qualify as a "pollutant" for permitting purposes, despite the fact that the Act defines "pollutant" broadly. Under this definition, "pollutants" include:

> [D]redged 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*.[147]

Sea and the Contiguous Zone).

141. *Id.* § 1362(10).

142. Proclamation No. 5030, 48 Fed. Reg. 10,605 (Mar. 10, 1983).

143. 33 U.S.C. § 1362(12).

144. *Id.* § 1362(14).

145. *See, e.g.*, Parker v. Scrap Metal Processors, Inc., 386 F.3d 993, 1009 (11th Cir. 2004) (interpreting "point source" broadly); Dague v. City of Burlington, 935 F.2d 1343, 1354–55 (2d Cir. 1991) (same).

146. *See* 33 U.S.C. § 1329 (governing state nonpoint source pollution plans).

147. *Id.* § 1362(6) (emphasis added). However, the Act also specifies that "pollutant":

> does not mean (A) "sewage from vessels or a discharge incidental to the normal operation of a vessel of the Armed Forces" within the meaning of section 1322 of this

Carbon dioxide is fairly easily classified as industrial waste, and indeed both the EPA and the United States Supreme Court have classified carbon dioxide and other greenhouse gases as "pollutants" under the Clean Air Act.[148] However, the fact that the sources of carbon dioxide that cause ocean acidification emit the gas into the air rather than discharging it directly into water again indicates that these sources cannot be regulated through the Clean Water Act's permit programs.

Finally, the Act does not define "addition."[149] Nevertheless, case law has defined this term to include most non-natural conveyances of pollutants to a water body.[150] Again, however, because carbon dioxide emitters do not add the carbon dioxide directly to waterways or the ocean, they are probably not "adding" pollutants to jurisdictional waters for purposes of individual Clean Water Act permitting requirements.

Thus, as the EPA and the states have already recognized in connection with atmospheric deposition of mercury, the ocean's absorption from the air of carbon dioxide emissions does not trigger individual regulation of the emitting sources under the Clean Water Act's permit programs. Thus, for example, even if an ocean acidification hot spot like Puget Sound were surrounded by coal-fired power plants emitting thousands of tons of carbon dioxide into the atmosphere every year, and even if it could be proven that those emissions were exacerbating ocean acidification within the Sound itself, the power plants would not need Clean Water Act regulatory (NPDES) permits.

Instead, the power plants' contributions to ocean acidification in the Sound would qualify as nonpoint source

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title; or (B) water, gas, or other material which is injected into a well . . . if the well used either to facilitate production or for disposal purposes is approved by authority of the State in which the well is located, and if such State determines that such injection or disposal will not result in the degradation of ground or surface water resources. *Id.*

148. Massachusetts v. EPA, 549 U.S. 497, 528–30 (2007).

149. *See* 33 U.S.C. § 1362 (failing to define "addition").

150. *See, e.g.*, Miccosukee Tribe of Indians of Fla. v. S. Fla. Water Mgmt. Dist., 280 F.3d 1364, 1368 (11th Cir. 2002) (establishing a "but for" test to determine whether an addition of pollutants has occurred); Catskill Mountains Chapter of Trout Unlimited, Inc. v. City of New York, 273 F.3d 481, 491–93 (2d Cir. 2001) (invoking a "natural flow" test to determine whether an addition of pollutants has occurred); Dubois v. U.S. Dep't of Agric., 102 F.3d 1273, 1297–98 (1st Cir. 1996) (holding that waters that flow non-naturally from a more polluted to a less polluted water body "add" pollutants for purposes of the Act).

pollution under the Act, the subject most directly of state water quality and nonpoint source control programs[151]—and, of course, regulation under the Clean Air Act.[152] Less directly, however, the Clean Water Act itself can also underscore the importance of nonpoint source pollution through its programs to protect ambient water quality, to which this section now turns.

2. The Clean Water Act's Protections for Ambient Water Quality: The States' Section 303 Water Quality Standards, the EPA's Section 304 National Reference Water Quality Criteria, and Total Maximum Daily Loads (TMDLs)

While much of the Clean Water Act focuses on permitting and regulating individual water polluters, Congress also recognized that these permitting programs might not be sufficient to achieve and maintain desired water quality in all waterbodies. In particular, although Congress chose not to address nonpoint source pollution at the federal level in the 1972 amendments to the Federal Water Pollution Control Act,[153] which created the contemporary Clean Water Act,[154] Congress was acutely aware that nonpoint source pollution existed and that it could dominate water quality problems in particular waterways.[155] As a result, in the 1972 amendments, Congress retained and expanded a pre-existing focus on water

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151. 33 U.S.C. § 1329 (providing for state management of nonpoint sources).

152. *See, e.g.*, 42 U.S.C. §§ 7411, 7412, 7423, 7473, 7475, 7491, 7503 (2012) (regulating air pollution).

153. Federal Water Pollution Control Act Amendments of 1972, Pub. L. No. 92-500, 86 Stat. 816 (codified as amended at 12 U.S.C. § 24, 15 U.S.C. §§ 633, 636, 31 U.S.C. § 711, 33 U.S.C. §§ 1251–65, 1281–92, 1311–28, 1341–45, 1361–76).

154. The name "Clean Water Act" actually derives from the 1977 amendments to the Act, *see* Clean Water Act of 1977, Pub. L. No. 95-217, sec. 2, § 518, 91 Stat. 1566, 1566 (codified as amended at 33 U.S.C. § 1251 nt), but it was the 1972 amendments that fundamentally changed the Act's structure and focus. *See generally* Federal Water Pollution Control Act Amendments of 1972, Pub. L. No. 92-500, 86 Stat. 816 (comprehensively amending the prior Federal Water Pollution Control Act, Pub. L. No. 80-845, ch. 758, 62 Stat. 1155 (1948) (codified as amended in scattered sections of 33 U.S.C.)).

155. Nonpoint source pollution was a prominent subject in congressional discussions leading up to the enactment of the 1972 amendments. For example, the Senate had before it estimates that "700 times as much suspended solids reach the Nation's waters from surface runoff in any period as reach the waters in the discharge of sewage." S. REP. NO. 92-414 (1971), *reprinted in* 1972 U.S.C.C.A.N. 3668, 3669.

quality standards, which are state-set goals for ambient water quality in particular waterbodies.

Under Section 303 of the Act, states are supposed to set water quality standards for all navigable waters, including the first three miles of ocean, within their boundaries; the EPA establishes water quality standards if a state fails to do so.[156] Water quality standards have two components: designated uses and water quality criteria.[157] Designated uses are the uses that the state wants the waters to support, including all existing uses.[158] Water quality criteria, in turn, are the numeric and narrative standards for various pollutants (e.g., toxics and nutrients) and other water quality parameters (e.g., pH and temperature) that the water body must meet in order to support the designated uses.[159] In addition, the Clean Water Act explicitly requires states to consider, inter alia, the waters' "use and value for . . . propagation of fish and wildlife."[160] As a result, because ocean acidification alters the pH and chemistry of ocean waters in ways that can harm aquatic life, states should be considering ocean acidification in their water quality standards.

In setting water quality standards, states often rely on the EPA's Section 304 national or reference water quality criteria.[161] These criteria have very little direct legal force of their own; instead, they function primarily to provide information and suggested criteria that states can then incorporate into their own Section 303(c) water quality standards.[162] Nevertheless, the Act specifies that the EPA's criteria must reflect:

[T]he latest scientific knowledge (A) on the kind and extent of all identifiable effects on health and welfare including, but not limited to, plankton, fish, shellfish, wildlife, plant life, shorelines, beaches, esthetics, and recreation which may be expected from the presence of pollutants in any body of water,

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156. Clean Water Act § 303(a), (c), 33 U.S.C. § 1313(a), (c) (2012).

157. 40 C.F.R. § 131.2–.3(b), (f) (2014).

158. *See id.*

159. *Id.*

160. 33 U.S.C. § 1313(c)(2)(A).

161. Clean Water Act § 304, 33 U.S.C. § 1314 (providing for development and publication of reference water quality criteria).

162. *See id.* § 1313(c).

including ground water; (B) on the concentration and dispersal of pollutants, or their byproducts, through biological, physical, and chemical processes; and (C) on the effects of pollutants on biological community diversity, productivity, and stability, including information on the factors affecting rates of eutrophication and rates of organic and inorganic sedimentation for varying types of receiving waters.[163]

In addition, the EPA is required to "develop and publish" information regarding how to restore and maintain water quality, how to protect shellfish, fish, and wildlife in various kinds of waters, how to measure water quality, and how to set TMDLs.[164]

Water quality criteria and water quality standards are supposed to ensure that states meet their water quality goals regardless of the particular pollution problems that impair a specific waterbody. Thus, for point sources of pollution, water quality criteria and state water quality standards can affect the exact terms of a particular permit.[165] With respect to nonpoint source pollution like ocean acidification, however, state water quality standards drive the Section 303(d) TMDL process,[166] which is designed to ensure that states continue to make progress toward their ultimate water quality goals. Under this process, states are supposed to identify all state waters that do not meet their water quality standards, generating a biennial "impaired waters" or Section 303(d) list.[167] States then rank these impaired waters in order of priority[168] and begin to set TMDLs for them. Specifically, the state sets a TMDL for each pollutant contributing to the water

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163. *Id.* § 1314(a)(1).

164. *Id.* § 1314(a)(2). The EPA's current water quality criteria are available at *National Recommended Water Quality Criteria*, U.S. EPA, http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm (last visited Oct. 18, 2015).

165. For Section 402 NPDES permits, violations of water quality standards require that waterbody-specific "water quality related effluent limitations" replace the national technology-based effluent limitations in a discharger's permit. Clean Water Act § 402, 33 U.S.C. § 1312. For Section 404 permits, the EPA's Section 404(b)(1) Guidelines require that discharges of dredge and fill material do not cause violations of water quality standards. Clean Water Act § 404(b)(1), 33 U.S.C. § 1344(b)(1); 40 C.F.R. §§ 230.1(c), 230.10(b) (2014).

166. 33 U.S.C. § 1313(d).

167. *Id.* § 1313(d)(1).

168. *Id.*

quality standard violation.[169] A TMDL is the total amount of a specific pollutant that can be added to the water body on a daily basis *without* violating the relevant water quality standard.[170]

Setting a TMDL can be time-consuming and expensive,[171] and most states and the EPA have set them only in response to litigation successfully challenging their failures to do so.[172] However, setting the TMDL is only the first step in the process. Once the TMDL exists, the state must divvy up this pollutant allowance among the point sources (the waste load allocation, or WLA), nonpoint sources (the load allocation, or LA), and natural background sources.[173] Thus, a TMDL can lead both to amendments of Clean Water Act permits to impose more stringent discharge requirements *and* to revisions in state nonpoint source regulation.

As is discussed more thoroughly in the next subsection, states have long included pH water quality criteria in their water quality standards for coastal waters, almost always based on the EPA's national recommended water quality criterion. As a result, as ocean acidification changes coastal pH enough to violate these water quality standards, states should be listing those coastal waters as impaired waters subject to the TMDL requirement. However, because ocean acidification qualifies as nonpoint source pollution, as states begin setting TMDLs for ocean acidification, better nonpoint source regulation is likely to be the most relevant state Clean Water Act response. Thus, TMDLs resulting from ocean acidification

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169. *Id.*

170. *What Is a TMDL?*, U.S. ENVTL. PROTECTION AGENCY, http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/overviewoftmdl.cfm (last visited Oct. 18, 2015).

171. U.S. EPA, TMDL DEVELOPMENT COST ESTIMATES: CASE STUDIES OF 14 TMDLS, at 13 (1996), http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=20004TFT.txt (reporting that eight of 14 TMDLs studied in the 1990s cost between $100,000 and over $1 million each just to develop). In 2007, Virginia estimated that with $2 million per year over four years, at an average cost of $19,000 per TMDL, it could complete 470 litigation-required TMDLs by 2010, but that more funding would be needed to fully comply. VA. DEP'T OF ENVTL. QUALITY, TMDL PROGRAM SIX YEAR PROGRESS REPORT 2000–2006, at 6–7 (2007), http://www.deq.state.va.us/Portals/0/DEQ/Water/TMDL/06prgrpt.pdf.

172. *See Litigation Status: Summary of Litigation on Pace of TMDL Establishment*, U.S. ENVTL. PROTECTION AGENCY, http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/lawsuit.cfm#_ga=1.35892640.1083550970.1425938851 (last visited Oct. 18, 2015).

173. 40 C.F.R. § 130.2(g)–(i) (2014).

might induce states to better control damaging nutrient runoff. They may also induce states to create state-mandated reductions in carbon dioxide emissions—even from sources not directly regulated under the Clean Air Act (and keeping in mind that the EPA's regulation of greenhouse gas emissions under the Clean Air Act is still also in its nascent stages). However, as Part III will discuss in more detail, there are also a number of measures that states can take to adapt to ocean acidification that fall outside of the Clean Water Act.

In sum, the Clean Water Act's water quality provisions can be relevant to ocean acidification issues. First, the EPA has a duty to promulgate reference water quality criteria under Section 304, and the states have duties to enact water quality standards, including water quality criteria. Both of these duties apply to pH and, as the next subsection discusses, there are reasons to suspect that both the federal criterion and coastal state water quality standards need updating to reflect the latest scientific knowledge regarding ocean acidification and the affects of pH changes on marine life. Second, as ocean acidification changes coastal pH, coastal waters will eventually (and in some locations, may already) violate the relevant state water quality standards, forcing states to acknowledge those impairments and write TMDLs. Ideally, both aspects of the Clean Water Act's water quality provisions will also prompt more comprehensive and creative responses to ocean acidification from both states and the EPA, starting with improvements in coastal acidification science.

3. The EPA's National Recommended Water Quality Criterion for Ocean pH

Because most of the coastal states' current water quality standards for ocean pH are based on the EPA's national recommended water quality criterion,[174] the history of that criterion is relevant to current Clean Water Act litigation regarding ocean acidification. This subsection thus traces the evolution, such as it was, of the EPA's criterion.

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174. *See* Memorandum from Denise Keehner, Dir., Office of Wetlands, Oceans & Watersheds, U.S. EPA, to Water Div. Dirs., Regions 1–10 (Nov. 15, 2010), http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/oa_memo_nov2010.pdf.

The EPA began assembling its national recommended water quality criteria in 1968, even before the Clean Water Act's passage.[175] Most of the current nationally recommended water quality criteria, however, have evolved from two later EPA compendia, the 1976 "Red Book"[176] and the 1986 "Gold Book,"[177] although they also include more recent additions and amendments.

The Red Book's criterion for pH in marine waters was based on the water quality needs of aquatic life (rather than, say, human health) and was set at 6.5–8.5, a narrower range than for freshwater[178] but still a fairly broad range.[179] The EPA limited this breadth, however, by further specifying that pH changes in specific waterways could be "not more than 0.2 units outside of normally occurring range."[180] The recommended criterion thus recognized both that marine waters have a wide range of "normal" pH statuses and that small changes in that normal range, whatever it is, are likely to cause harm to marine organisms.

According to the best science available in 1976, normal seawater pH at the surface ranges from 8.0 to 8.2, but ocean pH decreases to 7.7 or 7.8 in deeper waters,[181] a reflection, among other things, of the greater ability of cold water to absorb carbon dioxide. Tropical and subtropical marine waters can be even more variable, and "in the shallow, biologically active waters in tropical or subtropical areas, large diurnal pH changes occur naturally because of photosynthesis," ranging from a pH of 9.5 in daytime to a pH of 7.3 just before dawn.[182] The EPA also concluded that the science indicated that marine

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175. U.S. EPA, QUALITY CRITERIA FOR WATER 1986, at ii (1986) [hereinafter EPA GOLD BOOK], http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/upload/2009_01_13_criteria_goldbook.pdf.

176. U.S. EPA, QUALITY CRITERIA FOR WATER (1976) [hereinafter EPA RED BOOK], http://water.epa.gov/scitech/swguidance/standards/criteria/current/upload/2009_01_13_criteria_redbook.pdf.

177. EPA GOLD BOOK, *supra* note 175.

178. The EPA noted that "[b]ecause of the buffering system present in seawater, the naturally occurring variability of pH is less than in fresh water." EPA RED BOOK, *supra* note 176, at 342.

179. *See id*. at 337.

180. *Id*.

181. *Id*. at 342.

182. *Id*.

invertebrates were probably more sensitive to pH changes than marine fish, and it suggested that oysters and oyster larvae would be adversely affected at pH levels of about 6.5 (acidic) or 9.0 (basic).[183] Moreover, it cautioned states that "rapid pH fluctuations that are due to waste discharges should be avoided."[184]

The EPA carried the 1976 marine pH criterion unchanged into the 1986 "Gold Book,"[185] and these Gold Book marine pH recommended criterion remained in place for the 1998 compilation of water quality criteria, as well.[186] Indeed, the EPA's current website of national recommended water quality criteria still relies on both the Red Book and the Gold Book as the sources for the marine pH criterion.[187]

As a result, the EPA has not amended the Section 304 national recommended marine pH criterion since at least 1976—that is, since long before ocean acidification and marine life's more acute sensitivity to pH changes have been recognized in the scientific literature. As a result, both the EPA's reference criterion for ocean pH and the state water quality standards that depend on it are almost certainly, and unprotectively, out of date. Whether the science of ocean acidification is yet definitive enough to *force* either the EPA or the states to alter their standards, however, is a complex issue, and so far the EPA, the states, and the courts are not convinced.

B. The CBD, the EPA, NOAA, and the Courts on Ocean Acidification

1. The CBD's Legal Efforts to Address Ocean Acidification

The CBD has spearheaded a multi-faceted effort to bring ocean acidification within the ambit of state and federal law. For example, acknowledging the role of states in protecting water quality, on February 28, 2007, the CBD petitioned the State of California to regulate carbon dioxide pollution under

183. *Id.*

184. *Id.* at 343.

185. EPA GOLD BOOK, *supra* note 175.

186. National Recommended Water Quality Criteria; Republication, 63 Fed. Reg. 68,354, 68,361 (Dec. 10, 1998).

187. *National Recommended Water Quality Criteria*, *supra* note 164.

the Clean Water Act.[188] In addition, beginning in 2009, the CBD began working to have many coral species listed for protection under the federal Endangered Species Act (ESA)[189] because of the twin threats of ocean acidification and climate change.[190] The CBD later pursued ESA protections for black abalone, orange clownfish, and seven species of damselfish.[191]

With respect to federal efforts under the Clean Water Act, however, the CBD has concentrated its attention on the EPA's Section 304 criterion for marine pH and alleged violations of ocean water quality standards in Washington and Oregon. These efforts began on December 18, 2007, when the CBD formally petitioned the EPA to strengthen the national recommended water quality criterion for ocean pH and to provide guidance to the states regarding ocean acidification and water quality.[192] More specifically, the CBD petitioned the EPA to revise, pursuant to Section 304 of the Clean Water Act,[193] the EPA's water quality criterion for pH to acknowledge and address ocean acidification.[194]

The CBD's petition acknowledged that ocean acidification is primarily a result of carbon dioxide emissions into the air, but it also stressed how significant a water quality problem ocean acidification could become, emphasizing that the ocean's absorption of carbon dioxide is already lowering ocean pH and that many species of shell-forming marine organisms are

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188. Press Release, Ctr. for Biological Diversity, Conservation Group Petitions to Regulate Carbon Dioxide Under Clean Water Act (Feb. 28, 2007), http://www.biologicaldiversity.org/news/press_releases/ocean-acidification-02-28-2007.html. The petition itself is available at http://www.biologicaldiversity.org/campaigns/ocean_acidification/pdfs/acidification-cwa-petition.pdf.

189. 16 U.S.C. §§ 1531–1544 (2012).

190. Press Release, Ctr. for Biological Diversity, Suit Will Be Filed to Protect 83 Corals Threatened by Global Warming, Ocean Acidification (Jan. 20, 2010), http://www.biologicaldiversity.org/news/press_releases/2010/corals-01-20-2010.html.

191. *Action Timeline*, CENTER FOR BIOLOGICAL DIVERSITY, http://www.biologicaldiversity.org/campaigns/endangered_oceans/action_timeline.html (last visited Oct. 18, 2015).

192. Press Release, Ctr. for Biological Diversity, Lax Standard Fails to Prevent Souring Seas; Group Petitions EPA to Address the Threat of Ocean Acidification (Dec. 18, 2007), http://www.biologicaldiversity.org/news/press_releases/ocean-acidification-12-18-2007.html.

193. Clean Water Act § 304, 33 U.S.C. § 1314 (2012).

194. Petition for Revised pH Water Quality Criteria Under Section 304 of the Clean Water Act, 33 U.S.C. § 1314, to Address Ocean Acidification i, ii (Dec. 18, 2007), http://www.biologicaldiversity.org/programs/oceans/pdfs/section-304-petition-12-18-07.pdf.

already being impacted, including "corals, crabs, abalone, oysters, sea urchins, and other animals."[195] The CBD painted a worst-case scenario for the EPA, arguing that, "[a]bsent significant reductions in carbon dioxide emissions, ocean acidification will accelerate, likely ultimately leading to the collapse of oceanic food webs and catastrophic impacts on the global environment."[196]

The petition also emphasized, however, that the Clean Water Act is "the nation's strongest law protecting water quality" and that "[b]ecause ocean acidification is changing seawater chemistry and degrading water quality, [the] EPA needs to address this threat before it harms marine life and resources."[197] It argued that, in light of ocean acidification, the EPA's national recommended water quality criterion for ocean pH did not reflect the latest scientific knowledge.[198]

The CBD and the EPA have now engaged in an eight-years-and-counting skirmish over ocean acidification and the Clean Water Act, with the most helpful federal administrative response coming from NOAA. Moreover, the CBD's Clean Water Act efforts have now evolved beyond the Section 304 reference water quality criterion issue to the Section 303(d) impaired waters lists and TMDL process. The next subsections will explore these legal developments in turn.

2. The CBD's and the EPA's Actions with Respect to the Section 304 Reference Water Quality Criteria for Marine pH

When the EPA failed to respond to the CBD's 2007 petition, the CBD filed notice of its intent to sue for failure to respond on November 13, 2008.[199] The CBD alleged that "the EPA's current water-quality criterion for pH is outdated and woefully inadequate in the face of ocean acidification. A decline of 0.2 pH—allowed under the current standard—would be

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195. *Id.* at ii.

196. *Id.*

197. *Id.*

198. *Id.* at ii–iii.

199. Press Release, Ctr. for Biological Diversity, Environmental Protection Agency Warned to Address Ocean Acidification or Face Lawsuit (Nov. 13, 2008), http://www.biologicaldiversity.org/news/press_releases/2008/ocean-acidification-11-13-2008.html.

devastating to the marine ecosystem."[200] Thus, the CBD directly challenged the EPA's aquatic life protection rationale for the national recommended marine pH criterion, alleging that the permitted variation in pH was already too much for organisms to handle. Notably, however, the CBD also emphasized that ocean pH has already changed on average by 0.11 pH units,[201] meaning that—even under the EPA's current water quality criterion—ocean acidification has already driven ocean pH, on average, more than halfway to a pervasive Clean Water Act violation.

In response to the CBD's notice of intent to sue, in April 2009 the EPA published a Notice of Data Availability in the Federal Register, which both solicited additional scientific information regarding ocean acidification and notified the public of the EPA's intent to review the marine pH Section 304 water quality criterion to determine whether the science warranted a revision.[202] The EPA later stated its intent to respond to the CBD's petition by spring of 2010.[203]

Nevertheless, given the wide variability of "normal" marine pH values and insufficient data regarding ocean acidification and its impacts on aquatic life, the EPA decided in 2010 to *not* revise the Section 304 national recommended marine pH water quality criterion.[204] This decision is arguably scientifically vulnerable. Ocean science has evolved considerably since 1976, especially with respect to the more recently identified phenomenon of ocean acidification and its actual and potential impacts on marine organisms.[205] As noted above, current ocean acidification science indicates that shellfish impacts are already occurring with global average pH changes of 0.1, suggesting that the CBD may be correct that the 0.2 average deviation requirement in the current marine pH criterion is not in fact sufficient to protect marine aquatic life. Moreover, as will be discussed in more detail below, nothing in the EPA's

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200. *Id.*

201. *Id.*

202. Ocean Acidification and Marine pH Water Quality Criteria, 74 Fed. Reg. 17,484, 17,484 (Apr. 15, 2009).

203. Clean Water Act Section 303(d): Notice of Call for Public Comment on 303(d) Program and Ocean Acidification, 75 Fed. Reg. 13,537, 13,538 (Mar. 22, 2010).

204. Memorandum from Denise Keehner to Water Div. Dirs., *supra* note 174.

205. *See* discussion *supra* Part I.B–C.

national water quality criterion actually requires coastal states to tailor the standard to their own coastal waters—or, most maddeningly, to establish a baseline "normal" pH for those specific waters.

As a result, both the EPA's criterion and the states' implementation of it have become problematic, as will become more obvious in the context of the CBD's subsequent lawsuits against Washington and Oregon. Nevertheless, neither the EPA nor the CBD have (yet) pursued these Clean Water Act failures further.

3. The CBD's 2009 Impaired Waters Litigation Under Section 303(d) and Its Aftermath

In March 2009, the CBD refocused its Clean Water Act ocean acidification attention to Section 303(d) and TMDLs. Specifically, it filed a lawsuit against the EPA, alleging that the EPA should not have approved the State of Washington's 2008 Section 303(d) list of impaired waters because ocean acidification was already causing pH water quality standard violations in Washington's territorial sea, which Washington had failed to list as impaired.[206] According to the CBD, scientists had already documented ocean acidification's impacts in Washington coastal waters, and "[a]ccording to the 2008 report in the Proceedings of the National Academy of Sciences, since 2000 the pH of Washington's coastal waters has declined by more than 0.2 units, violating the state's water-quality standard for pH."[207] At the same time, and to little avail, the CBD sent letters to fourteen coastal states and two U.S. territories requesting that they include all ocean waters impaired by ocean acidification on their Section 303(d) impaired waters lists and revise their marine pH criteria.[208]

The lawsuit settled ten months later, with the EPA agreeing to consider "how states can address ocean acidification under

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206. Press Release, Ctr. for Biological Diversity, Lawsuit Filed Against Environmental Protection Agency for Failure to Combat Ocean Acidification (May 14, 2009), http://www.biologicaldiversity.org/news/press_releases/2009/ocean-acidification-05-14-2009.html.

207. *Id.*

208. Clean Water Act Section 303(d): Notice of Call for Public Comment on 303(d) Program and Ocean Acidification, 75 Fed. Reg. at 13,539 (citing Ctr. for Biological Diversity v. U.S. EPA, No. 2:09-cv-00670-JCC (W.D. Wash. 2009)).

the Clean Water Act."[209] As part of fulfilling its settlement promise, the EPA in March 2010 called for public comment on how the Clean Water Act's Section 303(d) program—that is, the impaired waters and TMDL program—could help to address ocean acidification.[210] According to the EPA, "[o]cean acidification presents a suite of environmental changes that would likely negatively affect ocean ecosystems, fisheries, and other marine resources."[211] It emphasized impacts on shell-forming organisms in particular, especially corals, oysters, clams, and crabs.[212] The EPA's notice generated about 30,000 comments (ranging from form letters to several extensive and well-documented responses) in 60 days, most of which supported using the Clean Water Act to address ocean acidification.[213]

In accordance with the settlement agreement, moreover, on November 15, 2010, the EPA issued a guidance memorandum to the ten EPA Regions on "Integrated Reporting and Listing Decisions Related to Ocean Acidification."[214] Perhaps most importantly for the future role of the Clean Water Act, the EPA concluded that, "[a]s a result of absorbing large quantities of human-made CO_2 emissions, ocean chemistry is changing, which is likely to negatively affect important marine ecosystems and species, including coral reefs, shellfish, and fisheries."[215] It also emphasized the synergistic impacts of ocean acidification and climate change (particularly increases in ocean temperatures) on marine ecosystems.[216] In terms of the Clean Water Act, the EPA noted that all 23 coastal states and five island U.S. territories still rely on the 1976 reference pH criterion.[217] However, the EPA also reported that coastal

209. Press Release, Ctr. for Biological Diversity, Legal Settlement Will Require EPA to Evaluate How to Regulate Ocean Acidification Under Clean Water Act (Mar. 11, 2010), http://www.biologicaldiversity.org/news/press_releases/2010/ocean-acidification-03-11-2010.html.

210. Clean Water Act Section 303(d): Notice of Call for Public Comment on 303(d) Program and Ocean Acidification, 75 Fed. Reg. at 13,537.

211. *Id.* (citations omitted).

212. *Id.*

213. Memorandum from Denise Keehner to Water Div. Dirs., *supra* note 174.

214. *Id.*

215. *Id.* at 1.

216. *Id.*

217. *Id.* at 4.

states have not completed the science necessary to be able to determine whether their coastal marine pH is changing.[218] Most importantly, most coastal states have not figured out what the baselines and standard pH ranges for their coastal waters actually are, and many do not adequately monitor these waters to detect any changes that may be occurring.[219]

In other words, states do not know what the "normal" pH of their territorial seas actually is, making quantifiable assessment of ocean acidification's impact almost impossible. This fact, as a practical if not legal matter, limits what states can do with their Section 303(d) listings of impaired coastal waters. Indeed, the EPA's November 2010 guidance reflects the increasing tension between legal requirements and scientific knowledge with respect to ocean acidification. Specifically, this guidance concludes that the Clean Water Act *does* apply to pH impacts but simultaneously acknowledges that states may not have sufficient information to implement the law:

> EPA has concluded that States should list waters not meeting water quality standards, including marine pH WQC [water quality criteria], on their 2012 303(d) lists, and should also solicit existing and readily available information on [ocean acidification] using the current 303(d) listing program framework. This Memorandum does not elevate in priority the assessment and listing of waters for [ocean acidification], but simply recognizes that waters should be listed for [ocean acidification] when data are available. EPA recognizes that information is absent or limited for [ocean acidification] parameters and impacts at this point in time and, therefore, listings for ocean acidification may be absent or limited in many States.[220]

The EPA promised more guidance when more scientific information becomes available.[221] In the interim, it recommended that coastal states regularly solicit information about ocean acidification in their individual waters.[222] It also

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218. *Id.* (citation omitted).

219. *Id.*

220. *Id.*

221. *Id.* at 4–5.

222. *Id.* at 6.

encouraged states to develop ocean acidification assessment methods for their territorial seas,[223] and, "to improve implementation of the marine pH criteria, EPA suggests States begin requesting information on, and developing methods for, interpreting their marine pH water quality standards related to natural condition,"[224] particularly with respect to marine life like coral reefs.[225] Finally, the EPA again emphasized that states have considerable discretion in prioritizing TMDL development for impaired waters, and it clearly conveyed its own position that it does not believe that enough information yet exists regarding ocean acidification to allow coastal states to develop ocean acidification-related carbon TMDLs.[226]

The clear implication of the EPA's guidance memorandum, therefore, is that states will not be rushing to generate ocean acidification-based TMDLs anytime in the near future. In fact, the EPA's memorandum implies that any such TMDLs would be scientifically indefensible. Nevertheless, as the EPA also acknowledged, coastal states are not powerless in the face of ocean acidification problems.[227] It recommended that states concentrate their efforts on waters already listed for other pollutants that are considered vulnerable to ocean acidification, such as waters with coral reefs, marine fisheries, and shellfish resources, and that states experiment with supplying these waters with extra calcium carbonate minerals.[228] The EPA also recommended that coastal states prioritize waters that were vulnerable to ocean acidification for ecological restoration, which would improve those waters' general resilience.[229]

Therefore, the EPA's advice to coastal states, in essence, is to learn more, measure more, start keeping long-term records, and take care of other pollution problems first. As such, the EPA's November 2010 guidance memorandum is hardly the ocean acidification "call to action" that the CBD was probably hoping for.

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223. *Id.* at 7.
224. *Id.* at 9.
225. *Id.* at 11.
226. *Id.* at 12.
227. *See id.*
228. *Id.* (citation omitted).
229. *Id.*

Before condemning states and the EPA for their lackluster responses to ocean acidification, however, it is also worthwhile to consider ocean acidification's impacts on water quality in the context of the Section 303(d) program more generally. A remarkably low percentage of the nation's waters have actually been subject to water quality assessments—only about 19% in 2002—and of those, about 40% are assessed to be impaired.[230] Given the dearth of water quality assessment even in freshwaters, it is perhaps unsurprising that states have not been assessing coastal waters for ocean acidification. Moreover, while more information about ocean acidification would certainly be helpful, a TMDL is highly unlikely to be the most efficient way to address the relevant sources—air emissions of carbon dioxide and mostly nonpoint (agricultural) sources of nutrient pollution (as in the Chesapeake Bay states). As Part III will discuss in more detail, motivated coastal states have in fact been using other mechanisms to address their ocean acidification problems.

4. The CBD's 2013 Lawsuit Against Washington and Oregon Under Section 303(d)

Despite the acknowledged scientific gaps regarding ocean acidification, the CBD contends that there is enough data about ocean acidification in some coastal waters to warrant the application of the Clean Water Act's Section 303(d) process. In 2013, the CBD filed suit against the EPA in the U.S. District Court for the Western District of Washington, challenging the EPA's approval of Washington's and Oregon's 2010 submissions of their Section 303(d) impaired waters lists—neither of which included coastal waters impaired by ocean acidification.[231]

On cross-motions for summary judgment, the Western District of Washington held that the EPA's approval of the two states' lists was not arbitrary and capricious, granting the EPA's motion for summary judgment and denying the CBD's.[232] The court acknowledged that both Washington and

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230. OLIVER A. HOUCK, THE CLEAN WATER ACT TMDL PROGRAM: LAW, POLICY, AND IMPLEMENTATION 4 (2d ed. 2002).

231. Ctr. for Biological Diversity v. U.S. EPA, 90 F. Supp. 3d 1177, 1181–82 (W.D. Wash. 2015).

232. *Id.* at 1216–17.

Oregon have water quality standards that implicate ocean acidification,[233] and it found the CBD to have standing.[234] On the merits, the CBD raised two issues: (1) the EPA inadequately explained why it approved both states' impaired waters lists; and (2) Washington and Oregon failed to consider all water quality data when creating their impaired waters lists.[235]

With respect to Washington, the CBD relied on the Wootton study, which analyzed eight years of pH data from a tidepool at the mouth of the Strait of Juan de Fuca.[236] According to the CBD, the data showed a steady decline in pH in the tidepool amounting to a decline of 0.368 pH units over eight years—more than the 0.2 pH unit change allowed under both the EPA's national reference marine pH criterion and Washington's own water quality standards.[237] Washington rejected the study for three reasons: it did not prove that the pH changes were from anthropogenic causes; the monitoring site was located within the Makah Indian Reservation, out of the state's regulatory jurisdiction; and data from the tidepool could not be extrapolated to the larger waters beyond, including the Strait itself.[238] The EPA also independently reviewed the Wootton study and rejected its implications for waters outside of the tidepool for many of the same reasons.[239] The court upheld both Washington's and the EPA's reasoning, emphasizing that the Wootton study "did not take into consideration natural processes, such as river discharge effects"[240] and concluding that "even if the Wootton study did prove violations of Washington's numerical pH standard [in the tidepool on tribal land], EPA was justified in determining that the study's results did not require listing adjacent waters, such as the Strait of Juan de Fuca."[241]

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233. *Id.* at 1183–84.

234. *Id.* at 1186–96.

235. *Id.* at 1196–97.

236. *Id.* at 1201–03.

237. Ctr. for Biological Diversity v. U.S. EPA, 90 F. Supp. 3d 1177, 1201 (W.D. Wash. 2015).

238. *Id.* at 1201–02.

239. *Id.* at 1202.

240. *Id.*

241. *Id.* at 1203.

The CBD also claimed that ocean acidification is causing violations of Oregon's and Washington's narrative water quality standards regarding shellfish.[242] For example, Washington designates most of its coastal waters as "extraordinary quality" or "excellent quality" for aquatic life uses, which include shellfish spawning and rearing as designated uses.[243] In addition, under Washington's water quality standards, in any waters with marine life or that are used to harvest shellfish, concentrations of any "deleterious material" must remain below the levels that have the "potential . . . to adversely affect" marine life.[244] Similarly, Oregon designates its coastal waters for "fish and aquatic life" and fishing.[245] Oregon's "[n]arrative water quality criteria provide that '[w]aters of the state must be of sufficient quality to support aquatic species without detrimental changes in the resident biological communities,' and that the 'creation of . . . conditions that are deleterious to fish or other aquatic life . . . may not be allowed.'"[246] According to the CBD, based primarily on laboratory and shellfish aquaculture studies, ocean acidification is clearly having detrimental impacts on shellfish in Oregon and Washington.[247] However, the district court concluded that the CBD's evidence of these impacts was "scant."[248] It also held that the EPA was reasonable in concluding that laboratory studies could not be extrapolated to show harm to wild populations[249] and that hatchery studies in specific bays could not be extrapolated to other coastal waters in Oregon and Washington, especially waters that were geographically distant or ecologically dissimilar.[250]

Nevertheless, the district court noted, it was a closer question as to whether the hatchery studies were sufficient to require listing of the waters actually studied, such as Netarts

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242. *Id.*

243. Ctr. for Biological Diversity v. U.S. EPA, 90 F. Supp. 3d 1177, 1183 (W.D. Wash. 2015) (citing WASH. ADMIN. CODE §§ 173-201A-612, 173-201A-210(1)(a) (2014)).

244. *Id.* at 1184 (citing WASH. ADMIN. CODE § 173-201A-260(2)(a)).

245. *Id.* (citing OR. ADMIN. R. 340-041-0220–340-041-0225 (2014)).

246. *Id.* (citing OR. ADMIN. R. 340-041-0011, 340-041-0007(10)).

247. *Id.* at 1203–04.

248. *Id.* at 1204.

249. Ctr. for Biological Diversity v. U.S. EPA, 90 F. Supp. 3d 1177, 1205–06 (W.D. Wash. 2015).

250. *Id.* at 1206–08.

Bay in Oregon, and it chided the EPA for relying solely on the states' *numeric* water quality criteria for pH to reject the studies' implications.[251] Nevertheless, deferring to the EPA's "technical expertise," the court accepted the EPA's explanation of why oyster hatchery die-offs from ocean acidification in both Oregon and Washington did not require those states to list the local waters as impaired. Specifically, the court deferred to the EPA's conclusion that hatchery die-offs demonstrated nothing about the effects of ocean acidification on *wild and natural* populations.[252] Notably, in so doing, the court also accepted that both states' water quality standards were in fact limited to wild and natural populations even though Oregon's standards (unlike Washington's) do not clearly exclude impacts on hatchery or farmed shellfish populations from constituting water quality violations.[253]

As for the CBD's second argument, the district court could identify no data that Oregon had not considered in compiling its 2010 impaired waters list.[254] The court also upheld Washington's reasoned explanation for rejecting long-term marine monitoring data as not credible,[255] and it concluded that there was no record evidence that marine pH data from other sources, like the United States Geological Survey or NOAA, had been either available or brought to the Washington State Department of Ecology's attention.[256]

As this Article goes to press, there is no indication that the CBD will appeal the district court's decision to the United States Court of Appeals for the Ninth Circuit. However, the CBD is already pursuing a similar lawsuit based on the EPA's decision to approve Oregon's and Washington's 2012 Section 303(d) impaired waters lists,[257] indicating its intent to bring recurrent lawsuits after each new EPA approval. These sequential lawsuits will presumably continue to focus on the

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251. *Id.* at 1207.

252. *Id.* at 1207–08.

253. *Id.* at 1207.

254. *Id.* at 1210.

255. Ctr. for Biological Diversity v. U.S. EPA, 90 F. Supp. 3d 1177, 1210–16 (W.D. Wash. 2015).

256. *Id.* at 1214–16.

257. Susannah L. Bodman, *Lawsuit over Ocean Acidification in Oregon, Washington Gets a Hearing in Seattle*, THE OREGONIAN (Feb. 10, 2015), http://www.oregonlive.com/pacific-northwest-news/index.ssf/2015/02/ocean_acidification_seattle.html.

issue of when exactly affected coastal states know enough about the particular impacts of ocean acidification in specific waters (and apparently on wild and natural populations) to trigger the Clean Water Act's Section 303(d) process.

Notably, the Western District of Washington upheld the EPA in allowing a fairly high knowledge threshold before coastal waters *must* be deemed "impaired" for ocean acidification under the Clean Water Act: Area-specific studies must demonstrate that anthropogenic causes (presumably human emissions of carbon dioxide) are causing decreases in local pH that either are greater than 0.2 pH units from "normal" or are causing demonstrable impacts on wild/natural populations of marine life.[258] This standard hardly reflects a precautionary approach to impaired waters listings for ocean acidification, perhaps hampering the full acknowledgement of ocean acidification's growing impacts on the United States' coastal waters.

Nevertheless, while the acknowledgement of ocean acidification's impacts on coastal waters could be important in its own right, the ultimate response to an impaired waters listing under the Clean Water Act is a TMDL—and it is still not clear what a TMDL for ocean acidification could accomplish to significantly improve ocean pH in most states. As noted, such a TMDL might prompt states to address locally important nutrient runoff pollution, which generally requires states to regulate agriculture—a politically unsavory option in many states. As Part III will discuss more fully, local stormwater problems can also exacerbate ocean acidification, although the Clean Water Act already has a fairly comprehensive stormwater program.[259] Finally, while state-based programs to reduce carbon dioxide emissions could become important for both climate change and ocean acidification, until *global* emissions and *global* atmospheric concentrations of carbon dioxide decrease significantly, ocean acidification will continue to be a problem.

Even so, some coastal states are likely to cross even the Western District of Washington's high knowledge threshold for ocean acidification-impaired coastal waters sometime in the near future. Indeed, one of the perverse ironies of the CBD's

258. *Ctr. for Biological Diversity*, 90 F. Supp. 3d at 1213–14.

259. *See* 33 U.S.C. § 1342(p) (2012).

Section 303(d) litigation is that some of the states—like Oregon and Washington—that are resisting ocean acidification-based Section 303(d) listings are also leaders in intensively pursuing state and regional ocean acidification programs. This Article turns to those state and regional programs in Part III.

5. Parallel Developments: The National Ocean Policy, the FOARAM Act, and NOAA

As the EPA itself has noted repeatedly,[260] the CBD's efforts to apply the Clean Water Act to ocean acidification arose concurrently with several other federal efforts to improve ocean management generally and to address ocean acidification in particular. For example, on July 19, 2010, President Barack Obama issued Executive Order No. 13,547 to establish a National Ocean Policy.[261] This Executive Order established the National Ocean Council and charged it and all federal agencies to pursue the recommendations of the Interagency Ocean Policy Task Force.[262] These recommendations included a policy to "provide for adaptive management to enhance our understanding of and capacity to respond to climate change and ocean acidification."[263] Thus, the National Ocean Council is now addressing ocean acidification.

Congress has also addressed ocean acidification. For instance, on March 30, 2009, it enacted (as part of the Omnibus Public Land Management Act of 2009) the Federal Ocean Acidification Research and Monitoring (FOARAM) Act of 2009.[264] This Act appropriated $96 million to NOAA and NASA, spread over four years,[265] to: (1) develop a comprehensive interagency plan to research and monitor ocean acidification and establish an interagency ocean acidification research and monitoring program; (2) establish an ocean acidification program within NOAA; (3) assess the effects of ocean acidification on ecosystems and socioeconomics, both

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260. *E.g.*, Clean Water Act Section 303(d): Notice of Call for Public Comment on 303(d) Program and Ocean Acidification, 75 Fed. Reg. 13,537, 13,539.

261. Exec. Order No. 13,547, 75 Fed. Reg. 43,023 (July 19, 2010).

262. *Id.* §§ 1, 4, 75 Fed. Reg. at 43,023, 43,024.

263. *Id.* § 1, 75 Fed. Reg. at 43,023.

264. Omnibus Public Land Management Act of 2009, Pub. L. No. 111–11, §§ 12401–12409, 123 Stat. 991, 1436–42 (codified as amended at 33 U.S.C. §§ 3701–3708).

265. *Id.* § 12409, 123 Stat. at 1441–42 (codified at 33 U.S.C. § 3708).

nationally and regionally; and (4) develop adaptation techniques that will effectively conserve marine ecosystems even as they cope with ocean acidification.[266]

In response to the FOARAM Act, NOAA has established an ocean acidification program.[267] Moreover, on March 26, 2014, NOAA and its partners in the Interagency Working Group on Ocean Acidification released their *Strategic Plan for Federal Research and Monitoring of Ocean Acidification*.[268] The Working Group's vision for the United States' ocean future is of "[a] nation, globally engaged and guided by science, sustaining healthy marine and coastal ecosystems, communities, and economies through informed responses to ocean acidification."[269] Its plan has seven themes—"(1) monitoring; (2) research; (3) modeling; (4) technology development; (5) socioeconomic impacts; (6) education, outreach, and engagement strategies; and (7) data management and integration"—and it recommends both short- and long-term research.[270]

The plan also identifies 13 goals for ocean acidification research and monitoring, five of which are directly relevant to effectively implementing Clean Water Act water quality criteria, water quality standards, and TMDL processes, including identifying coastal waters that actually have been impacted by ocean acidification. These goals include: (1) developing comprehensive models of ocean acidification; (2) developing technologies to adequately and accurately measure relevant changes in the ocean; (3) translating laboratory science into real-world applications; (4) developing ocean acidification vulnerability assessments for various future carbon dioxide emissions scenarios; and (5) engaging local communities and the public in marine stewardship efforts.[271]

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266. *Id.* § 12402, 123 Stat. at 1436–37 (codified at 33 U.S.C. § 3701).

267. *NOAA Ocean Acidification Program*, NAT'L OCEANIC & ATMOSPHERIC ADMIN. http://oceanacidification.noaa.gov (last visited Oct. 18, 2015).

268. INTERAGENCY WORKING GROUP ON OCEAN ACIDIFICATION, STRATEGIC PLAN FOR FEDERAL RESEARCH AND MONITORING OF OCEAN ACIDIFICATION (2014), https://www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC/iwg-oa_strategic_plan_march_2014.pdf.

269. *Id.* at 6.

270. *Id.*

271. *Id.* at 6–7.

The very need for this research plan, however, suggests that the EPA's 2010 assessment of the current state of place-specific ocean acidification science for Clean Water Act purposes is generally correct: Most coastal states do not have the scientific data and support necessary to even assess problematic changes in pH (short term or long term) in their local waters, let alone implement meaningful TMDLs that will make a difference to marine health. NOAA's research plan, if implemented well and quickly, may help to provide coastal states with much-needed information to undergird their coastal water quality programs, potentially improving legal responses to ocean acidification in the future. In the meantime, however, a few states are also exploring other approaches to ocean acidification, the subject of Part III.

IV. STATE AND REGIONAL APPROACHES TO OCEAN ACIDIFICATION

The Clean Water Act, of course, is not the only possible legal response to ocean acidification. Moreover, the purpose of the Section 303(d) process is arguably to make states aware of their ocean acidification problems and to prompt state law regulation of sources—often nonpoint sources like atmospheric carbon dioxide or nutrient pollution runoff—to improve water quality. However, as noted, without large-scale and global regulation of carbon dioxide emissions, the main cause of ocean acidification is largely beyond individual state control.

Some states and coastal regions affected by ocean acidification *have* been responding to that problem—but they have chosen to do so outside of the relatively constricting structure of the Clean Water Act. These state and regional programs document the potential scope of the ocean acidification problem for ecosystems and industries within individual states and tend to emphasize techniques to both minimize and adapt to ocean acidification.

This Part provides a snapshot of state and regional ocean acidification programs. It focuses on Washington, the first state to seriously address ocean acidification through state law and policy; Maine, which enacted ocean acidification legislation in 2014 and released its ocean acidification report and recommendations in 2015; and the still-nascent regional ocean acidification efforts along the West Coast.

A. Washington's Ocean Acidification Program

1. Ocean Acidification in Washington

As noted, the waters of Puget Sound have become particularly corrosive, most obviously interfering with oyster cultivation.[272] Indeed, effects on oyster and other shellfish aquaculture within the State of Washington—and especially in Puget Sound—are what first turned state regulators' attention to the ocean acidification problem.[273] Starting in 2005, oyster hatcheries within Puget Sound (and also in Oregon) experienced disastrous die-offs of oyster larvae as a result of low pH seawater.[274] Ocean acidification in Washington now threatens the state's coastal ecology, the livelihoods of its Tribes, and several economic industries,[275] in large part because of the state's dependence on shellfish.

Several sources cause and exacerbate ocean acidification in Washington coastal waters. As is true for oceans everywhere, "[c]arbon dioxide emissions are the leading cause of ocean acidification."[276] Nevertheless, other causes can exacerbate ocean acidification and, at the regional level, Washington and the Pacific Coast generally face increased threats from open ocean upwelling.[277] As in Alaska, this upwelling water "is naturally rich in nutrients, high in carbon dioxide, and low in pH."[278] Indeed, water upwelling from deeper parts of the ocean is increasing in carbon dioxide concentration, reflecting the ocean's long-term absorption of carbon dioxide, and these concentrations will only increase in the future, increasing the upwellings' corrosiveness.[279]

More locally, nutrient water pollution from land-based sources and organic carbon pollution flowing down rivers and

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272. *Acidifying Water Takes Toll on Northwest Shellfish*, *supra* note 114.

273. WASH. STATE BLUE RIBBON PANEL ON OCEAN ACIDIFICATION, OCEAN ACIDIFICATION: FROM KNOWLEDGE TO ACTION, WASHINGTON STATE'S STRATEGIC RESPONSE xi (2012) [hereinafter 2012 WASH. PANEL REPORT], https://fortress.wa.gov/ecy/publications/publications/1201015.pdf.

274. *Id.*

275. *Id.* at 4–5.

276. *Id.* at 9.

277. *Id.* at 10–11.

278. *Id.* at 11.

279. *Id.*

streams can exacerbate ocean acidification.[280] Nutrient pollution can spur algal blooms,[281] one form of which is a "red tide." When the algae then die and decompose, the decomposition process uses most of the oxygen in the water, creating a hypoxic area[282] (more colloquially, a "dead zone," like in the Gulf of Mexico). At the same time, however, the decomposing algae release carbon dioxide to the water column, exacerbating ocean acidification.[283] Freshwater inputs carrying organic carbon pollution, in turn, combine the generally lower pH of freshwater with the pH-reducing properties of sewage effluent, municipal wastewater discharges, and industrial discharges to exacerbate the pH effects of ocean acidification.[284] As a result, "[w]hen fresh water and seawater mix at river mouths or in estuaries, the water can sometimes be corrosive to calcifying organisms. This is the case for the Columbia River in summer and in Puget Sound in winter."[285]

Finally, the ocean's absorption of other gases besides carbon dioxide can exacerbate ocean acidification.[286] In particular, nitrogen oxides and sulfur dioxide have long been regulated under the Clean Air Act because they cause acid rain, and those same acidifying properties can locally exacerbate ocean acidification issues.[287]

These multiple causes of ocean acidification in Washington mean that different areas of Washington's coastal waters are vulnerable to different combinations of causes. In Washington's outer coast, the primary drivers of ocean acidification are absorption of carbon dioxide, coastal upwelling (especially in summer), and freshwater inputs from the Columbia River.[288] In contrast, in the Columbia River estuary, ocean acidification reflects the naturally lower pH of the Columbia River and its tributaries, plus the effects of

280. *Id*. at 10–12.

281. *Id*. at 11, 13.

282. *Id*. at 14.

283. *Id*. at 21–22.

284. *Id*. at 13.

285. *Id*. at 12. The seasonal differences are largely the result of different rainfall and snowmelt runoff patterns. *Id*.

286. *Id*. at 13.

287. *Id*.

288. *Id*. at 14.

organic decomposition.[289] In the Puget Sound and the Strait of Juan de Fuca, corrosive upwelling water from the ocean is a strong influence, but the more inward estuaries in Puget Sound also suffer from nutrient and organic carbon pollution flowing into the Sound from rivers and streams; these areas may also suffer from atmospheric deposition of nitrogen oxides and sulfur dioxide.[290] Puget Sound also exhibits much pH variability, with the Hood Canal basin having some of the lowest pH levels and calcium carbonate saturation in Washington.[291]

Reflecting back on Part II momentarily, Washington's coastal acidification underscores the potential limitations of the Clean Water Act in addressing the problem. As noted, there is little that U.S. domestic law can do to address *global* carbon dioxide emissions because many of the sources are outside of both federal and state jurisdiction. Offshore upwelling currents are driven by global and regional winds, air temperatures, and ocean temperature—physical ocean processes that are beyond human control. The naturally lower pH of freshwater rivers is similarly a natural phenomenon, and any attempts to increase freshwater pH to benefit the oceans would harm aquatic organisms and freshwater ecosystems through parallel changes in aquatic biochemistry, creating new violations of the Clean Water Act. Finally, increased state controls on nitrogen oxides and sulfur dioxide emissions would have to come through the Clean *Air* Act,[292] not the Clean Water Act.

However, the Clean Water Act can have some local relevance to ocean acidification, as previously noted.[293] In Washington, more stringent controls on land-based nutrient water pollution and pollution of water by organics—both clearly within the province of the Clean Water Act, especially in terms of state nonpoint source regulation—could bring some local relief from ocean acidification.

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289. *Id.* at 14–15.

290. *Id.* at 15.

291. *Id.*

292. *See* 42 U.S.C. §§ 7651–7651o (2012) (encompassing the Clean Air Act's acid rain program).

293. *See* discussion *supra* Part II.A.

2. Washington State Blue Ribbon Panel on Ocean Acidification

In 2011, Washington State Governor Christine Gregoire convened the Washington State Blue Ribbon Panel on Ocean Acidification. Within a year, the Panel issued its report, *Ocean Acidification: From Knowledge to Action*,[294] outlining a strategic state response to the impacts of ocean acidification.

The Panel concluded that Washington coastal waters are particularly vulnerable to ocean acidification because of upwelling.[295] It also emphasized, however, that upwelling is not the only local factor contributing to ocean acidification in Washington and that the relative importance of local factors varies by location.[296]

Shell-forming organisms, which are most vulnerable to ocean acidification, constitute over 30% of the Puget Sound's marine species and thus, a significant proportion of Washington's marine life.[297] Moreover, Washington's economy is directly impacted by the negative effects ocean acidification has on these species, because "Washington is the country's top provider of farmed oysters, clams, and mussels."[298] Washington provides about 85% of annual farmed shellfish sales in the western United States, and shellfish aquaculture is worth about $270 million annually to the state, employing 3200 people.[299] Recreational shellfish licenses generate another $3 million annually for the state, while recreational oyster and clam harvesters add $27 million annually to Washington's coastal economies.[300] "Overall, Washington's seafood industry generates over 42,000 jobs in Washington and contributes at least $1.7 billion to gross state product through profits and employment at neighborhood seafood restaurants, distributors, and retailers."[301]

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294. 2012 WASH. PANEL REPORT, *supra* note 273.
295. *Id.* at xii.
296. *Id.*
297. *Id.* at xiii.
298. *Id.* at xv.
299. *Id.* (citations omitted).
300. *Id.*
301. *Id.*

The Blue Ribbon Panel sought most generally to reduce Washington's ecological and economic vulnerability to ocean acidification. It recognized that global carbon dioxide emissions are the main cause of ocean acidification,[302] but it also stressed the need for local adaptation.[303] Specifically, given the pace of ocean acidification in Washington and the time it takes for reductions in carbon dioxide emissions to make a difference (even assuming those reductions actually occur), local adaptation and remediation is necessary to "buy time" while, hopefully, global society works on the emissions problem.[304]

The Panel also recognized that the Clean Water Act can be a helpful but incomplete mechanism to assist in these local adaptation and remediation efforts. For example, the Panel recommended local reductions in nitrogen and organic carbon inputs into coastal waters from point, nonpoint, and natural sources.[305] Point source discharges of these pollutants are directly subject to Washington's implementation of the Clean Water Act NPDES permit program; in turn, Washington can address nonpoint sources through its Clean Water Act-approved state nonpoint source pollution programs, as well as a parallel nonpoint source program approved under the federal Coastal Zone Management Act[306]—a recommendation that could have direct implications for Washington's implementation of its Clean Water Act program.

The Panel also stressed the need for increased research, monitoring, and public outreach to fill gaps in the science and help with risk assessment.[307] Public outreach and engagement were also critical so that Washington citizens could understand what an important threat ocean acidification poses to the state.[308] Finally, recognizing that ocean acidification is a long-term problem, the Panel recommended both "Key Early Actions" (KEAs) and longer-term strategies and actions.[309] The eighteen KEAs include both scientific and governance

302. *Id.* at xvii.

303. *Id.*

304. *Id.*

305. *Id.* at xviii.

306. 16 U.S.C. § 1455b (2012).

307. 2012 WASH. PANEL REPORT, *supra* note 273, at xviii.

308. *Id.*

309. *Id.* at xix–xxi.

suggestions that range from international and national advocacy regarding ocean acidification problems,[310] to reducing nutrient and organic carbon pollution in localities where they are contributing causes,[311] to improving water quality monitoring at the state's six shellfish hatchery and rearing areas,[312] to setting up "refuges for organisms vulnerable to ocean acidification and other stressors,"[313] to developing capability to forecast short-term acidic upwelling events,[314] to establishing a person or entity in the Governor's Office to coordinate all ocean acidification research and activity.[315]

The KEAs represent what the Panel considered to be "essential" first steps to implementing its six overall strategies for dealing with ocean acidification. These six strategies are: (1) reducing emissions of carbon dioxide; (2) reducing local land-based contributions to ocean acidification; (3) increasing Washington's ability to adapt to and remediate the impacts of ocean acidification; (4) investing in the state's ability to monitor and investigate the effects of ocean acidification; (5) informing, educating, and engaging stakeholders, the public, and decision makers in ocean acidification issues; and (6) maintaining a continued and coordinated focus on ocean acidification.[316] Longer-term recommendations to pursue these six strategies range from adding shells to specific marine areas to increase concentrations of calcium carbonate (calcite and aragonite) and support shell formation,[317] to enhancing ocean acidification modeling and long-term predictive capabilities,[318] to creating ocean acidification school curricula for K-12 and higher education.[319]

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310. *Id.* at xx, tbl.S-1.
311. *Id.*
312. *Id.*
313. 2012 WASH. PANEL REPORT, *supra* note 273, at xx, tbl.S-1.
314. *Id.* at xxi, tbl.S-1.
315. *Id.*
316. *Id.* at 28–32, tbl.1.
317. *Id.* at 30, tbl.1 (Strategy 6.1, Action 6.1.3.).
318. *Id.* at 31, tbl.1 (Strategy 7.4).
319. *Id.* at 32, tbl.1 (Strategy 8.2, Action 8.2.1).

3. Washington's Marine Advisory Councils

In response to the Blue Ribbon Panel's 2012 report, in 2013 the Washington legislature enacted Senate Bill 5603 to create the Washington Coastal Marine Advisory Council and the Washington Marine Resources Advisory Council (MRAC).[320] The Washington Coastal Marine Advisory Council operates out of the Office of the Governor,[321] although the Washington State Department of Ecology provides the administrative and staff support for the Council.[322] The Council's broad membership reflects the broad state, private, and tribal interests in Washington's marine waters.[323] It has several duties, including serving as a forum to discuss coastal issues such as coastal waters resource policy, planning, and management, and serving as a point of contact for various kinds of collaboration and fundraising.[324] Probably most importantly, the Council provides consensus-based[325] recommendations to all levels of government regarding coastal resource management issues, including marine spatial planning, principles and standards for emerging new coastal uses, and scientific research needed for coastal resources management,[326] which should include ocean acidification.

MRAC also operates out of the Office of the Governor[327] and also has a broad and representative membership.[328] However, its duties focus more directly on ocean acidification. Specifically, by statute, MRAC must: (1) coordinate governmental entities and citizens and focus their attention on ocean acidification issues; (2) work with the University of Washington and other scientific entities to develop practically applicable ocean acidification science; (3) make recommendations to the governor and Washington legislature; (4) develop funding resources for technical assistance; and (5)

320. S. 5603, 63d Leg., Reg. Sess. (Wash. 2013), http://lawfilesext.leg.wa.gov/biennium/201314/Pdf/Bills/Senate%20Passed%20Legislature/5603.PL.pdf.

321. *Id.* § 1(1).

322. *Id.* § 1(8).

323. *See id.* § 1(2) (listing all of the voting members).

324. *Id.* §§ 1(6), 2(1).

325. *Id.* § 1(6).

326. *Id.* § 2(1).

327. *Id.* § 4(1).

328. *Id.* § 4(2).

help to conduct public education on ocean acidification.[329] The Council sunsets on June 30, 2017.[330]

MRAC has been meeting since November 2013.[331] At its March 2014 meeting it announced its strategic plan, which focuses on four goals: (1) advancing implementation of the Blue Ribbon Panel's recommendations; (2) collaborating with and advocating for the Washington Ocean Acidification Center (WOAC); (3) ensuring effective multi-agency collaboration and coordination; and (4) engaging in broad public education about ocean acidification.[332] The main goal of the strategic plan was to develop an implementation plan.[333] In addition, MRAC began to focus on local contributions to ocean acidification, building off the Blue Ribbon Panel's recommendations. Noting that "[r]educing inputs of nutrients and organic carbon from local sources will decrease acidity in Washington's marine waters that are impacted by these local sources,"[334] it began to map local watershed contributions of these pollutants (including natural, onsite sewage facilities, upstream wastewater treatment plants, and agricultural runoff) and municipal and industrial marine point source contributors along the Washington coast.[335] It also noted that increased efforts were already underway in monitoring, modeling, and adaptation efforts, but that more would be needed.[336]

By November 2014, as part of the Puget Sound Action Agenda, MRAC identified seven priority ocean acidification actions and submitted them for funding, which became part of the 2014–2015 Puget Sound Action Plan as Near-Term Actions (NTAs).[337] These NTAs were to: (1) support MRAC and the

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329. *Id.* § 4(8).

330. *Id.* § 4(9).

331. *Ocean Acidification and Washington State: Washington Marine Resources Advisory Council (MRAC)*, WASH. STATE DEPARTMENT ECOLOGY, http://www.ecy.wa.gov/water/marine/oceanacidification.html (last visited Oct. 18, 2015).

332. Angie Thomson, Presentation Before the Wash. Marine Res. Advisory Council: MRAC Strategic Plan 4 (Mar. 7, 2014), http://www.ecy.wa.gov/water/marine/oa/20140307MRACstrategicplan.pdf.

333. *Id.* at 6–8.

334. Mindy Roberts, Presentation Before the Wash. Marine Res. Advisory Council: What Can We Do Locally? 2 (Mar. 7, 2014), http://www.ecy.wa.gov/water/marine/oa/20140307MRACroberts.pdf.

335. *Id.* at 3.

336. *Id.* at 4.

337. Brian Walsh & Libby Hudson, Presentation Before the Wash. Marine Res.

WOAC in research regarding the biological response to ocean acidification; (2) support MRAC and the WOAC in coordinating research with federal and state agencies; (3) expand the ocean acidification monitoring network; (4) develop a forecast modeling system; (5) identify local source impacts and develop modeling for them; (6) develop mitigation strategies to improve native oyster resilience; and (7) develop the cultivation and harvest of seaweed as a mitigation strategy.[338] In addition, MRAC further refined its own longer-term role in addressing ocean acidification, concluding that it would submit annual ocean acidification status reports to the Governor and Washington legislature; submit annual budget requests related to ocean acidification; engage in ongoing legislative, funding, and communication strategies; and facilitate public understanding of ocean acidification.[339]

In February 2015, MRAC produced its first Ocean Acidification Status Report,[340] which reported several positive conclusions. First, with respect to necessary funding, Washington invested $1.85 million in ocean acidification research in 2013–2015 and leveraged another $1.93 million for that research.[341] Second, Washington is improving scientific understanding of how ocean acidification affects marine shellfish industries. Specifically, the WOAC has been working with Washington's shellfish industry to gather basic information about local ocean acidification, with the goal of avoiding more devastating losses at the hatcheries.[342] Third, relatedly, shellfish growers in Washington are developing a suite of adaptation strategies to cope with ocean acidification, ranging from warning systems for upwellings to using shells to provide additional calcium carbonate.[343] Fourth, the

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Advisory Council: 2014/2015 Puget Sound Action Agenda Update 2 (Nov. 18, 2014), http://www.ecy.wa.gov/water/marine/oa/20141118MRACpresentationPSP.pdf.

338. *Id.* at 3.

339. MARINE RES. ADVISORY COUNCIL, MARINE RESOURCES ADVISORY COUNCIL LONG-RANGE VISION 1 (2014), http://www.ecy.wa.gov/water/marine/oa/20141118MRAChandoutLongRangeVision.pdf.

340. MARINE RES. ADVISORY COUNCIL, STATE OF OCEAN ACIDIFICATION IN WASHINGTON (2015), http://www.ecy.wa.gov/water/marine/oa/20150331MRACstatusOA.pdf.

341. *Id.* at 5.

342. *Id.*

343. *Id.* at 6–7.

Washington State Department of Ecology, which implements the Clean Water Act in Washington, is investigating the nutrient pollution problems in Washington to figure out whether additional controls on such pollution can help to minimize ocean acidification in certain localities.[344] Finally, ocean acidification efforts are increasing both locally and nationally; for example, both the University of Washington and the Suquamish Tribe have developed ocean acidification curricular materials for use in classrooms.[345]

However, as MRAC also noted, much remains to be done. It offered a long list of recommended actions to be undertaken between 2015 and 2017.[346] Most interesting for purposes of this Article is the ever-increasing list of adaptation strategies that Washington is proposing. Specifically, MRAC advocated both studies to assess how well various marine species can adapt to ocean acidification on their own and to assess the adaptation potential of a number of human interventions.[347] These interventions include restoring native oyster populations, which should increase those populations' resilience to both ocean acidification and other marine impacts, including climate change; developing a seaweed cultivation program, using the carbon dioxide needs of marine plants to reduce carbon dioxide concentrations in local waters; creating a shell recycling program, which would use the waste from human seafood consumption to increase calcium carbonate concentrations in Washington's coastal waters; and establishing refuges for species vulnerable to ocean acidification, presumably in the areas of Washington's coast that are less impacted by ocean acidification than the Puget Sound and the Columbia River estuary.[348]

All of Washington's adaptation suggestions and its proposals to work on locally important nutrient water pollution could both mitigate ocean acidification impacts in the state and help hatcheries and wild fisheries adapt to ongoing changes in marine pH. As MRAC acknowledges, however, the scientific evidence to show that these or other approaches can work is

344. *Id.* at 6.

345. *Id.*

346. *Id.* at 6–7.

347. *Id.*

348. *Id.* at 7.

generally lacking, and hence increased research remains for the moment the most important ocean acidification response. Of course, it also remains to be seen whether Washington can maintain the financial and political support necessary to fulfill MRAC's ambitious goals to address ocean acidification.

4. Washington Ocean Acidification Center

As another response to the Blue Ribbon Commission's 2012 report, in 2013 the Washington Legislature created the WOAC, housed in the University of Washington College of the Environment.[349] WOAC acts as Washington's ocean acidification science clearinghouse, pursuing five missions that the legislature articulated: (1) to establish an ocean acidification monitoring network in the state that can measure and assess local trends in ocean acidification (notably, a necessary prerequisite to implementing the Clean Water Act as well, as Part II discussed); (2) to monitor water quality at Washington's six hatcheries to support real-time ocean acidification management there; (3) to establish short-term forecasting capabilities; (4) to conduct laboratory experiments to assess the direct and synergistic impacts of ocean acidification on marine organisms; and (5) to develop commercial-scale water treatment systems for the hatcheries.[350] The Center also partners with a variety of institutions besides the University of Washington, including the Washington State Department of Natural Resources, the Washington State Department of Ecology, Western Washington University, NOAA, EPA, and Taylor Shellfish Farms.[351]

With regard to monitoring, WOAC has both leveraged existing coastal monitoring networks and deployed new sensors into Washington's coastal waters, creating a fairly geographically comprehensive monitoring system for

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349. *Washington Ocean Acidification Center*, U. WASH. C. ENV'T, http://environment.uw.edu/research/major-initiatives/ocean-acidification/washington-ocean-acidification-center/ (last visited Oct. 18, 2015).

350. *Id.*

351. Terrie Klinger & Jan Newton, Wash. Ocean Acidification Ctr., Presentation Before the Wash. Marine Res. Advisory Council: Science Update 3 (Mar. 31, 2015), http://www.ecy.wa.gov/water/marine/oa/20150331MRACnewton.pdf.

Washington's coast.[352] In addition, it has integrated water quality and biological monitoring,[353] allowing it to measure carbon variables, standard water quality parameters, and plankton concentrations simultaneously at the same locations.[354] This integrated monitoring reveals that pteropod shells in Puget Sound show signs of dissolution.[355]

In addition, WOAC has been able to map aragonite saturation variation (based on 2008 data)[356] and dissolved oxygen patterns (2014 data)[357] throughout Puget Sound. By tying these and other parameters to pteropod conditions, WOAC hopes to be able to use pteropods as a bio-indicator for assessing changing ocean conditions and species' responses to those changing conditions, generating results that are comparable across different regions of the ocean and across time.[358]

With regard to shellfish hatcheries, scientific research shows that there is a "great deal" of local variability in pH at the hatcheries but that pH changes in the summer already fall below what is best for shellfish.[359] WOAC provides real-time monitoring data to hatcheries and is working with shellfish facilities to install water treatment systems to improve shellfish growing conditions.[360] Smaller scale water treatment systems used at the Whiskey Creek hatchery have effectively kept pH at the levels that healthy growing shellfish need, and a pilot system at Taylor Shellfish has increased shellfish survival and growth.[361] While challenges remain in scaling up these technologies,[362] water treatment may prove to be a

352. *Id.* at 4.

353. *Id.* at 4, 6.

354. *Id.* at 6–9.

355. *Id.* at 7.

356. *Id.* at 5.

357. *Id.* at 8.

358. *Id.* at 9.

359. WASH. OCEAN ACIDIFICATION CTR. & WASH. MARINE RES. ADVISORY COUNCIL, MONITORING AND ADAPTATION TO OCEAN ACIDIFICATION IN THE SHELLFISH INDUSTRY: SCIENCE INFORMATION SHEET 1 (2015), http://www.ecy.wa.gov/water/marine/oa/20150331MRACsciencesheets.pdf.

360. *Id.* at 1–2.

361. *Id.* at 2.

362. *Id.*

significant and effective adaptation strategy for Washington's shellfish aquaculture industry.

5. Conclusion

Washington has invested considerable time—in terms both of scientific research and of policy development—and money into learning to monitor and cope with ocean acidification. Those efforts are beginning to bear fruit. While increased new scientific research remains an important cornerstone of Washington's response to ocean acidification in order to fill critical gaps in knowledge, Washington is beginning to build the monitoring and knowledge base that will allow it to meaningfully assess both the progress and impacts of ocean acidification in its waters and the effectiveness of various adaptation strategies. Specifically, Washington has installed a fairly comprehensive coastal monitoring system (especially in Puget Sound), achieved a greater understanding of how ocean acidification works in its state coastal waters, and developed the beginnings of bio-indicators and predictive models. Indeed, harking back to the Clean Water Act litigation, Washington appears to have improved its scientific understanding of ocean acidification enough that it is coming very close to triggering the Section 303(d) impaired water process, especially in coastal waters where pteropod shell dissolution has already been documented.

Washington is also making progress regarding ocean acidification adaptation measures. While the focus on shellfish hatcheries could be viewed as sacrificing public improvements to commercial interests, hatcheries have the longest and most complete records of local ocean chemistry, and some of the adaption techniques developed for hatcheries may prove useful in other contexts. For example, if researchers and hatcheries develop viable commercial-scale water treatment technology to increase seawater pH, that technology may prove beneficial to other coastal industries.

Nevertheless, progress in other areas seems slow or non-existent. For example, Washington has done little thus far to implement new water quality regulatory requirements for nutrient and organic carbon pollution. In addition, implementation of adaptation measures for natural stocks of marine species seems to be lagging far behind improvements at shellfish hatcheries. These ocean acidification measures are, to be sure, more scientifically challenging. Nevertheless, there

are also multiple reasons beyond ocean acidification for Washington to pursue them, including the reduction of algal blooms and hypoxic zones and the improvement of coastal ecosystems' general resilience to both ocean acidification *and* climate change. It is, of course, unfair to expect the state to have been able to address everything related to ocean acidification all at once, but it remains an open question whether Washington will continue the necessarily long term political, financial, and scientific support needed to fully mitigate and adapt to ocean acidification.

B. Maine's Efforts to Address Ocean Acidification

While impacts of ocean acidification in the United States have been most widely documented, and of most concern, along the West Coast and in Alaska, the nation's eastern seacoast has not been immune. Concern about ocean acidification is starting to emerge throughout the New England states, but particularly in Maine. As in Washington, Maine's economy depends significantly on healthy shellfish, from lobsters to clams. Moreover, as in Washington, impacts on these commercially important shelled species have driven legislative attention to ocean acidification. Nevertheless, Maine's ocean acidification problems do differ somewhat from Washington's, and the state response to ocean acidification is several years behind Washington's, with a much less certain future.

1. Ocean Acidification Issues in Maine

Ocean acidification problems in Maine initially and most visibly manifested as acidic muds. For example, in the clam-bearing mud flats of Casco Bay, clams began to disappear.[363] Research by the Friends of Casco Bay revealed that the clams at about 30 mud flats around Casco Bay dissolved entirely, or, if they managed to survive, grew up stunted and with pitted shells.[364] As this "dead mud" spread among Maine's shellfish flats, the *Bangor Daily News* reported in January 2014 that ocean acidification threatens many of Maine's fishermen.[365]

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363. *The Mystery of the Disappearing Clams*, FRIENDS CASCO BAY (Apr. 2, 2013), http://www.cascobay.org/the-mystery-of-the-disappearing-clams/.

364. *Id.*

365. Christopher Cousins, *As Ocean Becomes More Acidic, Will 'Dead Mud' Consume*

Indeed, the growing problem has caused increasing concern among wild clam harvesters, oyster aquaculturists, and lobster fishermen.[366]

As in Washington, increasing anthropogenic emission of carbon dioxide is the primary cause of ocean acidification in Maine,[367] but the process is also exacerbated by local factors. Specifically, two other sources increase ocean acidification of Maine's inshore waters: freshwater runoff and nutrient pollution from land-based sources.[368] As is true for rivers in Washington, freshwater runoff is typically more acidic than ocean water, and climate change models predict increasingly frequent and increasingly severe storms in Maine, leading to more such runoff.[369] In addition, the Gulf of Maine receives considerable freshwater input from watersheds and melting ice to the north, which enters the Gulf through the Scotian shelf.[370] Thus, Maine has a much greater freshwater exacerbation problem than Washington—a problem that is likely to increase into the future. In contrast, the effects of nutrient pollution in Maine are much the same as in other places, like the Chesapeake Bay and Puget Sound in Washington: "large phytoplankton blooms resulting from the addition of excess nutrients eventually decompose and release CO_2," exacerbating ocean acidification.[371]

2. The Maine Ocean Acidification Commission

On April 30, 2014, the Maine legislature used its emergency authority to establish the Commission to Study the Effects of Coastal and Ocean Acidification and Its Existing and Potential Effects on Species That Are Commercially Harvested and

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Maine's Bountiful Shellfish Flats?, BANGOR DAILY NEWS (Jan. 13, 2014), http://bangordailynews.com/2014/01/13/news/state/as-ocean-becomes-more-acidic-will-dead-mud-consume-maines-bountiful-shellfish-flats/.

366. *Id.*

367. COMM'N TO STUDY THE EFFECTS OF COASTAL & OCEAN ACIDIFICATION & ITS EXISTING & POTENTIAL EFFECTS ON SPECIES THAT ARE COMMERCIALLY HARVESTED & GROWN ALONG THE MAINE COAST, FINAL REPORT ii (2015) [hereinafter 2015 MAINE OCEAN ACIDIFICATION REPORT], http://www.maine.gov/legis/opla/Oceanacidificationreport.pdf.

368. *Id.*

369. *Id.*

370. *Id.*

371. *Id.*

Grown along the Maine Coast.[372] The Commission had several purposes, including identifying the actual and potential effects of ocean acidification on commercial fishing in Maine, figuring out basic gaps in ocean science regarding the progress and impacts of ocean acidification in Maine, prioritizing research needs, and identifying tools and policies to respond to ocean acidification's impacts on commercial fishing and aquaculture.[373] In addition, the Commission was directed to produce a report on these subjects by the end of the year.[374]

The Commission released its report on February 5, 2015.[375] It first acknowledged that both global and local factors influence ocean acidification in Maine waters.[376] Despite the complexities and knowledge gaps surrounding these interactions, moreover, the Commission was convinced that "[a]pplicable scientific research suggests that in the Gulf of Maine, such changes are likely having an impact on commercially important species."[377] The Commission also concluded that the basic chemistry of ocean acidification made the Gulf of Maine more susceptible to ocean acidification than other coastal waters, underscoring the additional impacts of freshwater inputs and the fact that the Gulf's cold waters can absorb more carbon dioxide.[378] As in Washington, the impact of ocean acidification on shell-forming organisms was particularly troubling: In Maine's critically important fishing industry, 87% of the value of both wild fisheries and aquaculture comes from species with shells, like lobsters, clams, and oysters.[379]

The Maine Commission concluded that ocean acidification in Maine is an urgent political and economic problem, requiring considerable public education and difficult statewide decisions.[380] It unanimously adopted six goals and 25

372. H.R. 1174, 126th Leg., 2d Reg. Sess. (Me. 2014), http://www.mainelegislature.org/legis/bills/getPDF.asp?paper=HP1174&item=6&snum=126.

373. *Id.*

374. *Id.* § 8.

375. Katie Valentine, *Maine Report Warns of 'Urgent' Need to Address Ocean Acidification*, CLIMATEPROGRESS (Feb. 6, 2015), http://thinkprogress.org/climate/2015/02/06/3619987/maine-ocean-acidification-report/.

376. 2015 MAINE OCEAN ACIDIFICATION REPORT, *supra* note 367, at ii.

377. *Id.* at 3.

378. *Id.* at 4.

379. *Id.*

380. *Id.* at 6.

recommendations to achieve those goals.[381] The six goals are to:

1. Invest in Maine's capacity to monitor and investigate the effects of ocean acidification and determine impacts of ocean acidification on commercially important species and the mechanisms behind the impacts;
2. Reduce emissions of carbon dioxide;
3. Identify and reduce local land-based nutrients and organic carbon that contribute to ocean acidification by strengthening and augmenting existing pollution reduction efforts;
4. Increase Maine's capacity to mitigate, remediate and adapt to the impacts of ocean acidification;
5. Inform stakeholders, the public and decision-makers about ocean acidification in Maine and empower them to take action; and
6. Maintain a sustained and coordinated focus on ocean acidification.[382]

Water quality improvements were an important component of the Commission's 25 recommendations. Specifically, the Commission recommended extensive water quality and marine life monitoring,[383] improved water assessment tools to identify ocean acidification,[384] identification of the specific causes of ocean acidification in different Maine coastal waters,[385] and identification of the effects of ocean acidification on marine organisms.[386] The Commission also advised Maine officials to pay considerably more attention to nutrient loading in coastal waters, including identifying the relevant point and nonpoint sources and considering the need for amended or new water quality criteria.[387]

However, as in Washington, the Maine Commission recognized that water quality measures were insufficient to neutralize ocean acidification. As a result, it also recommended that Maine employ a series of ocean acidification adaptation

381. *Id.* at iii.
382. *Id.*
383. *Id.* at 7–9.
384. *Id.* at 9.
385. *Id.* at 10.
386. *Id.* at 10–11.
387. *Id.* at 14–18.

measures. Some of these recommendations were fairly specific and mirror parallel strategies in Washington—"[s]pread shells or other forms of calcium carbonate ($CaCO_3$) in bivalve areas to remediate impacts of local acidification"[388] and "[i]dentify refuges and acidification hotspots to prioritize protection and remediation efforts,"[389] for example. Other recommended adaptation measures were more general and aspirational, such as increasing the adaptive capacity of the fishing and aquaculture industries[390] and encouraging the creation of new research hatcheries.[391] Like Washington, therefore, Maine concentrated first on its commercial marine aquaculture and fishing industries.

The Commission also proposed legislation to create a permanent Ocean Acidification Council.[392] The Council would both facilitate implementation of the Commission's recommendations and pursue seven goals, all concentrated around building research partnerships, improving scientific knowledge regarding ocean acidification, and using that improved science to adopt better policies, implement the Commission's recommendations, identify new economic opportunities, and better educate the public.[393]

3. The Aftermath of the Report and Regional Prospects for the Future

A bill was introduced into the Maine legislature in 2015 to implement the Commission's recommendations.[394] However, in June 2015, this legislation was held over until the next legislative session.[395]

Nevertheless, efforts to address ocean acidification appear to be spreading throughout the northeast states. In particular,

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388. *Id.* at 19.

389. *Id.* at 20.

390. *Id.* at 19.

391. *Id.* at 20.

392. *Id.* at iii app. D.

393. *Id.* at 22–23.

394. H.R. 332, 127th Leg., 1st Reg. Sess. (Me. 2015), http://www.maine legislature.org/legis/bills/getPDF.asp?paper=HP0332&item=1&snum=127&PID.

395. *See Chamber Status, HP 332*, ME. LEGISLATURE, http://www.mainelegislature. org/legis/bills/display_ps.asp?snum=127&paper=HP0332&PID=0 (last visited Oct. 21, 2015).

Massachusetts, Rhode Island, and New Hampshire have, to varying extents, begun to follow Maine's lead, potentially spurring a regional effort to address ocean acidification in northeast coastal waters in the future.[396]

4. Conclusion

Whereas Washington has seriously begun to invest money and other resources into ocean acidification research, monitoring, and adaptation, Maine's response remains largely nascent, not yet supported by state legislation or regional partnerships. Nevertheless, the Commission's report reveals considerable similarities to Washington's approach, suggesting that, if Maine moves forward, its initial responses to ocean acidification will look very similar to Washington's. For example, Washington and Maine are in agreement that scientific research into and public education about ocean acidification are key first steps, and both propose similar initial steps to adaptation that concentrate on improving the fate of key shellfish-related industries. One possible distinction between the two states—although it is far too early to discern whether it will make any practical difference—is that the Maine Commission more optimistically appears to see economic opportunity as well as ecological and economic threats in its responses to ocean acidification.

In addition, Maine and Washington agree that local water quality issues are exacerbating ocean acidification, and both states' commissions recommended improvements in state water quality laws—essentially, in the ways the two states implement the Clean Water Act. Nutrient pollution and freshwater inputs are problems in both states—although in Maine, as in Washington, some of the freshwater comes from stormwater that can be regulated, but some comes from natural processes that will simply have to be accepted as a background condition.

In the future, as a result of climate change, freshwater runoff is likely to increase along the East Coast. For example, according to the United States Global Research Program in

396. Patrick Whittle, *New England States Following a Model Set by Maine to Reduce Ocean Acidity*, PORTLAND PRESS HERALD (Mar. 29, 2015), http://www.pressherald.com/2015/03/29/new-england-states-following-a-model-set-by-maine-to-reduce-ocean-acidity.

2014, the Northeast Region is expected to experience increased winter and spring precipitation and increasing numbers of heavy rainfall events.[397] Because stormwater is already known to exacerbate ocean acidification, these climate change forecasts strongly suggest that eastern coastal states should think seriously about improving their stormwater water quality programs to more effectively address future ocean acidification.

Similarly, nutrient pollution is a recognized water quality problem throughout the Northeast.[398] As the Maine Commission's report suggested, therefore, New England coastal states' developing regional efforts to address ocean acidification should consider strengthening controls on nutrient pollution, as well. However, as the Maine Commission also acknowledged, these water quality controls are not enough, and these states must also pursue other efforts to adapt to ocean acidification.

C. West Coast Collaboration on Ocean Acidification

1. Ocean Acidification and the West Coast

While the State of Washington took the lead on ocean acidification responses, ocean acidification problems are common to the entire West Coast of the United States and Canada,[399] particularly in the Pacific Northwest region extending from Alaska and British Columbia to northern California. For example, shellfish hatcheries in Oregon began experiencing die-offs at the same time that Washington hatcheries did, from 2005 to 2009,[400] and, as already noted,

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397. John Walsh & Donald Wuebbles et al., U.S. Global Change Res. Program, *Chapter 2: Our Changing Climate*, *in* CLIMATE CHANGE IMPACTS IN THE UNITED STATES: THE THIRD NATIONAL CLIMATE ASSESSMENT 19, 20 (2014), http://s3.amazonaws.com/nca2014/low/NCA3_Full_Report_02_Our_Changing_Climate_LowRes.pdf?download=1.

398. *E.g.*, Letter from Ronald Poltak, Exec. Dir., New England Interstate Water Pollution Control Comm'n, to Lisa Jackson, Adm'r, U.S. EPA (Jan. 3, 2011), https://www.neiwpcc.org/neiwpcc_docs/NEIWPCCCommentLetteronNutrientCriteria1-3-11.pdf.

399. 2012 WASH. PANEL REPORT, *supra* note 273, at 3.

400. *Id.*

ocean acidification is already affecting multiple fisheries in Alaska.[401]

Moreover, the entire Pacific Coast suffers from the same upwelling that exacerbates ocean acidification in Washington. This coast is dominated by the California Current and its associated ecosystem.[402] Upwelling of nutrients along this coast is a well-known and normal phenomenon,[403] especially during the summer, when northerly winds and the earth's rotation bring nutrient-rich waters to the surface and cause blooms of phytoplankton.[404] This upwelling pattern "makes the west coast of North America one of the most productive marine ecosystems on earth."[405]

At the beginning of the 21st century, however, these currents began to change. As the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) reports, "the occurrence of low-oxygen water close to shore. . .is highly unusual and had not been reported prior to 2002 despite over 50 years of scientific observations along the Oregon coast."[406] In 2006, these changing ocean currents created an unprecedented anoxic (oxygen-lacking) "dead zone" off the coast of Oregon, "result[ing] in mass die-offs of long-lived marine animals such as seastars and sea cucumbers."[407]

Hypoxia is thus a climate change-related concern for the Pacific Coast states and British Columbia. However, as noted for Washington, the same changing patterns of upwelling bring low pH waters to the surface, while the plankton and algal

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401. Rojas-Rocha, *supra* note 106.

402. LINDSAY YOUNG ET AL., CLIMATE CHANGE AND SEABIRDS OF THE CALIFORNIA CURRENT AND PACIFIC ISLAND ECOSYSTEMS: OBSERVED AND POTENTIAL IMPACTS AND MANAGEMENT IMPLICATIONS: FINAL REPORT TO THE U.S. FISH AND WILDLIFE SERVICE, REGION 1, at 3 (2012), http://www.faralloninstitute.org/Publications/YoungEtal2012 USFWSRep.pdf. "The California Current ecosystem covers approximately 32,000 km of ocean habitat from British Columbia, Canada to Baja California, Mexico." *Id*. (citations omitted).

403. *Id*. (noting that "the California Current is a highly productive system where upwelling and advection transport nutrients and drive primary productivity in the system").

404. *Hypoxia in the Pacific Northwest*, PARTNERSHIP FOR INTERDISC. STUD. COASTAL OCEANS (Feb. 11, 2011), http://www.piscoweb.org/research/science-by-discipline/coastal-oceanography/hypoxia-new/hypoxia-in-pacific-northwest.

405. *Id*.

406. *Id*.

407. *Id*.

blooms resulting from the increased nutrients lead to increased carbon dioxide in the water; both effects exacerbate ocean acidification. As a result, exacerbated acidification and increased hypoxia are linked phenomena along the West Coast, leading to efforts to study them in tandem. Moreover, despite the fact that the California Current is in general very well studied because of its importance to fisheries,[408] "long-term records of pH in the [California Current] are very rare."[409] Thus, as with most places in the United States, basic scientific data regarding ocean acidification along the Pacific Coast were just missing. To deal with this region-wide problem, the states of California, Oregon, Washington, and Alaska, and the Canadian province of British Columbia have increasingly pooled their efforts to develop the necessary scientific information, ocean acidification adaptation tools and strategies, and policy recommendations.

2. West Coast Governors Alliance on Ocean Health

In 2006, the states of Washington, Oregon, and California formed a partnership—the West Coast Governors Alliance on Ocean Health—"to protect and manage ocean and coastal resources along the West Coast."[410] The Alliance, which includes tribal governments, reformulated its goals in 2012 to address ocean acidification.[411] In general, the Alliance develops "shared priorities and action plans across the region for marine debris, climate change, and ocean acidification."[412]

Building on the 2012 Washington Blue Ribbon Panel on Ocean Acidification, the Alliance supports and works with the West Coast Ocean Acidification and Hypoxia Science Panel,[413] which formed in November 2013.[414] The Alliance also works

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408. YOUNG ET AL., *supra* note 402, at 10.

409. *Id.* at 11.

410. W. COAST OCEAN SUMMIT, FINAL REPORT 5 (2015), http://www.westcoastoceansummit.org/media/wcos-final-report—-january-2015—-final.pdf.

411. *Id.*

412. WASH. MARINE RES. ADVISORY COUNCIL, OCEAN ACIDIFICATION SCIENCE AND POLICY LANDSCAPE 1 (2014) [hereinafter OCEAN ACIDIFICATION SCIENCE AND POLICY LANDSCAPE], http://www.ecy.wa.gov/water/marine/oa/20141118MRAChandoutLandscape.pdf.

413. *See infra* Part III.C.5.

414. *Ocean Acidification*, W. COAST GOVERNORS ALLIANCE ON OCEAN HEALTH, http://www.westcoastoceans.org/index.cfm?content.display&pageID=182 (last visited Oct. 19,

with shellfish farmers and hatcheries to provide access to monitoring data, and it partners with the California Current Acidification Network (C-CAN) to improve scientific understanding of ocean acidification in this region.[415] Finally, the Alliance is helping to create real-time and time-averaged oceanographic data reporting specific to West Coast ocean acidification, especially in connection with the Integrated Ocean Observing Systems (IOOS) and its West Coast regional partner systems.[416]

3. Pacific Coast Collaborative and Its Action Plan on Climate and Energy

On June 30, 2008, the leaders of Alaska, British Columbia, California, Oregon, and Washington signed the Pacific Coast Collaborative Agreement to promote cooperation on Pacific Coast issues through the next century.[417] The agreement led to the creation of the Pacific Coast Collaborative, through which the West Coast states and British Columbia provide a unified voice in politics and law about contemporary Pacific Coast issues.[418] Specifically, through this umbrella forum, the governors of the four West Coast states and the premier of British Columbia collaborate to advocate consistent regional policies for climate change, clean energy, and ocean conservation.[419]

As part of these collaborative efforts, in October 2013, the leaders of British Columbia, Washington, Oregon, and California signed the Pacific Coast Action Plan on Climate and Energy.[420] That plan covered 14 action items, one of which was to "[e]nlist support for research on ocean acidification and take action to combat it."[421] Specifically, this action item noted that

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415. *Id.*; *see infra* Part III.C.4.

416. *Ocean Acidification*, *supra* note 414.

417. PACIFIC COAST COLLABORATIVE, http://www.pacificcoastcollaborative.org/Pages/Welcome.aspx (last visited Oct. 19, 2015).

418. *Id.*

419. OCEAN ACIDIFICATION SCIENCE AND POLICY LANDSCAPE, *supra* note 412.

420. PACIFIC COAST COLLABORATIVE, PACIFIC COAST ACTION PLAN ON CLIMATE AND ENERGY (2013), http://www.pacificcoastcollaborative.org/Documents/Pacific%20Coast%20Climate%20Action%20Plan.pdf.

421. *Id.* at 1.

"[o]cean health underpins our coastal shellfish and fisheries economies" and promised that the Collaborative's members would urge both the United States and Canadian governments to take action on ocean acidification.[422]

As part of this Action Plan, in December 2013 the governors of California, Oregon, and Washington and the premier of British Columbia wrote to U.S. President Barack Obama and Canadian Prime Minister Stephen Harper, urging increased national attention in both countries to ocean acidification.[423] Specifically, the Collaborative declared that "[t]here is an urgent need for the U.S. and Canadian federal governments to bolster our ongoing regional and cross-border efforts to address this critical issue with enhanced federal coordination, monitoring, and research support."[424] The gist of the letter was that the ocean acidification problem was too big even for these regional efforts.[425]

4. California Current Acidification Network

Both the West Coast Governors Alliance and the Pacific Coast Collaborative help to improve ocean acidification science by supporting C-CAN. C-CAN emerged in 2010 as a result of a scientific workshop.[426] Its missions are to coordinate the development of an ocean acidification monitoring network for the Pacific Coast, to improve the science regarding how marine organisms respond to changing ocean conditions, to develop predictive models of ocean acidification, and to facilitate communication and sharing among C-CAN's many scientists, groups, and organizations. [427]

Thus, C-CAN serves primarily to fill gaps in scientific knowledge about ocean acidification. However, it has also developed guidelines and best practices for monitoring ocean

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422. *Id.*

423. Letter from Edmund G. Brown, Gov. of Calif., Christy Clark, Premier of British Columbia, John Kitzhaber, Gov. of Or., & Jay Inslee, Gov. of Wash., to U.S. President Barack Obama and Canadian Prime Minister Stephen Harper (Dec. 12, 2013), http://www.ecy.wa.gov/water/marine/oa/20131212_PacificCoastCollaborative_letter.pdf.

424. *Id.*

425. *Id.*

426. CAL. CURRENT ACIDIFICATION NETWORK, http://c-can.msi.ucsb.edu (last visited Oct. 19, 2015).

427. *Id.*

acidification—including monitoring relevant parameters (e.g., nutrients) in land-based pollution[428]—and it provides a clearinghouse of national and international publications related to ocean acidification, including the 2010 National Academy of Sciences study and the 2011 report from the IPCC on ocean acidification.[429]

5. The West Coast Ocean Acidification and Hypoxia Science Panel

As noted, changing upwelling patterns along the Pacific Coast simultaneously cause new hypoxia problems in coastal waters and exacerbate ocean acidification. California and Oregon initially teamed up to create the West Coast Ocean Acidification and Hypoxia Science Panel (WCOAHSP), but the collaboration now also includes scientists from Washington and British Columbia.[430] Unlike C-CAN, which focuses almost exclusively on scientific improvements, WCOAHSP actively seeks to advise and engage policymakers to change ocean law and policy along the Pacific Coast.[431] Specifically, WCOAHSP pursues a four-step iterative process to help policymakers effectively integrate ocean acidification science into law and policy: (1) develop a scientific research foundation based on decision makers' needs; (2) tailor the resulting scientific information to specific agency needs; (3) put together the scientific building blocks to consider effects on entire ocean ecosystems; and (4) inform policy and management at multiple levels of government.[432]

The Panel established a series of working groups to summarize relevant scientific knowledge to facilitate action on key themes identified by decision makers.[433] It emphasizes that

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428. *C-CAN Documents*, CAL. CURRENT ACIDIFICATION NETWORK, http://c-can.msi.ucsb.edu/c-can-documents (last visited Oct. 19, 2015).

429. *National/International OA Reference Materials*, CAL. CURRENT ACIDIFICATION NETWORK, http://c-can.msi.ucsb.edu/materials/oa-reference-materials (last visited Oct. 19, 2015).

430. *Overview*, W. COAST OCEAN ACIDIFICATION & HYPOXIA PANEL, http://westcoastoah.org/overview/ (last visited Oct. 19, 2015).

431. *Id.*

432. Skyli McAfee, Presentation Before the Wash. Marine Res. Advisory Council: The West Coast Ocean Acidification and Hypoxia Panel 4 (Mar. 31, 2015), http://www.ecy.wa.gov/water/marine/oa/20150331MRACmcafee.pdf.

433. *Id.*

ocean acidification cannot be studied or addressed in isolation, because it is "part of a shifting environment in which carbonate chemistry and dissolved oxygen are changing alongside nutrients and temperature."[434] Ocean acidification and climate change impacts thus synergistically create new stresses on Pacific coastal waters, rendering the science that underlies effective legal and policy responses complex and difficult for non-scientific policymakers to comprehend. To address this gap, the Panel actively seeks to combine the new insights from improving scientific research in a variety of disciplines regarding a wide range of ocean phenomena in order to distill for policymakers a much more comprehensive yet still comprehensible understanding of the coastal waters and resources that they regulate, including how those waters and resources are changing and what responses could be both appropriate and helpful.[435]

In pursuit of this "comprehensive picture" goal, in May 2014, the WCOAHSP, in collaboration with a host of other scientific bodies, including the University of Washington's Ocean Acidification Center and NOAA's Ocean Acidification Program, published a two-page fact sheet on Pacific Coast ocean acidification that summarized and explained the current state of scientific understanding in a readily digestible format.[436] This public education brochure announces that "[t]he evidence for ocean acidification in the Pacific Northwest is compelling."[437] Emphasizing the role of carbon dioxide emissions, the fact sheet also notes, however, that "[a]cidification can be more severe in areas where human activities further increase acidity, such as through nutrient inputs that fuel biological production and respiration processes."[438] Indeed, "[n]atural and anthropogenic factors combine to intensify ocean acidification in Pacific Northwest waters."[439] Perhaps most importantly, the fact sheet concludes

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434. *West Coast Ocean Acidification and Hypoxia Science Panel*, CAL. OCEAN SCI. TRUST, http://www.oceansciencetrust.org/project/west-coast-ocean-acidification-and-hypoxia-science-panel/ (last visited Oct. 19, 2015).

435. *Id.*

436. NANOOS ET AL., OCEAN ACIDIFICATION IN THE PACIFIC NORTHWEST (2014), http://www.ecy.wa.gov/water/marine/oa/201405-OAfactsheet.pdf.

437. *Id.* at 1.

438. *Id.*

439. *Id.* at 2.

that "[t]he human contribution to acidification in the Pacific Northwest is quantifiable and has increased the frequency, intensity, and duration of harmful conditions."[440]

The WCOAHSP also predicts increasingly worse ocean acidification for the Pacific Coast, especially the Pacific Northwest, where it anticipates that ocean pH will drop to 7.8 or 7.9 by 2100, doubling these regions' normal acidity.[441] Several types of coastal waters are particularly vulnerable, including those that receive a lot of freshwater, those that have or receive nutrient or organic pollution, and regions subject to coastal upwelling.[442] Juvenile shellfish—again, especially in the Pacific Northwest—are also particularly vulnerable,[443] and "[s]mall changes in the environment can cause large responses among living organisms."[444] The WCOAHSP ominously concludes that "[c]ontemporary ocean acidification could threaten the flow of goods and services to marine-dependent communities."[445]

On the policy side, the WCOAHSP has advocated a broad range of legal approaches to ocean acidification, emphasizing that "[t]here is a cost to inaction."[446] It advocates a coast-wide approach[447] that incorporates emission control goals and cap-and-trade programs for carbon dioxide emissions; incorporates "ocean health" as a priority mission across regulatory agencies; refines the Clean Water Act's role, focusing on new permit programs for nonpoint source pollution as well as greater ocean-related attention to NPDES permits; increases use of marine protected areas and ecosystem-based fisheries management; and increases the use of "smart monitoring" for adaptive learning.[448] Thus, as in Washington and Maine, the Panel recognizes that the Clean Water Act and improved water quality regulation can play an important role in addressing

440. *Id.*
441. *Id.* at 1.
442. *Id.*
443. *Id.*
444. *Id.*
445. *Id.*
446. McAfee, *supra* note 432, at 8.
447. *Id.* at 9.
448. *Id.* at 11.

ocean acidification but also that these efforts will not be sufficient on their own.

In addition, the WCOAHSP has produced or is producing a wide range of publications for both scientists and policymakers.[449] On the policy side, a recent report explains *Ocean Acidification and Hypoxia: Today's Need for a Coast-Wide Approach*, while forthcoming reports will discuss *Scientific Approaches to Making a 303(d) Assessment for Near Coastal Acidification* and *Rethinking the Federal Clean Water Act*.[450] Thus, in the near future, the WCOAHSP may provide coastal states with practical instructions for applying the Clean Water Act and state water quality standards to ocean acidification, among other advice.

6. West Coast State Laws on Ocean Acidification

Despite all of these regional efforts to analyze, understand, and respond to ocean acidification, legal responses to ocean acidification remain minimal. Neither Alaska's statutes nor its administrative code mention "ocean acidification." The long and complex California Code contains a single mention of ocean acidification, authorizing ocean acidification research to be funded by the California Ocean Protection Trust Fund;[451] California has no ocean acidification regulations. Oregon also has one statute that mentions ocean acidification, authorizing ocean acidification research as part of Oregon State University's Oceangoing Research Vessel Program.[452] The Washington statutes mention ocean acidification three times—once in connection with the duties of the Washington Marine Resources Advisory Council[453] and twice in relation to funding ocean acidification research.[454]

Moreover, cycling back to the Clean Water Act, none of the Pacific Coast states have tailored their marine water quality standards to acknowledge ocean acidification. Alaska, for

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449. *Products*, W. COAST OCEAN ACIDIFICATION & HYPOXIA SCI. PANEL, http://westcoastoah.org/panelproducts/ (last visited Oct. 19, 2015).

450. *Id.*

451. CAL. PUB. RES. CODE § 35650 (West, Westlaw through ch. 1 of 2015–2016 2d Ex. Sess.).

452. OR. REV. STAT. ANN. § 352.252 (West, Westlaw through 2015 Reg. Sess.).

453. WASH. REV. CODE § 43.06.338 (2014).

454. *Id.* §§ 70.105D.070(3)(v), 79.105.150(1).

example, classifies its marine waters according to four designated uses: (1) water supply (for aquaculture, seafood processing, or industrial uses); (2) water recreation, either contact recreation or secondary recreation; (3) growth and propagation of fish, shellfish, other aquatic life, and wildlife; and (4) harvesting for consumption of raw mollusks or other raw aquatic life.[455] For aquaculture water supply and growth and propagation of fish, shellfish, and other aquatic life and wildlife, marine pH "[m]ay not be less than 6.5 or greater than 8.5, and may not vary more than 0.2 pH unit outside of the naturally occurring range"[456]—the EPA's 1976 reference criterion. California's water quality standards for ocean waters specify that "[t]he pH shall not be changed at any time more than 0.2 units from that which occurs naturally" and that "[m]arine communities, including vertebrate, invertebrate, and plant species, shall not be degraded."[457] Oregon's water quality standards state that, in general, the pH for marine waters may not fall outside the range of 7.0 to 8.5.[458] While Oregon does set basin-specific water quality standards,[459] not one of the marine pH standards in these basins varies from Oregon's general marine pH requirement.[460] Washington establishes four categories of marine waters for aquatic life uses—extraordinary, excellent, good, and fair quality[461]—and establishes pH water quality criteria for each. In extraordinary marine waters, "pH must be within the range of 7.0 to 8.5 with a human-caused variation within the above range of less than 0.2 units;" in excellent and good marine waters, "pH must be within the range of 7.0 to 8.5 with a human-caused variation within the above range of less than 0.5 units;" and in fair

455. ALASKA ADMIN. CODE tit. 18, § 70.020(a)(2) (LexisNexis, current through Oct. 2015).

456. ALASKA DEP'T OF ENVTL. CONSERVATION, WATER QUALITY STANDARDS 19 (2012) (codified at ALASKA ADMIN. CODE. tit. 18, §§ 70.005–.990), http://dec.alaska.gov/commish/regulations/pdfs/18%20AAC%2070.pdf.

457. STATE WATER RES. CONTROL BD. & CAL. ENVTL. PROT. AGENCY, WATER QUALITY CONTROL PLAN: OCEAN WATERS OF CALIFORNIA 6, 10 (2012), http://www.waterboards.ca.gov/water_issues/programs/ocean/docs/cop2012.pdf.

458. OR. ADMIN. R. 340-041-0021(1)(a) (2014).

459. *See id*. 340-041-0101 to 340-041-0350.

460. *Id*. 340-041-0225 (Mid-Coast Basin); *id*. 340-041-0235 (North Coast Basin); *id*. 340-041-0275 (Rogue River Basin); *id*. 340-041-0305 (South Coast Basin); *id*. 340-041-0326 (Umpqua River Basin).

461. WASH. ADMIN. CODE § 173-201A-210(1)(a) (2014).

quality marine waters, "pH must be within the range of 6.5 to 9.0 with a human-caused variation within the above range of less than 0.5 units."[462]

Thus, while the Pacific Coast states and British Columbia have pursued several regional partnerships, these partnerships have so far been much more effective in generating the *science* needed to address ocean acidification than in changing ocean or water quality law and policy. Of course, efforts to address ocean acidification at all are still fairly new—we are only three years out from the Washington Blue Ribbon Panel's report, after all. The next five to ten years will likely be critical in determining whether state and regional efforts will mature into actual legal programs to address ocean acidification—or whether, instead, the dance of litigation using old tools like the Clean Water Act will continue.

V. CONCLUSION

Emerging ocean acidification science suggests that changing pH along the United States' coasts is already affecting marine species, ecology, and industries like shellfish aquaculture. Eventually (and maybe sooner rather than later for Oregon and Washington), states will compile enough scientific data and ocean pH will change enough to establish violations of marine pH water quality standards, setting the Clean Water Act's Section 303(d) processes in motion.

When that event occurs, however, a significant question will remain regarding what exactly the Clean Water Act can do. A carbon-based TMDL for the oceans would do little, legally, to reach the primary cause of ocean acidification—emissions of carbon dioxide. Similarly, no Clean Water Act legal requirement could do much to reach the major ocean acidification exacerbating factor along the West Coast—more destructive upwelling currents. These problems can ultimately be resolved, if at all, only by fixing the underlying problem of global greenhouse gas emissions. In the meantime, coastal states must begin to pursue ocean acidification adaptation strategies with the same urgency that they should be pursuing climate change adaptation strategies. In this sense,

462. *Id.* § 173-201A-210(1)(f).

Washington's and Maine's nascent efforts to buffer their wild shellfish populations with additional calcium carbonate by spreading shells and Washington's efforts to help its shellfish aquaculture industry to cope with low-pH seawater are steps in the right (and necessary) direction.

Nevertheless, emerging ocean acidification science also suggests that the CBD, the states, and the EPA should be thinking a bit more creatively about the role of the Clean Water Act in addressing ocean acidification. Washington, Maine, and Pacific Coast regional alliances have all identified nutrient and organic pollution and freshwater inputs as local factors that exacerbate ocean acidification. These types of pollution and freshwater inputs from stormwater runoff are all established subjects of Clean Water Act regulation. For example, municipal and industrial stormwater contributions to water pollution became such a widely-recognized water pollution problem that Congress added stormwater permitting requirements to the Clean Water Act's NPDES permit program in 1987.[463] However, like all NPDES permits, this program regulates only stormwater collected and discharged in point source form.[464] As the EPA acknowledges, urban stormwater runoff, a form of nonpoint source pollution, remains a significant water quality problem,[465] and the EPA has advocated measures such as increasing green infrastructure in cities to intercept and absorb stormwater before it can flow into waterways.[466] The WCOAHSP has suggested that Congress or the states create nonpoint source permitting programs to address these kinds of remaining problems, but Congress, the EPA, and NOAA could also strengthen both the requirements for and the funding available to state nonpoint source control

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463. Water Quality Act of 1987, Pub. L. No. 100-4, §§ 401–405, 101 Stat. 7, 65–71 (codified as amended at 33 U.S.C. §§ 1313, 1342 (2012)).

464. *See Stormwater Basic Information*, U.S. EPA, http://water.epa.gov/polwaste/npdes/stormwater/Stormwater-Basic-Information.cfm (last visited Oct. 19, 2015) (describing the NPDES stormwater permit program and its applicability).

465. *Managing Urban Runoff*, U.S. ENVTL. PROTECTION AGENCY, http://water.epa.gov/polwaste/nps/urban.cfm (last visited Oct. 19, 2015).

466. *Green Infrastructure*, U.S. ENVTL. PROTECTION AGENCY, http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm (last visited Oct. 19, 2015); *Nutrient Pollution: The Problem*, U.S. ENVTL. PROTECTION AGENCY, http://www2.epa.gov/nutrientpollution/problem (last visited Oct. 21, 2015) ("Nutrient pollution is one of America's most widespread, costly and challenging environmental problems, and is caused by excess nitrogen and phosphorus in the air and water.").

programs under both the Clean Water Act[467] and the Coastal Zone Management Act[468] to encourage coastal states to revise and strengthen their approaches to managing stormwater runoff.

Such improved stormwater management measures could doubly benefit many coastal states. Along the East Coast, for example, improved stormwater management could both slow ocean acidification and help coastal regions adapt to increasing flooding threats from climate change. In the West, in contrast, in the face of long and significant drought, cities like Los Angeles are already implementing significant infrastructure improvements to capture stormwater to recycle for water supply;[469] these measures could also reduce the severity of ocean acidification.

Nutrient pollution has also long been recognized as a pervasive and significant water quality problem throughout the United States,[470] with sources concentrated in agricultural nonpoint source pollution and stormwater runoff.[471] Along coasts, as noted, nutrient pollution has already been a significant problem, causing harmful algal blooms and dead zones (hypoxia) and damaging ecosystems like those in the Gulf of Mexico and Long Island Sound.[472] The additional problem of ocean acidification might finally prompt Congress to bring more agricultural sources within the Act's direct regulation.[473] Even without congressional intervention, however, the EPA has been strongly encouraging—even forcing—certain states to more aggressively address nutrient pollution. For example, between at least 2009 and January

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467. 33 U.S.C. § 1329 (2012).

468. 16 U.S.C. § 1455b (2012).

469. *Stormwater Capture*, L.A. DEPARTMENT WATER & POWER, https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-water/a-w-sourcesofsupply/a-w-sos-stormwatercapture (last visited Oct. 30, 2015).

470. *Nutrient Pollution: The Problem*, *supra* note 466.

471. *Nutrient Pollution: Sources and Solutions*, U.S. EPA, http://www2.epa.gov/nutrientpollution/sources-and-solutions (last visited Oct. 19, 2015).

472. *Nutrient Pollution: Where Nutrient Pollution Occurs*, U.S. ENVTL. PROTECTION AGENCY, http://www2.epa.gov/nutrientpollution/where-nutrient-pollution-occurs (last visited Oct. 19, 2015).

473. For example, the Clean Water Act currently explicitly exempts some forms of agricultural pollution that would otherwise count as point source pollution, such as channelized "agricultural stormwater discharges and return flows from irrigated agriculture." 33 U.S.C. § 1362(14) (2012).

2014, the EPA and Florida engaged in a heated legal battle over Florida's duty under the Clean Water Act to incorporate stringent numeric water quality criteria for nitrogen and phosphorus into its state water quality standards.[474] Indeed, the EPA considered Florida's nutrient pollution problems to be so serious that it decided at one point to impose federal nutrient water quality standards on the state.[475] Even more significantly, in 2010 the EPA imposed a multi-state TMDL for nitrogen, phosphorus, and sediment on the Chesapeake Bay states (Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia, plus the District of Columbia).[476] This TMDL is forcing these governments to progressively reduce the loading of these pollutants to the Chesapeake Bay, subject to continuing EPA oversight.[477]

Nevertheless, the role of the federal Clean Water Act in addressing ocean acidification will remain limited, both because of the actual causes of ocean acidification and because of the Act's own structure and limitations. As a result, states and regions experiencing significant ocean acidification problems, like Maine and the Pacific Coast states and region, must continue to think beyond the Clean Water Act to effectively deal with ocean acidification, generating locally and regionally relevant basic scientific data, establishing comprehensive and well-funded ocean monitoring systems, and experimenting with increasingly diversified adaptation measures, from shell recycling to seawater treatment to ecological restoration and the creation of new refugia in carefully sited marine protected areas.

Even so, the Clean Water Act *can* play a more significant local and regional role in mitigating ocean acidification than it

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474. *Nutrients Water Quality Standards for the State of Florida*, U.S. ENVTL. PROTECTION AGENCY, http://water.epa.gov/lawsregs/rulesregs/florida-index.cfm (last visited Oct. 19, 2015).

475. *Id.*

476. The EPA established this multi-state TMDL—the first of its kind—in December 2010, and it covers the nutrients nitrogen and phosphorus, as well as sediment. *Chesapeake Bay Total Maximum Daily Load (TMDL)*, U.S. ENVTL. PROTECTION AGENCY, http://www.epa.gov/chesapeakebaytmdl/ (last visited Oct. 19, 2015). The TMDL has been subject to numerous legal challenges, but on July 6, 2015, the U.S. Court of Appeals for the Third Circuit unanimously upheld it. Am. Farm Bureau Fed'n v. U.S. EPA, 792 F.3d 281, 287 (3d Cir. 2015).

477. *See Chesapeake Bay Total Maximum Daily Load (TMDL)*, *supra* note 476 (describing implementation and progress on the Chesapeake Bay TMDL).

currently does, particularly with respect to stormwater runoff and nutrient (especially agricultural) pollution. Somewhat ironically, the much-beleaguered Chesapeake Bay nutrient TMDL may someday prove to be the first, best thing that the Clean Water Act ever did to address regional ocean acidification—and that TMDL may also become the most pragmatic model for making the Clean Water Act an effective instrument within a growing ocean acidification legal toolbox.