

OCEAN GOVERNANCE FOR THE 21ST CENTURY: MAKING MARINE ZONING CLIMATE CHANGE ADAPTABLE

*Robin Kundis Craig**

The variety of anthropogenic stressors to the marine environment — including, increasingly, climate change — and their complex and synergistic impacts on ocean ecosystems testifies to the failure of existing governance regimes to protect these ecosystems and the services that they provide. Marine spatial planning has been widely hailed as a means of improving ocean governance through holistic ecosystem-based planning. However, that concept arose without reference to climate change, and hence it does not automatically account for the dynamic alterations in marine ecosystems that climate change is bringing.

This Article attempts to adapt marine spatial planning to climate change adaptation. In so doing, it explores three main topics. First, it examines how established marine protected areas can aid climate change adaptation. Second, it looks at how nations have incorporated climate change considerations into marine spatial planning to increase marine ecosystem resilience, focusing on the international leader in marine spatial planning: Australia. Finally, the Article explores how marine spatial planning could become flexible enough to adapt to the changes that climate change will bring to the world's oceans, focusing on anticipatory zoning. Governments, of course, can establish marine zoning governance regimes in anticipation of climate change impacts, as has already occurred in the Arctic. However, drawing on work by Josh Eagle, Barton H. Thompson, and James Sanchirico, this Article argues that governments could also combine anticipatory zoning and comprehensively regulated marine use rights bidding regimes to encourage potential future private users to make informed bets about the future productivity value of different parts of the ocean, potentially improving both our ability to anticipate climate change impacts on particular marine environments and the ocean governance regimes for climate-sensitive areas.

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* Professor of Law, University of Utah S.J. Quinney College of Law, Salt Lake City, Utah. This Article derives from work for my recently published book, *Comparative Ocean Governance: Placed-Based Protections in an Era of Climate Change* (Edward Elgar Press), and I again gratefully thank all of the persons and organizations acknowledged in that book for their help in my research. Particular thanks goes to Professors J.B. Ruhl and Buzz Thompson for their willingness to comment repeatedly on drafts of this Article. Nevertheless, I remain solely responsible for its contents, and comments should be directed to me by e-mail at robin.craig@law.utah.edu.

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INTRODUCTION

In June 2011, the International Programme on the State of the Ocean (“IPSO”) released its latest “State of the Oceans Report,” compiling and analyzing the latest scientific evidence regarding ocean conditions. IPSO identified seven key concerns regarding the world’s oceans, including the facts that “[t]he speeds of many negative changes to the ocean are near to or are tracking the worst-case scenarios from IPCC and other predictions,”¹ “[t]he magnitude of the cumulative impacts on the ocean is greater than previously understood,”² “[r]esilience of the ocean to climate change impacts is severely compromised by the other stressors from human activities, including fisheries, pollution and habitat destruction,”³ and “[e]cosystem collapse is occurring as a result of both current and emerging stressors.”⁴ In other words, the oceans are rapidly losing their ability to cope with the many stressors that impact them, those impacts are worse than we thought, the potential losses are great, and we are running out of time to reverse course.⁵

Importantly for law and policy makers, IPSO also emphasized that improved governance was a necessary step to prevent massive ocean extinctions and loss of marine ecosystems.⁶ Specifically, IPSO concluded that current uses of the oceans “are not sustainable” and that continued human dependence on marine goods and services “demands change in how we view, manage, govern and use marine ecosystems.”⁷ Like many other ocean governance commentators,⁸ moreover, IPSO recommended the rapid adop-

¹ ALEX D. ROGERS & DANIEL D’A. LAFFOLEY, INT’L PROGRAMME ON THE STATE OF THE OCEAN, INTERNATIONAL EARTH SYSTEM EXPERT WORKSHOP ON OCEAN STRESSES AND IMPACTS, SUMMARY REPORT 5 (2011) [hereinafter 2011 STATE OF THE OCEANS REPORT], *available at* http://www.stateoftheocean.org/pdfs/1906_IPSO-LONG.pdf.

² *Id.* at 6.

³ *Id.*

⁴ *Id.*

⁵ *See id.* at 5–7.

⁶ *Id.*

⁷ *Id.* at 5.

⁸ *See, e.g.*, TUNDI AGARDY, OCEAN ZONING: MAKING MARINE MANAGEMENT MORE EFFECTIVE 5 (2010) (concluding, after discussing the weaknesses of marine governance to date, that “[a] new paradigm, or at the very least, a substantial ramping up of truly effective management, is badly needed”).

tion of a more holistic approach to ocean management, one that addresses “all activities that impinge marine ecosystems.”⁹

Marine spatial planning, including the increased use of marine protected areas and marine reserves, has widely been promoted as the answer to this call for improved ocean governance. For example, in a July 2010 executive order, President Obama — following up on extensive reports in 2003,¹⁰ 2004,¹¹ and 2010¹² that detailed how desperately ocean governance in the United States needs to improve — called for marine spatial planning at the federal level.¹³ Internationally, the United Nations (“U.N.”) Educational, Scientific and Cultural Organization (“UNESCO”) has been promoting marine spatial planning for the past decade.¹⁴

As Part I explains in more detail, marine spatial planning is place-based regulation of allowable ocean uses. Conceptually, however, marine spatial planning arose without reference to climate change and hence does not automatically account for the dynamic impacts of climate change on marine ecosystems or the special importance of preserving and improving marine resilience in the face of those impacts. While marine spatial planning should remain an important ocean governance tool throughout the climate change era, it nevertheless must incorporate additional flexibility and climate change considerations to improve ocean governance most effectively. This Article suggests ways in which marine spatial planning can pursue those needed incorporations — in other words, to adapt marine spatial planning to climate change adaptation.

This Article begins with an overview of marine spatial planning. In Part II, it looks at the climate change-driven need for adaptability in ocean governance, detailing the impacts and ecosystem changes that climate

⁹ 2011 STATE OF THE OCEANS REPORT, *supra* note 1, at 9.

¹⁰ See generally PEW OCEANS COMM’N, AMERICA’S LIVING OCEANS: CHARTING A COURSE FOR SEA CHANGE (2003), available at http://www.pewtrusts.org/uploadedFiles/wwwpewtrusts.org/Reports/Protecting_ocean_life/POC_Summary.pdf (reviewing the various laws and regimes governing marine living resources and recommending a more coordinated and centralized governance regime that incorporates ecosystem protections).

¹¹ See generally U.S. COMM’N ON OCEAN POLICY, AN OCEAN BLUEPRINT FOR THE 21ST CENTURY, FINAL REPORT (2004), available at http://www.oceancommission.gov/documents/full_color_rpt/000_ocean_full_report.pdf (providing a comprehensive and detailed review of all marine management law and programs in the United States and recommending a more holistic and centralized approach to ocean governance).

¹² See generally WHITE HOUSE COUNCIL ON ENVTL. QUALITY, FINAL RECOMMENDATIONS OF THE INTERAGENCY OCEAN POLICY TASK FORCE (2010), available at http://www.whitehouse.gov/files/documents/OPTF_FinalRecs.pdf [hereinafter 2010 OCEAN POLICY RECOMMENDATIONS] (making detailed recommendations to the President on how to improve ocean governance in the United States); see also Robin Kundis Craig, *Regulation of U.S. Marine Resources: An Overview of the Current Complexity*, NAT. RESOURCES & ENV’T, Summer 2004, at 3 (detailing the pervasively fragmented approach to regulating marine resources under current U.S. law).

¹³ See Exec. Order No. 13,547, 3 C.F.R. 227 (2011).

¹⁴ See, e.g., INTERGOVERNMENTAL OCEANOGRAPHIC COMM’N, UNESCO, MARINE SPATIAL PLANNING: A STEP-BY-STEP APPROACH TOWARD ECOSYSTEM-BASED MANAGEMENT (2009), available at <http://www.unesco-ioc-marinesp.be/uploads/documentenbank/d87c0c421da4593fd93bbe1898e1d51.pdf>.

change is bringing to the world's seas. In Part III, the Article examines in more detail three ways in which marine spatial planning could be made more climate change adaptable. First, it looks at how established marine protected areas such as the Papahānaumokuākea Marine National Monument can play a role in climate change adaptation. Second, it examines how Australia, one of the earliest leaders in marine spatial planning, has incorporated climate change into that planning and is using marine spatial planning to increase the Great Barrier Reef's resilience to climate change. Finally, Part III explores how anticipatory zoning could add much needed flexibility to marine spatial planning, allowing ocean zoning to address the complex and dynamic impacts of climate change on the marine environment.

I. MARINE SPATIAL PLANNING AND OCEAN GOVERNANCE

When discussing how to improve legal regimes, it helps to figure out what you are generally trying to accomplish. As IPSO's 2010 "State of the Oceans" Report demonstrates, one oft-stated goal for improving marine governance is to move from the species-by-species and activity-by-activity approaches that dominate current marine governance regimes to a more holistic approach that restores and preserves healthy and representative marine ecosystems.¹⁵ However, that really just begs the question: what do we mean when we say that the governance goal is healthy ocean ecosystems?

In a climate change era, the governance goal of healthy ocean ecosystems should encompass four components. First, the governance regime should seek to protect and maintain multiple kinds of marine ecosystems — that is, to promote marine biodiversity at the ecosystem level. This is a fairly uncontroversial goal. As one example, Canada is pursuing a national representative system of "national marine conservation areas" ("NMCAs").¹⁶

Second, ocean governance regimes in a climate change era should ensure that each protected marine ecosystem has appropriate species-level biodiversity, as judged against a baseline status that reflects minimal human exploitation.¹⁷ Establishing the appropriate baseline by which to judge the health of marine ecosystems, and hence the effectiveness of marine govern-

¹⁵ 2011 STATE OF THE OCEANS REPORT, *supra* note 1, at 9.

¹⁶ Canada National Marine Conservation Areas Act, S.C. 2002, c. 18 (Can.). NMCAs "divide the country's oceans and Great Lakes into 29 marine regions, each one a distinct combination of physical and biological characteristics." *National Marine Conservation Areas of Canada*, PARKS CAN., http://www.pc.gc.ca/progs/amnc-nmca/intro/index_E.asp (last visited May 10, 2012) (on file with the Harvard Law School Library).

¹⁷ See, e.g., Jeremy B.C. Jackson et al., *Historical Overfishing and the Recent Collapse of Coastal Ecosystems*, 293 SCIENCE 629, 629 (2001) (arguing that current ocean management has to take account of much earlier historical baselines because "[o]verfishing and ecological extinction predate and precondition modern ecological investigations and the collapse of marine ecosystems in recent times, raising the possibility that many more marine ecosystems may be vulnerable to collapse in the near future").

ance, is one of the most difficult aspects of creating and implementing a marine governance regime because most marine ecosystems have been heavily exploited and transformed by fishing and coastal development.¹⁸ Moreover, climate change impacts, as discussed in Part II, are likely to alter the appropriateness of any historical baseline actually chosen. Nevertheless, historical states of ecosystems, when known, still provide relevant points for assessment, just as the current state of ecosystems provide an important reference point for both the amount of degradation that has already occurred and the measurable impacts of climate change now and in the future.¹⁹

Third, especially in a climate change era, ocean governance regimes should seek to make marine ecosystems — and the socio-ecological systems of which they are a part — as resilient as possible for as long as possible.²⁰ In a climate change era, disturbances of various kinds will be continual stressors to marine ecosystems. As a result, ocean governance regimes should seek to reduce other stressors on marine ecosystems and to enhance marine ecosystem resilience so that, for as long as possible, existing ecosystems will have the capacity to adapt to a changing world while still maintaining their productive functionality.

Finally, however, in a climate change era, ocean governance must acknowledge that marine ecosystems will change over time and often shift into new ecological states.²¹ As climate change makes such ecological shifts inevitable, governance regimes should help to ensure that marine ecosystems and the socio-ecological systems of which they are a part will transition to new states that are productive and adaptive, rather than collapsing into the equivalent of decimated marine deserts.²²

Marine spatial planning is a widely promoted technique for achieving at least the first three of these goals, but its integration with climate change adaptation is less than complete. The concept of marine spatial planning derives from terrestrial counterparts: land use planning and municipal zon-

¹⁸ See Paul K. Dayton et al., *Sliding Baselines, Ghosts, and Reduced Expectations in Kelp Forest Communities*, 8 *ECOLOGICAL APPLICATIONS* 309, 320 (1998) (concluding that discerning an ecological baseline for southern California kelp communities was impossible because there are too many “ghosts” — missing species — to accurately reconstruct the ecosystem’s pre-impact functioning); see also Jackson et al., *supra* note 17 (tracing changes through various kinds of marine ecosystems using a variety of historical records); *id.* at 636 (concluding that “[t]he shifting baseline syndrome is thus even more insidious and ecologically widespread than is commonly realized”).

¹⁹ See Jackson et al., *supra* note 17, at 636.

²⁰ Robin Kundis Craig, “Stationarity Is Dead” — *Long Live Transformation: Five Principles for Climate Change Adaptation Law*, 34 *HARV. ENVTL. L. REV.* 9, 21–22, 39, 43–53 (2010). Resilience is the capacity of a system to absorb disturbance without shifting to another systematic state or regime. Lance H. Gunderson & Craig R. Allen, *Why Resilience? Why Now?*, in *FOUNDATIONS OF ECOLOGICAL RESILIENCE* xiii, xv–xvi (Lance H. Gunderson et al. eds., 2010).

²¹ Craig, *supra* note 20, at 10–16.

²² See generally Jackson et al., *supra* note 17, at 629–36 (describing the collapses of a variety of different kinds of marine ecosystems).

ing.²³ However, unlike most land use planning, marine spatial planning seeks from the beginning to account for the health of the relevant marine ecosystems, balancing biodiversity protection with human use to achieve ecosystem-based management in the oceans.²⁴ As a result, marine spatial planning will often provide special protections for, and perhaps even forbid all human use of, those areas of an ocean ecosystem that are particularly critical to maintaining its function, productivity, and biodiversity, such as spawning grounds and critical habitat areas.

Marine spatial planning is becoming more popular as an ocean governance tool.²⁵ Australia's zoning of the Great Barrier Reef over three decades ago is generally deemed to be the first use of marine spatial planning,²⁶ and the governance regime for the reef remains "an iconic marine park that may well provide the best example of large-scale ocean zoning in existence today."²⁷ Besides Australia, other nations pursuing marine spatial planning include Belgium, Germany, the Netherlands, and Norway, for the North Atlantic Ocean; Canada, through the actions of British Columbia; Guinea-Bissau in the Bijagos Biosphere Reserve; Italy in the Asinara Marine Park; Namibia in the Benguela large marine ecosystem; New Zealand, throughout its exclusive economic zone; Tanzania in the Mafia Island Marine Park and the Chumbe Island Coral Park; and the United Kingdom in the Irish Sea.²⁸

As noted, marine spatial planning is essentially marine zoning — that is, the spatial separation of incompatible uses of the ocean through legal fiat. For example, in the late 1980s and early 1990s, the southwestern coastal area of St. Lucia began to experience notable degradation as a result of overuse — and competition for use — by fishers and a growing tourist industry based on diving and snorkeling on the coral reefs.²⁹ Measurable impacts and problems included degradation of water quality, depletion of local fish stocks, loss of tourism revenue, decreasing quality of beach recreation, pollution, and increasing conflicts among the various types of users.³⁰ St. Lucia used a public process to establish a zoning system to help resolve these growing problems.³¹

The resulting zoning plan for the Soufrière Marine Management Area ("SMMA") is rather simple, designed primarily to separate commercial

²³ AGARDY, *supra* note 8, at 6, 9–10.

²⁴ See INTERGOVERNMENTAL OCEANOGRAPHIC COMM'N, UNESCO, *supra* note 14, at 10.

²⁵ As Tundi Agardy has discussed at length, "[m]any countries that struggle with how to accommodate multiple uses of ocean space and resources are now experimenting with larger scale zoning, usually referred to as 'marine spatial planning.'" AGARDY, *supra* note 8, at 8.

²⁶ INTERGOVERNMENTAL OCEANOGRAPHIC COMM'N, UNESCO, *supra* note 14, at 7.

²⁷ AGARDY, *supra* note 8, at 60.

²⁸ See generally *id.* at 75–154.

²⁹ SOUFRIÈRE MARINE MGMT. ASS'N, CONFLICT RESOLUTION AND PARTICIPATORY PLANNING: THE CASE OF THE SOUFRIÈRE MARINE MANAGEMENT AREA 2 (1999), available at <http://www.smma.org.lc/Public/CaseStudies/SMMACaseStudy.pdf>.

³⁰ *Id.*

³¹ See *id.* at 3–5.

fishers from recreational divers and boaters.³² Thus, for example, in the fishing priority areas, divers, snorkelers, and recreational boaters are cautioned that “commercial fishing has precedence over all other activities. Access by other users is allowed only to the extent that it does not interfere with any fishing activities.”³³ However, the system’s assortment of marine reserves also protects the coral reef ecosystem itself.³⁴ Specifically, the primary purpose of these marine reserves “is to allow fish stocks to regenerate in order to ensure healthy fish populations in the future. These areas of high ecological value have been set aside for the protection of all marine flora and fauna, scientific research, and the enjoyment of divers and snorkelers.”³⁵ A permit is necessary for divers to use these zones, although licensed dive operators and dive leaders, in addition to the management authority, can issue permits.³⁶

In the United States, the current driving force toward increased use of marine spatial planning is President Obama’s July 2010 Ocean Stewardship Executive Order.³⁷ The order recognizes the pervasive importance of the oceans, ranging from basics such as jobs, food, and energy to transportation and national security.³⁸ It then sets out ten goals for protecting the United States’ ocean ecosystems, including to: “protect, maintain, and restore the health and biological diversity of ocean, coastal, and Great Lakes ecosystems and resources;” “improve the resiliency of ocean, coastal, and Great Lakes ecosystems, communities, and economies;” and “improve our understanding and awareness of changing environmental conditions, trends, and their causes, and of human activities taking place in ocean, coastal, and Great Lakes waters[.]”³⁹ The Ocean Stewardship Executive Order thus incorporates both climate change and improved resilience into its goals, a fact also made clear in the Order’s purposes, which include “provid[ing] for adaptive management to enhance our understanding of and capacity to respond to climate change and ocean acidification.”⁴⁰

To implement these goals, the Order creates a National Ocean Council with representatives from a wide variety of federal agencies and departments.⁴¹ Most relevant for this Article, the National Ocean Council is charged with approving and implementing marine spatial planning in U.S. waters, and its plans are binding on all federal agencies to the extent allowed

³² See *About Our Zones*, SOUFRIÈRE MARINE MGMT. ASS’N, <http://www.smma.org.lc/index.php?title=aboutourZones&page=zoning> (last visited May 10, 2012) (on file with the Harvard Law School Library).

³³ *Id.*

³⁴ See SOUFRIÈRE MARINE MGMT. ASS’N, *supra* note 29, at 7–9.

³⁵ *About Our Zones*, *supra* note 32.

³⁶ *Id.*

³⁷ Exec. Order No. 13,547, 3 C.F.R. 227 (2011).

³⁸ *Id.*

³⁹ *Id.* at 227–28.

⁴⁰ *Id.* at 227.

⁴¹ *Id.* at 229–30.

by current statutes.⁴² The Order defines “coastal and marine spatial planning” to mean:

a comprehensive, adaptive, integrated, ecosystem-based, and transparent spatial planning process, based on sound science, for analyzing current and anticipated uses of ocean, coastal, and Great Lakes areas. Coastal and marine spatial planning identifies areas most suitable for various types or classes of activities in order to reduce conflicts among uses, reduce environmental impacts, facilitate compatible uses, and preserve critical ecosystem services to meet economic, environmental, security, and social objectives.⁴³

The National Ocean Council is pursuing marine spatial planning for the United States through a regional approach,⁴⁴ incorporating the July 2010 final recommendations of the Interagency Ocean Policy Task Force referenced in the Order.⁴⁵ Two of the Task Force’s four primary recommendations included “a strengthened governance structure to provide sustained, high-level, and coordinated attention to ocean, coastal, and Great Lakes issues” and “a framework for effective coastal and marine spatial planning . . . that establishes a comprehensive, integrated, ecosystem-based approach to address conservation, economic activity, user conflict, and sustainable use of ocean, coastal, and Great Lakes resources.”⁴⁶ More specifically, the Task Force identified nine priority implementation objectives for the United States. Relevant to this Article, these include: the adoption of “ecosystem-based management as a foundational principle for the comprehensive management of the ocean, our coasts, and the Great Lakes” (#1); the implementation of “comprehensive, integrated, ecosystem-based coastal and marine spatial planning and management in the United States” (#2); and the strengthening of “resiliency of coastal communities and marine and Great Lakes environments and their abilities to adapt to climate change impacts and ocean acidification” (#5).⁴⁷

While President Obama’s Executive Order and the Task Force’s report link marine spatial planning to climate change and the need to strengthen marine ecosystems’ resilience, neither document is clear regarding precisely how ocean zoning can contribute to climate change adaptation and increased

⁴² *Id.* at 230.

⁴³ *Id.* at 228.

⁴⁴ *Regional Planning Bodies*, NAT’L OCEAN COUNCIL, <http://www.whitehouse.gov/administration/eop/oceans/cmsp/regional-planning> (last visited May 10, 2012) (on file with the Harvard Law School Library).

⁴⁵ 3 C.F.R. at 228; *see also generally* 2010 OCEAN POLICY RECOMMENDATIONS, *supra* note 12 (presenting the Task Force’s recommendations to the President).

⁴⁶ 2010 OCEAN POLICY RECOMMENDATIONS, *supra* note 12, at 2–3.

⁴⁷ *Id.* at 6. The other recommended priorities are to inform decisions and to improve understanding of the ocean and its services (#3); to coordinate better across the federal government and among federal agencies, the states, tribes, and local governments (#4); to implement regional marine ecosystem protection and restoration (#6); to improve water quality and sustainable practices on land (#7); to address changing conditions in the Arctic (#8); and to strengthen and integrate basic ocean observation, measuring, and monitoring (#9). *Id.*

resilience. Instead, like most proponents of marine spatial planning, the Task Force viewed marine spatial planning predominantly as a way to deal rationally with the multiple and conflicting users of the United States' marine ecosystems.⁴⁸ Details regarding how the federal government will pursue marine spatial planning and climate change adaptation are likely to emerge as the National Ocean Council formulates its implementation plan, which was released in draft form in January 2012.⁴⁹

Addressing the issue of exactly how to make marine spatial planning climate change adaptive is important, because, by its very nature, marine spatial planning imports a static quality into marine management. Like terrestrial zoning, marine spatial planning establishes boundaries for areas of use that, while not necessarily set in stone, may be difficult to alter, both legally and practically. Indeed, some such stability is desirable. For example, the U.S. Ocean Policy Task Force, while emphasizing that comprehensive marine spatial planning in the United States needs to be “adaptive”⁵⁰ and “flexible,”⁵¹ also stressed that such planning would increase predictability for users, underscoring the static element of marine spatial planning.⁵²

Therefore, as in terrestrial zoning, one of the tensions in promoting marine spatial planning is how to balance this desire for predictability and stability with the knowledge that human needs and desires will change over time. To these anthropocentric concerns, however, the oceans add a backdrop of physical, chemical, and biological dynamism with which terrestrial planners — especially those working with traditional urban and suburban zoning — rarely have to contend. As an example, one phenomenon of importance to both global currents and global weather patterns is the El Niño/Southern Oscillation, in which sea surface temperatures in the eastern Southern Pacific Ocean vary over cycles lasting from two to seven years.⁵³ The oscillation between warm El Niño and cold La Niña patterns changes the relative sea level in the Pacific Ocean basin, alters current patterns, changes fishing grounds and species' ranges, and affects rainfall patterns throughout the world.⁵⁴ More local variations of a variety of durations also occur in ocean ecosystems, potentially limiting the value of static ocean zones for certain kinds of marine uses, such as fishing.

And that is even *before* climate change impacts on the oceans are considered. As the next Part discusses, these impacts sharply call into question

⁴⁸ See *id.* at 32–33, 41.

⁴⁹ NAT'L OCEAN COUNCIL, NATIONAL OCEAN POLICY DRAFT IMPLEMENTATION PLAN (2012), available at http://www.whitehouse.gov/sites/default/files/microsites/ceq/national_ocean_policy_draft_implementation_plan_01-12-12.pdf.

⁵⁰ 2010 OCEAN POLICY RECOMMENDATIONS, *supra* note 12, at 41.

⁵¹ *Id.* at 42.

⁵² *Id.* at 48.

⁵³ *Frequently Asked Questions About El Niño and La Niña*, NAT'L WEATHER SERV., NAT'L OCEANIC & ATMOSPHERIC ASS'N (“NOAA”), http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensofaq.shtml (last visited May 10, 2012) (on file with the Harvard Law School Library).

⁵⁴ *Id.*

the long-term viability of static marine spatial planning, suggesting that conventional marine spatial planning (as new as it is as a marine management tool) needs to better incorporate climate change adaptation to improve marine governance over the longer term.

II. THE NEED FOR CLIMATE CHANGE ADAPTABILITY IN OCEAN MANAGEMENT

As the Ocean Policy Task Force recognized in July 2010, “[t]he importance of ocean, coastal, and Great Lakes ecosystems cannot be overstated; simply put, we need them to survive.”⁵⁵ Climate change, however, not only compounds existing threats to ocean resources but also adds its own.⁵⁶ This Part will examine these impacts, making the general point that climate change is already altering, and will continue to alter, ocean ecosystems in ways that not only exacerbate the “normal” dynamism of the seas but also threaten to push marine ecosystems over resilience thresholds. As a result, marine governance regimes will increasingly need to take account of climate change impacts to remain relevant and effective.

A. *The Oceans’ Role in Climate Change*

The oceans play a significant role in climate change impacts, and understanding the interactions between the atmosphere and the oceans is widely acknowledged to be critical to understanding and modeling climate change impacts more generally.⁵⁷ For example, the interactions between the oceans and the atmosphere create the heat circulation and the wind and weather patterns that in turn express the realities of climate change and determine its impacts on all terrestrial life.⁵⁸ As Al Gore reported in *An Inconvenient Truth*, “scientists say that the world’s climate is best understood as a kind of engine for redistributing heat from the Equator and the tropics to the poles.”⁵⁹ This redistribution “drives the wind and ocean currents — like the Gulf Stream and the jet stream.”⁶⁰

The oceans are also the world’s largest carbon sinks, giving the oceans a direct and important role in regulating climate⁶¹ — and mitigating climate change. At the beginning of the twenty-first century, the oceans and land

⁵⁵ 2010 OCEAN POLICY RECOMMENDATIONS, *supra* note 12, at 12.

⁵⁶ *Id.*

⁵⁷ J. M. Levy, *Global Oceans*, in STATE OF THE CLIMATE IN 2009, 91 BULL. AM. METEOROLOGICAL SOC. S53, S59, S61 (2010) (citations omitted).

⁵⁸ MILLENNIUM ECOSYSTEM ASSESSMENT, ECOSYSTEMS AND HUMAN WELL-BEING: CURRENT STATE AND TRENDS 498 (2005) [hereinafter MEA 2005: CURRENT STATE AND TRENDS], available at <http://www.maweb.org/en/Condition.aspx>.

⁵⁹ AL GORE, AN INCONVENIENT TRUTH: THE PLANETARY EMERGENCY OF GLOBAL WARMING AND WHAT WE CAN DO ABOUT IT 149 (2006).

⁶⁰ *Id.*

⁶¹ FRED PEARCE, WITH SPEED AND VIOLENCE: WHY SCIENTISTS FEAR TIPPING POINTS IN CLIMATE CHANGE 86 (2007).

ecosystems (mostly plants) were absorbing about half of the anthropogenic emissions of carbon dioxide (“CO₂”)⁶² — roughly twenty-five percent by land plants and twenty-five percent by the oceans.⁶³ According to the National Oceanic and Atmospheric Administration (“NOAA”) oceanographers in 2006, “[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.”⁶⁴ The oceans continue to uptake about twenty-two million tons of CO₂ per day.⁶⁵

However, the oceans appear to be losing their ability to act as carbon sinks. As a general matter, the cold water at ocean depths can sequester more CO₂ than warmer waters at the surface.⁶⁶ As a result, any process that circulates cold water to the surface will reduce an ocean’s ability to act as a carbon sink. Research published in 2009 indicated that, as a result of climate change, the Southern Indian Ocean is being subjected to stronger winds. The winds, in turn, mix the ocean waters, bringing up CO₂ from the depths and preventing the ocean from absorbing more CO₂ from the atmosphere.⁶⁷ For similar reasons, “the CO₂ sink diminished by 50% between 1996 and 2005 in the North Atlantic.”⁶⁸ The implications for future climate change are still uncertain, but any reduction in this sink’s effectiveness could potentially accelerate the impacts of climate change for the entire world.

B. *Climate Change’s Exacerbation of Existing Ocean Stresses*

Climate change will increase the dynamism of the oceans by exacerbating current stresses, such as pollution. About eighty percent of ocean pollution, perhaps more, comes from land.⁶⁹ Mercury, for example, frequently reaches the oceans through atmospheric deposition: land-based sources emit the mercury into the air, which falls back into waters or onto land, where runoff carries it to sea.⁷⁰ Methyl mercury, the organic form of mercury, bioaccumulates in marine organisms, becoming more concentrated the fur-

⁶² Peter M. Cox et al., *Acceleration of Global Warming Due to Carbon-Cycle Feedbacks in a Coupled Climate Model*, 408 NATURE 184, 184 (1995).

⁶³ *The Ocean Carbon Cycle*, HARV. MAG., Nov.-Dec. 2002, available at <http://harvardmagazine.com/2002/11/the-ocean-carbon-cycle.html>.

⁶⁴ Richard A. Feely, Christopher L. Sabine, & Victoria J. Fabry, *Carbon Dioxide and Our Ocean Legacy*, NOAA, 1 (2006), <http://www.pmel.noaa.gov/pubs/PDF/feel2899/feel2899.pdf>.

⁶⁵ *Id.*

⁶⁶ *The Ocean Carbon Cycle*, *supra* note 63.

⁶⁷ CNRS (Délégation Paris Michel-Ange), *Ocean Less Effective at Absorbing Carbon Dioxide Emitted by Human Activity*, SCI. DAILY, Feb. 23, 2009, <http://www.sciencedaily.com/releases/2009/02/090216092937.htm>.

⁶⁸ *Id.*

⁶⁹ *Marine Problems: Pollution*, WORLD WILDLIFE FUND, http://wwf.panda.org/about_our_earth/blue_planet/problems/pollution/ (last visited May 10, 2012) (on file with the Harvard Law School Library).

⁷⁰ *See Mercury Contamination in Fish: Know Where It’s Coming From*, NAT. RES. DEF. COUNCIL, <http://www.nrdc.org/health/effects/mercury/sources.asp> (last visited May 10, 2012) (on file with the Harvard Law School Library).

ther up the food web a species resides.⁷¹ High-level predators such as tuna, swordfish, shark, and mackerel can end up with mercury concentrations in their bodies that are 10,000 times the ambient concentration of mercury in the water.⁷² Mercury contamination is already prevalent in fish, and in 2003, seventy percent of the coastal waters in the contiguous forty-eight states⁷³ and waters in Hawai'i⁷⁴ were under fish consumption advisories for mercury.

Mercury methylation and the consequent bioaccumulation of mercury in marine organisms appear to be temperature-dependent. As a result, mercury contamination of fish and marine mammals is likely to increase as ocean temperatures rise in response to climate change.⁷⁵

The oceans also already suffer from another form of land-based pollution: nutrient runoff. Water from farms, in the forms of both irrigation return flows and runoff from rain or snowmelt, carries excess fertilizer to the ocean.⁷⁶ Nutrients also reach the waters through atmospheric deposition, such as from the burning of fossil fuels.⁷⁷ Once in ocean waters, the nutrients induce large blooms of marine plants — phytoplankton and algae. As the blooms then die off, their decomposition consumes all of the oxygen in the water column, leading to hypoxic conditions that make large areas of the ocean uninhabitable for marine animals.⁷⁸

Dead zones are now common throughout the world's coastal regions and often impinge on fisheries.⁷⁹ The number of dead zones in the world's seas has doubled every decade since 1960 as a result of increasing marine pollution, and a study that appeared in *Science* in 2008 identified more than 400 dead zones throughout the world.⁸⁰ Perhaps most disturbingly, dead zones have less biomass than would be expected, suggesting that the oxygen deprivation can have long-term effects on the region's biodiversity and productivity.⁸¹

One of the general impacts of climate change will be changes in precipitation patterns, including increased rainfall in some places and more severe rain events in many more — even in some places where the overall impact

⁷¹ *Mercury Contamination in Fish: Learn About Mercury and Its Effects*, NAT. RES. DEF. COUNCIL, <http://www.nrdc.org/health/effects/mercury/effects.asp> (last visited May 10, 2012) (on file with the Harvard Law School Library).

⁷² *Id.*

⁷³ ZACHARY CORRIGAN, ENV'T COLO. RESEARCH & POLICY CTR., *FISHING FOR TROUBLE: HOW TOXIC MERCURY CONTAMINATES FISH IN U.S. WATERWAYS 5* (2004), available at http://cdn.publicinterestnetwork.org/assets/7014xouqei5JOkGAMODHLA/Fishing_for_Trouble_2004.pdf.

⁷⁴ *Id.*

⁷⁵ Shawn Booth & Dirk Zeller, *Mercury, Food Webs, and Marine Mammals: Implications of Diet and Climate Change for Human Health*, 113 ENVTL. HEALTH PERSP. 521, 525 (2005).

⁷⁶ Robert J. Diaz & Rutger Rosenberg, *Spreading Dead Zones and Consequences for Marine Ecosystems*, 321 SCIENCE 926, 926 (2008).

⁷⁷ *Id.* at 926.

⁷⁸ *Id.*

⁷⁹ *See id.* (“[D]ead zones have developed in continental seas, such as the Baltic, Kattegat, Black Sea, Gulf of Mexico, and East China Sea, all of which are major fishery areas.”).

⁸⁰ *Id.* at 926, 928.

⁸¹ *See id.* at 927.

of climate change will be to reduce overall precipitation. Increased and more severe storm events, especially when combined with increased heat, which stimulates algal blooms, means that climate change is likely to increase the size and severity of many ocean dead zones.⁸²

In addition, climate change will almost certainly increase the frequency and severity of coral bleaching events.⁸³ Most surface coral species rely on symbiotic zooxanthellae, a type of algae contained within the coral polyps' tissues, to supplement their nutrition.⁸⁴ However, when water temperatures warm, corals expel their zooxanthellae, turning white (hence the term "coral bleaching") and, especially if the bleaching event is prolonged or repeated, potentially dying.⁸⁵ Mass coral bleaching events occurred in 1982–1983 in Panama and the Galapagos Islands, and in 1997–1998 across the globe.⁸⁶ Both events were associated with strong El Niño currents that elevated sea surface temperatures in much of the world.⁸⁷ In the 1982-1983 event, coral reef mortalities in the Galapagos Islands reached ninety-nine percent;⁸⁸ in the 1997-1998 event, "[c]oral reefs suffered mortalities of up to 95% in Kenya, Tanzania, the Maldives, the Seychelles, Sri Lanka, and India."⁸⁹

The IPCC projected increasing coral bleaching events even at current levels of increases in sea surface temperatures.⁹⁰ Widespread coral mortality is likely to begin occurring if such temperatures increase by approximately 2.5 to 3.0°C.⁹¹

Finally, climate change is likely to increase outbreaks of marine diseases. Such outbreaks signal that the world's marine resources are already over-stressed and vulnerable. For example, according to research published in 2004, disease outbreaks are increasing among sea turtles, corals, marine mammals, sea urchins, and marine mollusks.⁹² The U.N. Environment Programme ("UNEP") considers the number of outbreaks of marine disease in the last few decades and the resulting mortalities to be "unprecedented."⁹³

⁸² See *id.* at 929; see also INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: SYNTHESIS REPORT 47 fig.3.3 (2007) [hereinafter 2007 IPCC SYNTHESIS REPORT] (demonstrating that there will likely be increases in precipitation in the tropics and at the poles and mostly decreases in precipitation at the mid-latitudes of the oceans, with corresponding increases and decreases of runoff into the oceans).

⁸³ MEA 2005: CURRENT STATE AND TRENDS, *supra* note 58, at 523.

⁸⁴ *Id.*

⁸⁵ *Id.*

⁸⁶ *Coral Bleaching*, CORAL HEALTH AND MONITORING PROGRAM, NOAA, http://www.coral.noaa.gov/index.php?option=com_content&view=article&id=132&Itemid=166 (last visited May 10, 2012) (on file with the Harvard Law School Library).

⁸⁷ *Id.*

⁸⁸ *Id.*

⁸⁹ Francine Kershaw, *Climate Change and Marine Diseases: The Socio-Economic Impact*, WORLD CONSERVATION MONITORING CTR., U.N. ENV'T PROGRAMME ("UNEP"), 5 (2009), http://www.unep-wcmc.org/medialibrary/2010/09/19/c92481b0/Climate_Change_Marine_Diseases.pdf.

⁹⁰ 2007 IPCC SYNTHESIS REPORT, *supra* note 82, at 51 fig.3.6.

⁹¹ *Id.*

⁹² Jessica R. Ward & Kevin D. Lafferty, *The Elusive Baseline of Marine Disease: Are Diseases in Ocean Ecosystems Increasing?*, 2 PLoS BIOLOGY 542, 542 (2004).

⁹³ Kershaw, *supra* note 89, at 1.

As UNEP reported in 2009, climate change is likely to increase outbreaks of marine diseases. Climate change causes increasing sea temperatures, changes in ocean currents, changes in ocean chemistry, and increasing levels of ultraviolet radiation, all of which “influence the prevalence and potency of marine pathogens and biotoxins, with serious ecological and socio-economic ramifications.”⁹⁴ An increase in diseases among marine organisms also has direct implications for human health, in the form of shellfish contamination and increased outbreaks of cholera.⁹⁵ Marine disease also threatens the sustainability of marine aquaculture and tourism.⁹⁶

C. *Climate Change’s Additional Stresses on Marine Ecosystems*

Besides exacerbating existing stressors to marine ecosystems, climate change is already creating new stressors that both increase the long-term dynamism of these systems and reduce their resilience.⁹⁷ For example, climate change has already caused rising sea temperatures, rising sea levels, and changes in ocean circulation and pH, and it has exposed the oceans to increasing levels of ultraviolet radiation.⁹⁸ In addition, ocean salinity patterns also appear to be changing in response to changes in global precipitation patterns, although the trend data is too short to be sure of that connection.⁹⁹

One of the most direct impacts of increasing global average atmospheric temperatures is increasing surface sea temperatures (“SSTs”) and ocean heat content (“OHC”), both of which contribute significantly to ocean currents and world weather patterns. As NOAA recently noted, OHC contributes to sea-level rise¹⁰⁰ and has been increasing “for the last several years.”¹⁰¹

While SSTs in specific oceans can vary noticeably from year to year as a result of changes in current patterns such as El Niño and La Niña events,¹⁰² the overall trend of SSTs since 1950 has been upward.¹⁰³ Indeed, in 2007, the IPCC indicated that most regions of the oceans have already experienced SST increases of between 0.2 and 1.0°C.¹⁰⁴ It predicted that, under a “business-as-usual” scenario, ocean temperatures would increase by another 0.5 to 1.0°C by 2029 and by up to 4°C by 2099, with warming continuing for at least another century thereafter.¹⁰⁵ However, research by an international

⁹⁴ *Id.*

⁹⁵ *Id.* at 2.

⁹⁶ *Id.* at 4–5.

⁹⁷ Levy, *supra* note 57, at S53–S61.

⁹⁸ Kershaw, *supra* note 89, at 1.

⁹⁹ Levy, *supra* note 57, at S63–S64.

¹⁰⁰ *Id.* at S59 (citations omitted).

¹⁰¹ *Id.* at S53; *see also id.* at S58 fig.3.7 (graphing upward trend of OHC since 1994).

¹⁰² *Id.* at S53–S55.

¹⁰³ *Id.* at S55 fig.3.3.

¹⁰⁴ *See* 2007 IPCC SYNTHESIS REPORT, *supra* note 82, at 32 fig.1.2.

¹⁰⁵ *Id.* at 45–46, 46 fig.3.2.

team of scientists published in June 2008 indicated “that ocean temperature and associated sea level increases between 1961 and 2003 were 50 percent larger than estimated in the 2007 Intergovernmental Panel on Climate Change report.”¹⁰⁶ Moreover, scientists have detected temperature increases almost two miles below the ocean’s surface.¹⁰⁷

Changes in ocean temperatures cause temperature-sensitive species to migrate poleward,¹⁰⁸ and such migrations have already been detected. For example, in November 2009, researchers at NOAA reported that about half of the commercially important fish stocks in the western North Atlantic Ocean, such as cod, had been shifting north in response to rising sea temperatures.¹⁰⁹ Unfortunately, temperature-sensitive species at the poles have nowhere to go.¹¹⁰

A few marine species may go extinct because of temperature-induced changes in their habitat or food supply.¹¹¹ More importantly, climate change will have more general impacts on marine biodiversity¹¹² and on fishing and fish stocks.¹¹³ As the U.N. Food and Agriculture Organisation noted in 2009, “[c]limate change is a compounding threat to the sustainability of capture fisheries and aquaculture development.”¹¹⁴ A study published in *Nature* in late July 2010 suggests that the magnitude of the problem is even greater

¹⁰⁶ *Ocean Temperatures and Sea Level Increases 50 Percent Higher Than Previously Estimated*, Sci. Daily, June 18, 2008, <http://www.sciencedaily.com/releases/2008/06/080618143301.htm>.

¹⁰⁷ See Tim P. Barnett, David W. Pierce, & Reiner Schnur, *Detection of Anthropogenic Climate Change in the World’s Oceans*, 292 *SCIENCE* 270, 271 fig.2 (2001) (reporting detection of increases in some oceans’ temperatures to depths of at least 3000 meters — almost two miles).

¹⁰⁸ U.N. FOOD & AGRIC. ORG., *THE STATE OF WORLD FISHERIES AND AQUACULTURE 2008*, at 87 (2009) [hereinafter 2009 FAO STATE OF FISHERIES REPORT], available at <ftp://ftp.fao.org/docrep/fao/011/i0250e/i0250e.pdf>.

¹⁰⁹ Press Release, Ne. Fisheries Sci. Ctr., NOAA, North Atlantic Fish Populations Shifting as Ocean Temperatures Warm (Nov. 2, 2009), available at http://www.nefsc.noaa.gov/press_release/2009/SciSpot/SS0916; see also B. Planque & T. Frédou, *Temperature and the Recruitment of Atlantic Cod (Gadus morhua)*, 56 *CAN. J. FISHERIES & AQUATIC SCI.* 2069 (1999) (reporting similar results for cod).

¹¹⁰ See Julie M. Roessig et al., *Effects of Global Climate Change on Marine and Estuarine Fishes and Fisheries*, 14 *REVS. IN FISH BIOLOGY & FISHERIES* 251, 262–63 (2005) (explaining the limited options for polar fish species). According to the MEA, “[c]limate change, acting through changes in sea temperature and especially wind patterns, will disturb and displace fisheries. Disruptions in current flow patterns in marine and estuarine systems, including changes to freshwater inputs as predicted under climate change, may cause great variations in reproductive success.” MEA 2005: CURRENT STATE AND TRENDS, *supra* note 58, at 498.

¹¹¹ The MEA indicated that marine extinctions resulting directly from climate change will probably be rare, although local extirpations are likely. MEA 2005: CURRENT STATE AND TRENDS, *supra* note 58, at 490. Indirect effects are likely to be more important. For example, recent studies “monitoring sea temperatures in the North Atlantic suggest that the Gulf Stream may be slowing down and affecting abundance and seasonality of plankton that are food for larval fish. Declining larval fish populations and ultimately lower adult stocks of fish will affect the ability of overexploited stocks to recover.” *Id.* (citation omitted).

¹¹² *Id.* at 489.

¹¹³ See generally Roessig et al., *supra* note 110 (comprehensively reviewing climate change’s impacts on fisheries).

¹¹⁴ 2009 FAO STATE OF FISHERIES REPORT, *supra* note 108, at 87.

than suspected; the researchers determined that ocean temperature is a major determinant of marine biodiversity and concluded that changes in ocean temperature “may ultimately rearrange the global distribution of life in the ocean.”¹¹⁵

Temperature changes also affect ocean currents.¹¹⁶ The science-fiction movie *The Day After Tomorrow*¹¹⁷ capitalized on projected changes to one of the largest of the ocean currents, known as the Great Ocean Conveyor. This global “pump” depends on the sinking of cold water in the North Atlantic Ocean, which in turn pulls warm water from the tropics up the coast of the eastern United States and across the Atlantic Ocean to Europe.¹¹⁸ In the fifteen years prior to 2009, cold water in the North Atlantic was not sinking as fast as it used to, leading to speculation that the Great Ocean Conveyor was shutting down.¹¹⁹ However, the sinking of cold water “resumed vigorously” in the winter of 2008–2009, surprising scientists and underscoring just how complex climate change predictions are.¹²⁰

Nevertheless, even if the Great Ocean Conveyor remains intact, smaller changes to ocean current patterns can still disrupt marine ecosystems at the local or regional scale. As one example, much of the northwest coast of the United States, Canada, and Alaska benefits from nutrient-rich upwelling currents that support numerous species of fish — and strong fishing industries — in the northern Pacific Ocean. However, at the beginning of the twenty-first century, a mysterious dead zone grew off the coasts of Oregon and Washington.¹²¹ This dead zone, which occurs in the middle of a commercially important fishery, has been attributed to climate change — specifically, to changing interactions of wind and offshore currents that prevent the normal dissipation of oxygen-deprived waters.¹²² Three other such climate change-related dead zones have been detected, one off the coast of Chile and Peru in South America and one each off the west and east coasts of Africa.¹²³

As climate change impacts increase, more dramatic ecosystem impacts resulting from changing ocean currents are also possible. Indeed, the IPCC projected widespread ecosystem changes as a result of changes in major marine currents beginning at the point when global average temperatures increase by about 2.5 to 3.0°C.¹²⁴

Ocean temperature increases also contribute to sea level rise. Climate change-driven sea level rise occurs for two main reasons. First, water ex-

¹¹⁵ Derek P. Tittensor et al., *Global Patterns and Predictors of Marine Biodiversity Across Taxa*, 466 NATURE 1098, 1098 (2010).

¹¹⁶ MEA 2005: CURRENT STATE AND TRENDS, *supra* note 58, at 490.

¹¹⁷ THE DAY AFTER TOMORROW (Twentieth Century Fox 2004).

¹¹⁸ *Ocean Conveyor's 'Pump' Switches Back On*, WOODS HOLE OCEANOGRAPHIC INST. (Jan. 9, 2009), <http://www.whoi.edu/oceanus/viewArticle.do?id=54347&archives=true>.

¹¹⁹ *See id.*

¹²⁰ *Id.*

¹²¹ *Oregon Dead Zone Blamed on Climate Change*, ENV'T NEWS SERVICE, Oct. 8, 2009, <http://www.ens-newswire.com/ens/oct2009/2009-10-08-092.asp>.

¹²² *Id.*

¹²³ *Id.*

¹²⁴ 2007 IPCC SYNTHESIS REPORT, *supra* note 82, at 51 fig.3.6.

pands as it warms.¹²⁵ Second, hotter atmospheric temperatures are also causing ice caps and glaciers all over the world to melt, providing influxes of fresh water to the oceans and increasing the total volume of water that they hold. According to researchers in this field, “[d]uring the past decade, ocean warming has contributed roughly half of the observed rate of sea-level rise, leaving the other half for ocean-mass increase caused by water exchange with continents, glaciers, and ice sheets.”¹²⁶ Sea-level rise causes multiple impacts on coastal ecosystems, especially with respect to highly productive — but also highly vulnerable — estuaries.¹²⁷

According to the Climate Institute, “[d]uring the 20th century, sea level rose about 15–20 centimeters (roughly 1.5 to 2.0 mm/year), with the rate at the end of the century greater than over the early part of the century.”¹²⁸ However, the more recent unexpected increase in the pace of polar and glacier ice melting around the world has made predicting future sea level rise difficult, to say the least.¹²⁹ Recent studies, for example, indicate that the Greenland ice sheet and Antarctic ice are melting faster than expected.¹³⁰

The estimates of sea-level rise range from six or seven inches in the next century to a possibility of 215 feet over many centuries,¹³¹ suggesting an equally wide — and difficult to predict — range of potential implications for marine ecosystems and their services. However, initial sea-level rise (say, over the next fifty years) is a problem primarily for already low-lying coastal areas. The IPCC indicated that, with about a three-degree Celsius increase in global average temperature, approximately thirty percent of the

¹²⁵ *Id.* at 32 fig.1.2; see also, e.g., Michael Byrnes, *Southern Ocean Rise Due to Warming, Not Ice Melts*, ENVTL. NEWS NETWORK, Feb. 18, 2008, http://www.enn.com/top_stories/article/31325 (reporting that “[r]ises in the sea level around Antarctica in the past decade are almost entirely due [to] a warming ocean, not ice melting,” and quoting a temperature increase of “three-tenths of a degree Celsius”).

¹²⁶ Anny Cazenave, *How Fast Are the Ice Sheets Melting?*, 314 *SCIENCE* 1250, 1250 (2006) (footnotes omitted). But see Mark F. Meier et al., *Glaciers Dominate Eustatic Sea-Level Rise in the 21st Century*, 317 *SCIENCE* 1064, 1065 (2007) (arguing that glaciers and ice caps “contribute about 60% of the eustatic, new-water component of sea-level rise”).

¹²⁷ *Coastal Zones and Sea Level Rise*, U.S. ENV’T PROT. AGENCY, <http://www.epa.gov/climatechange/effects/coastal/index.html> (last visited May 10, 2012) (on file with the Harvard Law School Library).

¹²⁸ *Oceans & Sea Level Rise*, CLIMATE INST., <http://www.climate.org/topics/sea-level/index.html> (last visited May 10, 2012) (on file with the Harvard Law School Library) (footnotes omitted).

¹²⁹ See Cazenave, *supra* note 126, at 1251 (“The greatest uncertainty in sea-level projections is the future behavior of the ice sheets.”).

¹³⁰ See *id.* at 1250–51; J.L. Chen, C.R. Wilson, & B.D. Tapley, *Satellite Gravity Measurements Confirm Accelerated Melting of Greenland Ice Sheet*, 313 *SCIENCE* 1958, 1958–60 (2006).

¹³¹ Vivien Gornitz, *Sea Level Rise, After the Ice Melted and Today*, GODDARD INST. FOR SPACE STUDIES, NASA (Jan. 2007), http://www.giss.nasa.gov/research/briefs/gornitz_09/; *Future Sea Level Changes*, U.S. ENV’T PROT. AGENCY, <http://www.epa.gov/climatechange/science/futureslc.html> (last visited May 10, 2012) (on file with the Harvard Law School Library); see also ANTARCTIC TREATY CONSULTATIVE MEETING XXIX, THE ANTARCTIC AND CLIMATE CHANGE 3 (2006), available at <http://asoc.org/storage/documents/Meetings/ATCM/XXIX/climate%20change%20ip.pdf>.

world's coastal wetlands will be lost,¹³² and barrier islands, mangrove forests, and near-shore coral reefs are similarly vulnerable.

Increasing concentrations of CO₂ in the atmosphere have led to increasing absorption of CO₂ by the oceans, resulting in a phenomenon known as "ocean acidification."¹³³ However, it appears that the ocean's capacity to absorb atmospheric CO₂ may be waning.¹³⁴

Ocean absorption of CO₂ is changing the ocean's chemistry and will continue to do so for some time. Ocean acidification begins when CO₂ in the atmosphere dissolves into seawater.¹³⁵ Once dissolved, CO₂ reacts with the seawater to form carbonic acid.¹³⁶ The oceans are naturally basic, with a pH of about 8.16 that has been remarkably stable over geological time.¹³⁷ However, since the Industrial Revolution, the average ocean surface water pH has dropped by 0.1 units.¹³⁸ While this may sound like a small change, the pH scale is logarithmic, so that a pH decrease of 0.1 unit means that the oceans have become 30% percent more acidic in the last 250 years. 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."¹³⁹ Moreover, the ocean's pH is expected to drop by up to another 0.35 units by the end of the century,¹⁴⁰ causing continued ocean acidification to "an extent and at rates that have not occurred for tens of millions of years."¹⁴¹

These changes to the ocean's pH can interfere with the ability of a variety of marine creatures — "coral, sea urchins, starfish, many shellfish, and some plankton" — to form and maintain their calcium carbonate shells¹⁴² by depriving these organisms of raw materials that they need to grow.¹⁴³ Both ocean acidification and its effects on sea life have already been observed.¹⁴⁴

¹³² 2007 IPCC SYNTHESIS REPORT, *supra* note 82, at 51.

¹³³ Richard A. Feeley, Scott C. Doney, & Sarah R. Cooley, *Ocean Acidification: Present Conditions and Future Changes in a High-CO₂ World*, OCEANOGRAPHY, Dec. 2009, at 36, 37. Almost half of anthropogenic CO₂ emissions remain in the atmosphere; the rest of the CO₂ is divided between the oceans and terrestrial plants. Scott C. Doney et al., *Ocean Acidification: A Critical Emerging Problem for the Ocean Sciences*, OCEANOGRAPHY, Dec. 2009, at 16, 16; *see also* Levy, *supra* note 57, at S53.

¹³⁴ Jeffrey Park, *A Re-Evaluation of the Coherence Between Global-Average Atmospheric CO₂ and Temperatures at Interannual Time Scales*, 36 GEOPHYSICAL RES. LETTERS L22704, L22708 (2009); *see also* *Oceans Absorbing Carbon Dioxide More Slowly, Scientist Finds*, SCI. DAILY, Nov. 24, 2009, <http://www.sciencedaily.com/releases/2009/11/091124140957.htm>.

¹³⁵ *How is Ocean Acidity Changing?*, OCEAN ACIDIFICATION NETWORK, <http://www.ocean-acidification.net/FAQacidity.html> (last visited May 10, 2012) (on file with the Harvard Law School Library).

¹³⁶ *Id.*

¹³⁷ *Ocean Acidification: Another Undesired Side Effect of Fossil Fuel-burning*, SCI. DAILY, May 24, 2008, <http://www.sciencedaily.com/releases/2008/05/080521105151.htm>.

¹³⁸ 2007 IPCC SYNTHESIS REPORT, *supra* note 82, at 52.

¹³⁹ Feely et al., *supra* note 64, at 2.

¹⁴⁰ 2007 IPCC SYNTHESIS REPORT, *supra* note 82, at 52.

¹⁴¹ Feely et al., *supra* note 64, at 2.

¹⁴² PEARCE, *supra* note 61, at 87–88.

¹⁴³ *Id.* at 88.

¹⁴⁴ PETER D. WARD, UNDER A GREEN SKY: GLOBAL WARMING, THE MASS EXTINCTIONS OF THE PAST, AND WHAT THEY CAN TELL US ABOUT OUR FUTURE 121 (2007).

Ocean acidification is also likely to impair coral reefs, leading to declines in coral reef ecosystems and associated losses of marine habitat and biodiversity.¹⁴⁵

However, 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. 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.”¹⁴⁶ At the physical level, decreasing pH levels reduce the oceans’ ability to absorb sound, and the resulting increased noise in the ocean may impact acoustically sensitive whales and dolphins, while decreasing concentrations of calcium carbonate allow for more light penetration that may have unknown effects on ocean life.¹⁴⁷ Ecosystem impacts could be tremendous, resulting in the loss of commercially and locally important fisheries and coastal protection from storms.¹⁴⁸ Because “projected human-driven ocean acidification over this century will be larger and more rapid than anything affecting sea life for tens of millions of years,”¹⁴⁹ the economic and cultural costs for humans, especially those in developing nations and coastal countries, could be enormous.¹⁵⁰

As a harbinger of things to come, climate change impacts, especially increases in SSTs and ocean acidification, are already interacting synergistically to impair the oceans’ primary productivity. Phytoplankton — tiny plants that generally float near the surface of the world’s oceans — are critical to marine ecosystems,¹⁵¹ and chlorophyll provides a measure of plant life in the ocean.¹⁵² According to NOAA, “[t]he downward trend in global chlorophyll observed since 1999 has continued through 2009, with current chlorophyll stocks in the central stratified oceans now approaching record lows since 1997.”¹⁵³ Chlorophyll, and hence phytoplankton growth, is inversely correlated to temperature changes, meaning that as SSTs increase, phytoplankton growth decreases.¹⁵⁴

¹⁴⁵ Joan A. Kleypas & Kimberly K. Yates, *Coral Reefs and Ocean Acidification*, OCEANOGRAPHY, Dec. 2009, at 108, 109.

¹⁴⁶ Doney et al., *supra* note 133, at 18.

¹⁴⁷ *Id.*

¹⁴⁸ *Id.* at 18; *see also* Sarah R. Cooley, Hauke L. Kite-Powell, & Scott C. Doney, *Ocean Acidification’s Potential to Alter Global Marine Ecosystem Services*, OCEANOGRAPHY, Dec. 2009, at 172, 172–76 (detailing these ecosystem impacts).

¹⁴⁹ Doney et al., *supra* note 133, at 24.

¹⁵⁰ *See generally* Cooley et al., *supra* note 148, at 172–76 (detailing the value of marine ecosystem services that could be impacted by ocean acidification).

¹⁵¹ MEA 2005: CURRENT STATE AND TRENDS, *supra* note 58, at 484; Levy, *supra* note 57, at S75.

¹⁵² Levy, *supra* note 57, at S75.

¹⁵³ *Id.* at S53; *see also id.* at S78 & fig.3.33 (“From 1999 onward, an overall progressive decrease in chlorophyll is observed and coincident with a general increasing trend in ocean-surface temperature . . .”).

¹⁵⁴ *See id.* at S77–S78.

III. MAKING MARINE ZONING ADAPTABLE TO CLIMATE CHANGE: THREE THOUGHTS

A. *The Role of Marine Protected Areas and Marine Reserves in a Climate Change Era*

Most existing marine protected areas (“MPAs”) were established without consideration of climate change. Nonetheless, they could facilitate climate change adaptation now and into the future.

Moreover, additional MPAs are likely in the future, and the nations that establish new MPAs should consider climate change in their creation. Currently, for example, the 193 nations¹⁵⁵ that have ratified the United Nations Convention on Biological Diversity¹⁵⁶ — which do not include the United States — are still far from achieving the Convention’s goals regarding MPAs. At the tenth meeting of the Conference of the Parties in October 2010, the parties adopted the Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets.¹⁵⁷ Target 11 is for the parties to protect, by 2020, “10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services,” in MPAs.¹⁵⁸ The parties extended the original deadline of 2012 because, as of 2010, only one percent of marine areas was protected in MPAs.¹⁵⁹ Nevertheless, if party nations continue to pursue this target, they will continue to create MPAs and zone them for some time to come. Further, although the United States is not a party to the Biodiversity Convention, it is pursuing a national system of MPAs,¹⁶⁰ aided by efforts of the states and territories.¹⁶¹ Considerations of climate change impacts, resilience building, and protection for probable “survivor” ecosystems can and should play a role in how these new MPAs are established.

¹⁵⁵ *List of Parties*, CONVENTION ON BIOLOGICAL DIVERSITY, <http://www.cbd.int/convention/parties/list> (last visited May 10, 2012) (on file with the Harvard Law School Library).

¹⁵⁶ United Nations Convention on Biological Diversity, June 5, 1992, 31 I.L.M. 818, 1993 A.T.S. 32 (entered into force Dec. 29, 1993).

¹⁵⁷ *Strategic Plan for Biodiversity 2011–2020, Including Aichi Biodiversity Targets*, CONVENTION ON BIOLOGICAL DIVERSITY, <http://www.cbd.int/sp> (last visited May 10, 2012) (on file with the Harvard Law School Library).

¹⁵⁸ *COP 10 Decision X/2. Strategic Plan for Biodiversity 2011–2020*, CONVENTION ON BIOLOGICAL DIVERSITY, <http://www.cbd.int/decision/cop/?id=12268> (last visited May 10, 2012) (on file with the Harvard Law School Library).

¹⁵⁹ *With Global MPA Coverage Falling Short of 10% Target, Biodiversity Summit Extends Deadline*, MPA NEWS (Marine Affairs Research & Educ., Woodinville, WA), Nov.–Dec. 2010, at 1, 1, available at <http://depts.washington.edu/mpanews/MPA117.pdf>.

¹⁶⁰ Exec. Order No. 13,158, 3 C.F.R. 273 (2001) (calling for a national system of MPAs). NOAA catalogs the system and continues to enroll MPAs into it. See, e.g., *Updates to List of National System of Marine Protected Areas*, 76 Fed. Reg. 16,732, 16,732 (Mar. 25, 2011) (approving thirty-nine MPAs for inclusion in the national system).

¹⁶¹ For example, of the thirty-nine MPAs added to the national system in March 2011, American Samoa established seven of them and California established the other thirty-two. 76 Fed. Reg. at 16,732–33.

An example of an existing MPA with climate change adaptation potential is the Papahānaumokuākea Marine National Monument (“PMNM”), which protects the Northwestern Hawaiian Islands. This island chain stretches more than 1100 miles north and west of the Main Hawaiian Islands that tourists visit¹⁶² (Kaua’i being the farthest north that tourists usually go, although Ni’ihau is also inhabited); laid across the continental United States, the chain would stretch from Washington, D.C. to Minnesota.¹⁶³ The ten small islands and atolls that make up the chain¹⁶⁴ encompass “some of the healthiest and most undisturbed coral reefs on the planet.”¹⁶⁵ These reefs are home to over 7000 species, about twenty-five percent of which are endemic to the islands — that is, found nowhere else on Earth.¹⁶⁶

The islands’ remoteness has protected them and their attendant coral reef ecosystem from many kinds of marine stressors, especially pervasive development and extensive overfishing. Regular tourism has not been a part of these islands since World War II (and even then it was largely limited to Pan Am’s luxury flights to Midway),¹⁶⁷ and it requires a five-hour chartered flight to get from Honolulu to Midway, the only island or atoll with a landing strip. Sea voyages take even longer, and safe landings are difficult on most of the islands and atolls. While Native Hawaiians and high seas fishers from other nations have fished and used these islands to the detriment of certain species such as seals and lobsters,¹⁶⁸ the islands generally have not been the site of long-term, large-scale fishing efforts, especially not since the United States began actively protecting this region at the start of the twentieth century. As a result, the reef system in the Northwestern Hawaiian Islands is

a “predator-dominated ecosystem,” an increasingly rare phenomenon in the world’s oceans For instance, [predator] species comprise only 3 percent of fish biomass in the heavily used main Hawaiian Islands, but by contrast represent 54 percent of fish biomass in the waters of the Monument.¹⁶⁹

In terms of overall fish biomass, “[t]he long-term protection from fishing pressure that has been afforded the NWHI has resulted in high standing

¹⁶² MARK J. RAUZON, *ISLES OF REFUGE: WILDLIFE AND HISTORY OF THE NORTHWESTERN HAWAIIAN ISLANDS* 2 (2001).

¹⁶³ PAPAHAŌAUMOKUĀKEA MARINE NAT’L MONUMENT, PAPAHAŌAUMOKUĀKEA MARINE NATIONAL MONUMENT MANAGEMENT PLAN 5 fig.1.2 (2008) [hereinafter 2008 PMNM MANAGEMENT PLAN], available at http://www.papahānaumokuākea.gov/management/mp/vol1_mmp08.pdf.

¹⁶⁴ RAUZON, *supra* note 162, at 2.

¹⁶⁵ *Northwestern Hawaiian Islands: Encyclopedia of the Sanctuary: Papahānaumokuākea Marine National Monument*, NAT’L MARINE SANCTUARIES, NOAA, <http://www8.nos.noaa.gov/onms/park/Parks/?pID=12> (last visited May 10, 2012) (on file with the Harvard Law School Library).

¹⁶⁶ *Id.*

¹⁶⁷ RAUZON, *supra* note 162, at 152–54.

¹⁶⁸ *Id.* at 65, 73–76, 86–87, 143–44.

¹⁶⁹ 2008 PMNM MANAGEMENT PLAN, *supra* note 163, at 8.

stocks of fish more than 260 percent greater than the main Hawaiian Islands.”¹⁷⁰ To explore these reefs, therefore, is to see tropical coral reefs the way they are “supposed” to be, free of most of the detrimental effects of pervasive fishing, urban runoff, and coastal development.

The relatively pristine nature of the Northwestern Hawaiian Islands’ coral reef ecosystem was a large factor in the U.S. government’s decision to protect it through place-based management. Now that those protections are in place, however, the Northwestern Hawaiian Islands ecosystem could also make several contributions to climate change adaptation.

After a century of executive order protections that began with President Teddy Roosevelt¹⁷¹ and expanded under President Clinton,¹⁷² NOAA was well underway in designating the Northwestern Hawaiian Islands as a National Marine Sanctuary in June 2006. At that point, however, to the surprise of many, President George W. Bush used his authority under the 1906 Antiquities Act¹⁷³ to proclaim the creation of the Northwestern Hawaiian Islands Marine National Monument,¹⁷⁴ later renamed the Papahānaumokuākea Marine National Monument in reference to ancient Hawaiian creation stories.¹⁷⁵ The proclamation established management authority for the PMNM jointly in the U.S. Department of the Interior, exercised through the U.S. Fish & Wildlife Service; the U.S. Department of Commerce, exercised through NOAA; and the State of Hawai’i.¹⁷⁶ It ordered the phase-out of all fishing in the PMNM over five years and subjected almost every activity in the monument to regulation;¹⁷⁷ a notable exception is for military activities.¹⁷⁸ Finally, at the international level, on July 30, 2010, the PMNM was enrolled as a World Heritage site under the U.N. World Heritage Convention, with the designation recognizing the monument’s contributions to protecting both cultural and ecological heritage.¹⁷⁹

The PMNM protects almost 140,000 square miles of coral reef ecosystem.¹⁸⁰ Management of the PMNM is an ecosystem-based approach that relies on marine spatial planning and adaptive management.¹⁸¹ Thus, the PMNM is managed through a place-based governance regime.

¹⁷⁰ *Id.* at 31.

¹⁷¹ Exec. Order No. 1019 (Feb. 3, 1909) (on file with the Harvard Law School Library).

¹⁷² Exec. Order No. 13,022, 3 C.F.R. 224 (1997).

¹⁷³ 16 U.S.C. §§ 431–433 (2006).

¹⁷⁴ Proclamation No. 8031, 71 Fed. Reg. 36,443 (June 26, 2006).

¹⁷⁵ *Papahānaumokuākea: A Sacred Name, A Sacred Place*, PAPAHAANAUMOKUĀKEA MARINE NAT’L MONUMENT, <http://www.papahanaumokuakea.gov/about/name.html> (last visited May 10, 2012) (on file with the Harvard Law School Library).

¹⁷⁶ 71 Fed. Reg. 36,443.

¹⁷⁷ *Id.* at 36,446–47.

¹⁷⁸ *Id.*

¹⁷⁹ *Papahānaumokuākea Marine National Monument Becomes First Mixed UNESCO World Heritage Site in the U.S.*, PAPAHAANAUMOKUĀKEA MARINE NAT’L MONUMENT, <http://www.papahanaumokuakea.gov/wheritage/welcome.html> (last visited May 10, 2012) (on file with the Harvard Law School Library).

¹⁸⁰ 2008 PMNM MANAGEMENT PLAN, *supra* note 163, at ES-1.

¹⁸¹ *Id.* at 85, 100–02.

The entire PMNM is an MPA and a form of marine reserve, where commercial fishing was legally eliminated in 2011,¹⁸² and all non-military access is monitored through permitting and vessel monitoring system requirements.¹⁸³ However, the monument is also zoned for different levels of protection and management goals. As the 2008 Management Plan summarizes, “[m]onument regulations define three types of marine zones to manage activities. The zones are: Special Preservation Areas, Ecological Reserves, and the Midway Atoll Special Management Area (SMA).”¹⁸⁴ In general, “[z]oning provides protection to highly sensitive habitats, particularly shallow coral reefs.”¹⁸⁵ Special Preservation Areas surround Kure Atoll, Pearl and Hermes Atoll, Lisianski Island, Laysan Island, Maro Reef, Gardner Pinnacles, Mokumanamana and part of Nihoa Island; a swath of the French Frigate Shoals area is also designated as a Special Preservation Area.¹⁸⁶ According to the PMNM’s regulations, “SPAs are used to avoid concentrations of uses that could result in declines in species populations or habitat, to reduce conflicts between uses, to protect areas that are critical for sustaining important marine species or habitats, or to provide opportunities for scientific research.”¹⁸⁷ In addition, “resource harvest and almost all forms of discharge are prohibited” in Special Preservation Areas.¹⁸⁸ Midway, in contrast, is surrounded by the Midway Atoll Special Management Area,¹⁸⁹ which extends “out to a distance of 12 nautical miles” and exists “for the enhanced management, protection, and preservation of Monument wildlife and historical resources.”¹⁹⁰ Finally, the areas of ocean surrounding Kure, Midway, and Pearl and Hermes Atolls, outside of the Special Preservation Areas and the Midway Atoll Special Management Area to the limits of the PMNM boundary (essentially, the entire northernmost end of the PMNM), as well as the area surrounding the French Frigate Shoals, are designated as Ecological Reserves.¹⁹¹ This designation protects “contiguous, diverse habitats that provide natural spawning, nursery, and permanent residence areas for the replenishment and genetic protection of marine life, and also [protects and preserves] natural assemblages of habitats and species within areas representing a broad diversity of resources and habitats found within the Monument.”¹⁹²

The PMNM is thus an example of marine spatial planning used to promote ecosystem-based management, but several aspects of the PMNM also

¹⁸² 50 C.F.R. § 404.10(c)(7) (2011). Commercial fishing actually ceased within the PMNM in 2010.

¹⁸³ *Id.* §§ 404.4, 404.11.

¹⁸⁴ 2008 PMNM MANAGEMENT PLAN, *supra* note 163, at 98.

¹⁸⁵ *Id.* at 100.

¹⁸⁶ *Id.* at 99 fig.2.1.

¹⁸⁷ 50 C.F.R. § 404.3.

¹⁸⁸ 2008 PMNM MANAGEMENT PLAN, *supra* note 163, at 100.

¹⁸⁹ *Id.* at 99 fig.2.1.

¹⁹⁰ 50 C.F.R. § 404.3.

¹⁹¹ 2008 PMNM MANAGEMENT PLAN, *supra* note 163, at 99 fig.2.1.

¹⁹² 50 C.F.R. § 404.3.

allow it to promote climate change adaptation. As a preliminary matter, the fact that the PMNM protects coral reefs is itself important. Coral reefs are some of the most economically important marine ecosystems in the world,¹⁹³ providing ecosystem goods, such as fish, and services, such as tourism and storm protection, which together are worth approximately \$375 billion per year worldwide.¹⁹⁴ They are also among the ecosystems most endangered by climate change. As one example, “[o]ver 85 percent of the reefs of Malaysia and Indonesia are threatened” by human activities,¹⁹⁵ which increasingly include anthropogenic climate change.¹⁹⁶ Conventional stressors generally exacerbate such climate change threats because most coral reefs are already stressed as a result of overfishing, marine pollution, habitat destruction, or disease outbreaks.¹⁹⁷

Given the socio-ecological importance of and climate change risks to coral reefs, promoting reefs’ survival and continuing functionality is itself a climate change adaptation effort. Moreover, coral reef MPAs and other place-based approaches to reef ecosystem management are likely to become an increasingly important part of marine climate change adaptation strategies. Indeed, in the Coral Triangle of Southeast Asia (encompassing Indonesia, Malaysia, the Philippines, East Timor, Papua New Guinea, and the Solomon Islands), both the Nature Conservancy and the World Wildlife Fund are spearheading efforts to, respectively, “accelerate the development and effective management of Marine Protected Areas that are resilient in the face of climate change, places that are so ecologically important that they are set aside from intensive human use”¹⁹⁸ and “[r]educe the social, economic and biological impacts of climate change by developing adaptation policies and providing funding, especially for establishing and managing networks of marine protected areas.”¹⁹⁹

¹⁹³ Coral reefs in the Coral Triangle, for example, “provide livelihoods and food to well over 100 million people. They lure tourism dollars, generate export revenue and buffer coastal communities from the onslaught of tropical storms.” *Coral Triangle: Protecting the Most Diverse Reefs on Earth*, THE NATURE CONSERVANCY, <http://www.nature.org/ourinitiatives/regions/asiaandthepacific/coraltriangle/overview/index.htm> (last visited May 10, 2012) (on file with the Harvard Law School Library).

¹⁹⁴ DIRK BRYANT ET AL., REEFS AT RISK: A MAP-BASED INDICATOR OF THREATS TO THE WORLD’S CORAL REEFS 8 (1998), available at <http://pdf.wri.org/reefs.pdf>.

¹⁹⁵ *WRI Maps More Threats to Epicenter of Global Marine Diversity*, CORAL REEF UNIT, UNEP (Feb. 14, 2002), <http://coral.unep.ch/trseapr.htm>.

¹⁹⁶ See *Coral Triangle: Threats*, WORLD WILDLIFE FUND, <http://www.worldwildlife.org/what/wherewework/coraltriangle/threats.html> (last visited May 10, 2012) (on file with the Harvard Law School Library).

¹⁹⁷ ROBERT W. BUDDEMEIER, JOAN A. KLEYPAS, & RICHARD B. ARONSON, PEW CTR. ON GLOBAL CLIMATE CHANGE, CORAL REEFS AND GLOBAL CLIMATE CHANGE: POTENTIAL CONTRIBUTIONS OF CLIMATE CHANGE TO STRESSES ON CORAL REEF ECOSYSTEMS iii (2004) [hereinafter 2004 PEW CORAL REEF CLIMATE CHANGE REPORT], available at http://www.pewclimate.org/docUploads/Coral_Reefs.pdf.

¹⁹⁸ *Coral Triangle: Protecting the Most Diverse Reefs on Earth*, supra note 193.

¹⁹⁹ Fitrian Ardiansyah & Ari Muhammad, *Dealing with Climate Change Dangerous Impacts*, JAKARTA POST, Oct. 13, 2009, available at <http://www.thejakartapost.com/news/2009/10/13/dealing-with-climate-change-dangerous-impacts.html>.

These approaches to protecting coral reefs could also translate to other climate change-threatened marine ecosystems, and the PMNM illustrates several adaptation strategies. First, while the PMNM protects one of the least-exploited coral reef ecosystems in the world, the area is not pristine, providing room for resilience building in the PMNM's management. Recent scientific studies have confirmed that "[m]any orthodox conservation practices, such as the restoration and protection of habitats and the removal of anthropogenic pressures unrelated to climate, will continue to increase species and ecosystem adaptive capacity to climate change."²⁰⁰ Place-based approaches to marine governance give managers a focus for such conventional — but still climate change adaptive — management measures. This fact suggests that many MPAs focused on restoration and protection are already contributing to the climate change adaptability and resilience of those marine ecosystems, even if management plans do not explicitly address climate change.

As discussed above, the PMNM's proclamation and zoning eliminate fishing, restrict access, and establish ocean zones that are not just "no take" but also "no discharge," virtually eliminating the locally controllable sources of marine pollution. In addition, restoration of the islands for wildlife protection purposes is also underway. For example, black rats were introduced to Midway in World War II, virtually extirpating the several local petrel populations.²⁰¹ However, when the military left the atoll in the mid-1990s, the U.S. Department of Agriculture's Wildlife Services unit systematically exterminated the rats, allowing the several species of petrels to re-establish breeding populations.²⁰² The atoll's managers are also actively removing the invasive weed *Verbesina encelioides*, which chokes out ground habitat for albatross and Laysan ducks, in hope of eventually eradicating it from Midway.²⁰³ Soil contamination from military fuels on Midway has largely been eliminated, and remediation of contamination from lead-based paint began in 2005.²⁰⁴ In 2004 and 2005, the endemic Laysan duck was reintroduced to Midway.²⁰⁵ All of these conventional restoration measures, undertaken for purposes other than climate change adaptation, nevertheless contribute positively to the ecosystem's overall resilience and adaptive capacity.

²⁰⁰ Terence P. Dawson et al., *Beyond Predictions: Biodiversity Conservation in a Changing Climate*, 332 SCIENCE 53, 57 (2011).

²⁰¹ 2008 PMNM MANAGEMENT PLAN, *supra* note 163, at 177.

²⁰² *Id.* at 20, 36.

²⁰³ *Midway Atoll National Wildlife Refuge: Management*, U.S. FISH & WILDLIFE SERV., <http://www.fws.gov/midway/management.html> (last visited May 10, 2012) (on file with the Harvard Law School Library).

²⁰⁴ *Midway Atoll National Wildlife Refuge: Lead Paint Abatement*, U.S. FISH & WILDLIFE SERV., <http://www.fws.gov/midway/lpa.html> (last visited May 10, 2012) (on file with the Harvard Law School Library).

²⁰⁵ *Midway Atoll National Wildlife Refuge: Birds of Midway Atoll: Laysan Duck*, U.S. FISH & WILDLIFE SERV., <http://www.fws.gov/midway/ladu.html> (last visited May 10, 2012) (on file with the Harvard Law School Library).

However, place-based protections cannot eliminate all stressors to the Northwestern Hawaiian Islands ecosystem — even the ones unrelated to climate change — because some of them have causes outside the management system. Most obviously, the chain sits right in the middle of the Great Pacific Garbage Patch, a collection of plastic from around the world that gets caught into the northern Pacific gyre, a swirling of ocean currents in the northern Pacific Ocean.²⁰⁶ Plastic accumulation in the waters and on the beaches within the PMNM remains an ongoing and difficult-to-correct problem.²⁰⁷

Nevertheless, even in this context, the PMNM managers are reducing stressors and building resilience by continuing and expanding the plastic removal programs that have been active since 1982.²⁰⁸ NOAA and fourteen partners removed 582 tons of plastic, fishing lines and nets, and other debris from the islands between 1996 and 2007.²⁰⁹

Second, the PMNM, like other well-placed existing MPAs, serves as a biodiversity reservoir for the world as a whole. An April 2011 study in *Science* noted that populations exposed to climate change have “a range of natural coping mechanisms, . . . with diverse consequences for resilience at local to global scales. The capacity to cope depends on both intrinsic factors (species biology, genetic diversity) and extrinsic factors (rate, magnitude, and nature of climactic change).”²¹⁰ MPAs and other place-based management regimes cannot do much about the extrinsic factors, but they *can* improve the intrinsic factors that contribute to an ecosystem’s adaptive capacity, especially when marine reserves and other no-take zones reduce or eliminate fishing pressure and allow depleted stocks to rebuild.²¹¹

As a marine reserve, the PMNM similarly allows depleted stocks (like those of lobsters) to rebuild. Notably in this regard, the monument shelters twenty-three species that are listed as endangered or threatened under both the federal Endangered Species Act²¹² and Hawai’i state law.²¹³ These species range from the charismatic Hawaiian monk seal and green sea turtle to plants without a common name.²¹⁴

Because the coral reef ecosystems of the Northwestern Hawaiian Islands are on the whole less exploited than other coral reef ecosystems, the area protected by PMNM retains a rare level of coral reef biological diver-

²⁰⁶ See 2008 PMNM MANAGEMENT PLAN, *supra* note 163, at 8 fig.1.4; *De-Mystifying the “Great Pacific Garbage Patch”*, OFFICE OF RESPONSE & RESTORATION, NOAA, <http://marine.debris.noaa.gov/info/patch.html> (last visited May 10, 2012) (on file with the Harvard Law School Library).

²⁰⁷ 2008 PMNM MANAGEMENT PLAN, *supra* note 163, at 193.

²⁰⁸ *Id.*

²⁰⁹ *Id.*

²¹⁰ Dawson et al., *supra* note 200, at 53.

²¹¹ See, e.g., James A. Estes et al., *Trophic Downgrading of Planet Earth*, 333 SCIENCE 301, 304 (2011) (noting the rebuilding of lobster populations in no-take marine reserves in California’s Channel Islands).

²¹² 16 U.S.C. §§ 1531–1544 (2006).

²¹³ 2008 PMNM MANAGEMENT PLAN, *supra* note 163, at 43.

²¹⁴ *Id.*

sity and hence biological resilience, although the islands' isolation does render them less biodiverse than some other relatively pristine coral reefs.²¹⁵ The reefs are built and maintained by a wide variety of species of coral and coralline algae, providing the ecosystem with resilience in the face of warming waters or new diseases.²¹⁶ Moreover, as noted, apex predators — the tops of the marine food webs, the presence of which is a sign of ecological health — make up fifty-four percent of the biomass in the Northwestern Hawaiian Islands, compared to three percent in the Main Hawaiian Islands.²¹⁷ A July 2011 study in *Science* emphasized just how rare such ecosystems have become, noting that humans are causing a sixth mass extinction that “has been characterized by the loss of larger-bodied animals in general and of apex consumers in particular.”²¹⁸ Removing apex predators, the authors argue, results in “trophic downgrading” that has “far-reaching effects” on ecosystems, affecting phenomena as diverse as disease dynamics, carbon sequestration, and invasive species.²¹⁹ They traced these effects in several types of marine ecosystems, including seafloor communities in the Aleutian archipelago, California’s rocky intertidal zone, and tropical coral reefs.²²⁰ Moreover, the absence of apex predators can limit the effectiveness of place-based management, because “when large apex consumers are missing, protected areas often fail to function as intended.”²²¹ By protecting an ecosystem where apex predators remain present, the PMNM is protecting not only genetic and species biodiversity but also trophic diversity and ecosystem functionality, and is thus providing insurance against stressors such as invasive species and disease.

Third, effective climate change adaptation in the marine environment will depend on increasing and evolving scientific understanding of how climate change is actually affecting marine ecosystems.²²² Because of the Northwestern Hawaiian Islands’ relative health and full trophic functioning, the PMNM provides coral researchers throughout the world with a climate change reference site. Such reference sites are important both for basic climate change science and for MPA management,²²³ allowing researchers to distinguish the largely unmanageable impacts of climate change from the regulable impacts of more immediate and local human activities — information that is likely to become increasingly important to managers of MPAs near human populations. As the Nature Conservancy’s Eric Conklin has

²¹⁵ See *id.* at 27–43.

²¹⁶ See *id.* at 27–28.

²¹⁷ *Id.* at 31.

²¹⁸ Estes et al., *supra* note 211, at 301.

²¹⁹ *Id.*; see also *id.* at 303 (noting that “trophic cascades have now been documented in all of the world’s major biomes” and that “[t]he impacts of trophic cascades on communities are far-reaching”).

²²⁰ *Id.* at 302 fig.1.

²²¹ *Id.* at 305.

²²² See generally Dawson et al., *supra* note 200, at 53–57 (discussing the need to improve understanding of present and possible future impacts of climate change on biodiversity).

²²³ See 2004 PEW CORAL REEF CLIMATE CHANGE REPORT, *supra* note 197, at iv.

noted, “[t]he value of MPAs isn’t just protection. [They allow you] to manage as many stressors as you can to give reefs the best chance to survive.”²²⁴

Given their remoteness and place-based protections, if the PMNM’s reef ecosystems experience degradation, the likely causes are the ecological impacts of climate change, not human exploitation or carelessness. As a result, the PMNM provides coral reef managers the world over with a baseline of what impacts to coral reef ecosystems are the largely unavoidable results of climate change.²²⁵ Specifically, if reefs elsewhere are experiencing degradation that the PMNM’s reefs are not, there is the distinct possibility that more immediate human activities, apart from climate change, are the cause and hence that better regulation could improve the health of the reefs.

Fourth, climate change adaptation measures will probably arrive at the point of needing to distinguish between places where management is futile — namely where climate change impacts will overwhelm the ecosystem regardless of human effort — and places that will truly benefit from human governance efforts.²²⁶ Given this probable scenario, predicting “survivor ecosystems” may — and arguably should — become an important component of place-based marine governance.

Although the PMNM was not set up for this purpose, the Northwestern Hawaiian Islands may become one of these important “survivor ecosystems.” This tropical coral reef ecosystem exists at the very edge of such reefs’ current range in terms of cold-water temperature tolerance. As Mark Rauzon has observed, “[b]eyond Kure, the waters are too cool for coral to grow.”²²⁷ As such, the PMNM place-based governance regime protects one of the coral reef ecosystems that is most likely to survive the increasing sea surface temperatures that climate change is bringing.

In addition, the PMNM sits — at least with respect to conditions now prevailing — at the receiving end of Pacific currents from Johnson Atoll²²⁸

²²⁴ Interview with Eric Conklin, Dir. of Marine Sci., The Nature Conservancy Haw. Program, in Honolulu, Haw. (July 15, 2010).

²²⁵ Interviews with Eric Conklin, Dir. of Marine Sci., The Nature Conservancy Haw. Program; Terrence R. George, Vice President & Exec. Dir., Harold K.L. Castle Found.; Kim S. Hum, Marine Program Dir., The Nature Conservancy Haw. Program; Jack Kittinger, Dep’t of Geography, Univ. of Haw. at Manoa; John Parks, Senior Advisor, Community-Based Marine Program, The Nature Conservancy Haw. Program; Rodney Salm, Dir., Marine Science & Strategies, The Nature Conservancy S. Pacific/Coral Triangle Programs, in Honolulu, Haw. (July 2010).

²²⁶ See Craig, *supra* note 20, at 70. J.B. Ruhl has more hopefully framed the issue by arguing that one purpose of adaptation law “is to supply interim strategies to put us in a position to resume long-term planning for sustainable development when climate change is ‘over.’ Adaptation law, in other words, is about building a bridge to get us across the chasm of climate change intact.” J.B. Ruhl, *Climate Change Adaptation and the Structural Transformation of Environmental Law*, 40 ENVTL. L. 363, 376 (2010).

²²⁷ RAUZON, *supra* note 162, at 181 (citation omitted).

²²⁸ Joyce Miller et al., *The State of Coral Reef Ecosystems of the Pacific Remote Island Areas*, in THE STATE OF CORAL REEF ECOSYSTEMS IN THE UNITED STATES AND PACIFIC FREELY ASSOCIATED STATES 353, 353 & fig.11.1, 370 (J.E. Waddell & A.M. Clarke eds., 2008), available at <http://ccma.nos.noaa.gov/ecosystems/coralreef/coral2008/pdf/CoralReport2008.pdf>.

and probably Wake Island.²²⁹ More expansively, as the Great Pacific Garbage Patch demonstrates, this area of the Pacific Ocean receives material from the Pacific coasts of both North America and Southeast Asia.²³⁰ Thus, as climate change progresses, the PMNM is well-positioned both to survive all but the most severe impacts of climate change and to serve as a refuge and reservoir for coral reef species from other areas of the world, including, potentially, the northern portions of the species-rich Coral Triangle, such as the Philippines.

The PMNM is thus an example of what might be termed “accidental adaptation” — a place-based marine governance regime set up for other purposes that fortuitously also happens to promote climate change adaptation in a number of ways. Specifically, the PMNM improves the resilience and adaptive capacity of the subject ecosystem, contributes to increased biodiversity, and sets off a site that will provide important scientific knowledge for managers of similar ecosystems and that is more likely than most of its type to be a climate change survivor. The PMNM also suggests factors that governments might consider when establishing new MPAs, marine reserves, and other place-based governance regimes, particularly with regard to enhancing the survivability of marine ecosystems currently at the cold end of their range.

Other governments, however, are taking a more proactive approach to incorporating climate change adaptation into their place-based management regime. The next section discusses this more conscious use of marine spatial planning as a climate change adaptation tool.

B. Actively Incorporating Climate Change Adaptation into Place-Based Marine Governance: The Example of Australia

Nations have addressed marine protection and its relationship to climate change in a variety of ways, including not at all. Australia provides a good first case study because it has been a world leader in both marine spatial

²²⁹ See *id.* at 353 fig.11.1 (showing currents flowing generally from Wake Island toward the Northwestern Hawaiian Islands).

²³⁰ Richard Grant, *Drowning in Plastic: The Great Pacific Garbage Patch Is Twice the Size of France*, THE TELEGRAPH, April 24, 2009, <http://www.telegraph.co.uk/earth/environment/5208645/Drowning-in-plastic-The-Great-Pacific-Garbage-Patch-is-twice-the-size-of-France.html>.

planning²³¹ and climate change adaptation.²³² Moreover, the nation's adaptation focus has a strong marine component.²³³

At the federal level, Australia's marine spatial planning efforts have centered on the Great Barrier Reef, which lies offshore of a large portion of Australia's eastern coast.²³⁴ The Commonwealth of Australia first enacted legislation to establish the Great Barrier Reef Marine Park in 1975.²³⁵ The Park encompasses 344,400 square kilometers (about 132,974 square miles) and runs over 2000 kilometers (1243 miles) long.²³⁶ The entire Park was zoned by 1988 — over twenty years ago.²³⁷ However, “[f]rom 1988 until mid-2004, less than 5 per cent of the entire [Great Barrier Reef] was zoned in highly protected ‘no-take’ zones.”²³⁸

That changed in 2004, when the Great Barrier Reef Marine Park Authority (“GBRMPA”), through an act of the Australian Parliament, comprehensively re-zoned the reef to implement a Representative Areas Program to better protect the reef's biodiversity through an ecosystem-based approach.²³⁹ More specifically, the Representative Areas Program sought to increase the number of no-take zones, referred to as “Green Zones,” within the Park to maintain the ecosystem's biological diversity, “allow species to evolve and function undisturbed,” “provide an ecological safety margin against human-induced disasters,” allow threatened species and habitats to recover,

²³¹ See AGARDY, *supra* note 8, at 60–61.

²³² While Australia, like the United States, delayed in addressing climate change mitigation through the Kyoto Protocol, it has long been conscious of the impacts that climate change is having within its borders, especially with respect to water supply, and of climate change's implications for important resources such as the Great Barrier Reef. Australia now has a commonwealth-level Department of Climate Change and Energy Efficiency and a national climate change adaptation program. *Climate Change Adaptation Program*, AUSTRALIAN DEPARTMENT OF CLIMATE CHANGE & ENERGY EFFICIENCY, <http://www.climatechange.gov.au/government/initiatives/climate-change-adaptation-program.aspx> (last visited May 10, 2012) (on file with the Harvard Law School Library).

²³³ See generally, e.g., AUSTRALIAN DEPARTMENT OF CLIMATE CHANGE & ENERGY EFFICIENCY, *CLIMATE CHANGE RISKS TO AUSTRALIA'S COAST* (2009), available at <http://www.climatechange.gov.au/~media/publications/coastline/cc-risks-full-report.pdf>; AUSTRALIAN DEPARTMENT OF CLIMATE CHANGE & ENERGY EFFICIENCY, *DEVELOPING A NATIONAL COASTAL ADAPTATION AGENDA* (2010), available at <http://www.climatechange.gov.au/~media/publications/adaptation/developing-national-coastal-adaptation-agenda.pdf>; STANDING COMM. ON CLIMATE CHANGE, WATER, ENV'T & THE ARTS, AUSTRALIAN HOUSE OF REPRESENTATIVES, *MANAGING OUR COASTAL ZONE IN A CHANGING CLIMATE: THE TIME TO ACT IS NOW* (2010), available at <http://www.climatechange.gov.au/~media/publications/adaptation/HoR-managing-coastal-zone.pdf>.

²³⁴ See AGARDY, *supra* note 8, at 60.

²³⁵ *Great Barrier Reef Marine Park Act 1975* (Cth) ss 30–31 (Austl.).

²³⁶ AGARDY, *supra* note 8, at 60.

²³⁷ See *id.*

²³⁸ *Id.*

²³⁹ GREAT BARRIER REEF MARINE PARK AUTH., *THE GREAT BARRIER REEF REPRESENTATIVE AREAS PROGRAM: AN ECOSYSTEM APPROACH TO PROTECTING BIODIVERSITY 1* (2003), available at http://kurrawa.gbrmpa.gov.au/corp_site/management/zoning/rap/rap/pdf/rap_overview_brochure.pdf.

and “maintain ecological processes and systems.”²⁴⁰ The new zoning plan also protects examples of all seventy bioregions within the Park.²⁴¹

The 2004 marine spatial plan identifies a number of different kinds of use zones for the Great Barrier Reef Marine Park. The Park is established for multiple uses,²⁴² and some of the zones in the 2004 plan are designed to separate potentially incompatible uses. For example, designated Shipping Areas facilitate the passage of ships through the marine park,²⁴³ while Fisheries Experimental Areas “provide for the continuation of scientific research into the effects of line fishing on the fish stocks and ecosystems of the Great Barrier Reef”²⁴⁴ Finally, Special Management Areas add flexibility to the zoning plan by allowing the GBRMPA to deal with a variety of use conflict situations, including arising problems and emergencies.²⁴⁵

The 2004 zoning plan also creates a number of protective zones offering different levels of protection for different areas of the Park. In General Use Zones (“Light Blue Zones”), most uses are permitted, but the collection of animals and plants is regulated through a permit system.²⁴⁶ In Conservation Parks (“Yellow Zones”), fishing is restricted by gear to a single hook on a line — in essence, to lower-yield recreational fishing.²⁴⁷ Habitat Protection Areas (“Dark Blue Zones”) cover about twenty-eight percent of the Great Barrier Reef Marine Park and protect sensitive habitats, primarily by forbidding trawling.²⁴⁸ Marine National Parks (“Green Zones”) are no-take marine reserves designed to protect biodiversity, where even anchoring is occasionally limited.²⁴⁹ Even more protective are the Preservation Areas (“Pink Zones”), which the GBRMPA describes as “no-go areas”: no entry into these zones is allowed without prior written permission.²⁵⁰ Preservation Areas cover less than one percent of the Park, but they provide high-level protection for special and unique areas that can provide an undisturbed baseline measurement of reef health for use in managing the rest of the ecosystem.²⁵¹ Likewise, public access is forbidden in Scientific Research Areas

²⁴⁰ *Id.* (emphasis added).

²⁴¹ *Id.* at 2.

²⁴² GREAT BARRIER REEF MARINE PARK AUTH., GREAT BARRIER REEF MARINE PARK ZONING PLAN 2003, at 1 (2004) [hereinafter 2003 GBRMP ZONING PLAN], available at http://www.gbrmpa.gov.au/_data/assets/pdf_file/0015/3390/GBRMPA-zoning-plan-2003.pdf.

²⁴³ *Id.* at 5.

²⁴⁴ *Id.*

²⁴⁵ *Id.*

²⁴⁶ *Interpreting Zones*, GREAT BARRIER REEF MARINE PARK AUTH., <http://www.gbrmpa.gov.au/visit-the-reef/zoning/zoning-guide-to-using-the-marine-park/interpreting-zones> (last visited May 10, 2012) (on file with the Harvard Law School Library); see also 2003 GBRMP ZONING PLAN, *supra* note 242, at 16–18 (detailing the requirements for general use zones).

²⁴⁷ *Interpreting Zones*, *supra* note 246; see also 2003 GBRMP ZONING PLAN, *supra* note 242, at 20–23 (detailing the requirements for conservation parks).

²⁴⁸ *Interpreting Zones*, *supra* note 246; see also 2003 GBRMP ZONING PLAN, *supra* note 242, at 18–20 (detailing the requirements for habitat protection areas).

²⁴⁹ *Interpreting Zones*, *supra* note 246.

²⁵⁰ *Id.*; see also 2003 GBRMP ZONING PLAN, *supra* note 242, at 27–28 (detailing the requirements for this zone).

²⁵¹ *Interpreting Zones*, *supra* note 246; see also 2003 GBRMP ZONING PLAN, *supra* note 242, at 29 (detailing the requirements for preservation areas).

(“Orange Zones”); these zones also cover less than one percent of the Park.²⁵² Buffer Zones (“Olive Green Zones”) on the outer edge of the reef provide protection for these lesser-used areas in their natural state; trolling for pelagic species is allowed, but other fishing or collecting is prohibited.²⁵³ These areas cover about three percent of the Park.²⁵⁴ Finally, Estuarine Conservation Zones (“Brown Zones”) protect areas where rivers discharge to the ecosystem.²⁵⁵

As is true in the PMNM, many aspects of the GBRMPA’s biodiversity zoning plan help to make this place-based governance system climate change adaptive, particularly by reducing stressors to the reef and protecting biodiversity, both of which increase the reef’s resilience and adaptive capacity. Nevertheless, the GBRMPA is also now consciously incorporating climate change considerations into its governance regime. Specifically, three years after revising its marine spatial plan, the GBRMPA published the *Great Barrier Reef Climate Change Action Plan*,²⁵⁶ detailing measures to improve the reef’s resilience in the face of climate change impacts.

In this plan, the Authority emphasized that tourism on and near the Great Barrier Reef contributes AUS\$6 billion to the Australian economy each year.²⁵⁷ Moreover, it recognized that a variety of climate change-related impacts were already affecting the reef: coral bleaching events in 1998 and 2002 affected fifty percent of the reef each time and killed five percent of the coral affected; a more localized coral bleaching event in 2006 destroyed forty percent of the coral in the Keppel Islands; and mass die-offs of seabird chicks have been observed during periods of unusually high ocean temperatures.²⁵⁸ The GBRMPA anticipates future impacts on an assortment of other species, including sea turtles and commercially important fish stocks.²⁵⁹

This recognition of climate change impacts, the GBRMPA acknowledged, had governance implications for the marine park. Specifically:

Two major factors will dictate the future health of the Reef: the rate and extent of climate change, and the resilience of the Reef ecosystem to climate change. While the bigger issue of climate change mitigation is a matter for international policy, the resili-

²⁵² *Interpreting Zones*, *supra* note 246; *see also* 2003 GBRMP ZONING PLAN, *supra* note 242, at 25–26 (detailing the requirements for scientific research areas).

²⁵³ *Interpreting Zones*, *supra* note 246; *see also* 2003 GBRMP ZONING PLAN, *supra* note 242, at 23–24 (detailing the requirements for buffer zones).

²⁵⁴ *Interpreting Zones*, *supra* note 246.

²⁵⁵ *Id.*

²⁵⁶ GREAT BARRIER REEF MARINE PARK AUTH., GREAT BARRIER REEF CLIMATE CHANGE ACTION PLAN 2007–2012 (2007), *available at* http://www.gbrmpa.gov.au/__data/assets/pdf_file/0020/4493/climate-change-action-plan-2007-2012.pdf.

²⁵⁷ *Id.* at 4.

²⁵⁸ *Id.* at 3–4.

²⁵⁹ *Id.* at 4.

ence of the Reef is under the influence of local management strategies.²⁶⁰

Thus, it is actively incorporating resilience thinking into its climate change adaptation strategy.

The GBRMPA's Climate Change Action Plan has four objectives. First, the Authority plans to target its science to address climate change issues on the Great Barrier Reef.²⁶¹ Specifically, it seeks to fill in gaps in knowledge about climate change and its impacts on the Great Barrier Reef, including by identifying areas of the reef with both high and low resilience to change.²⁶² Another critical aspect of the science objective is to "[i]dentify thresholds beyond which climate change causes irreversible damage to vulnerable species (eg [sic] sharks, marine turtles, seabirds, corals, fishes and plankton), habitats (eg [sic] seagrass, mangroves and pelagic) and processes (eg [sic] productivity and connectivity)."²⁶³ Finally, the GBRMPA recognizes the need to translate this new scientific information into workable management responses, and it intends to "[u]se cost-benefit analyses to select management responses that maximise ecological resilience while minimising social and economic costs."²⁶⁴

The Authority's second objective is to build and maintain a resilient Great Barrier Reef ecosystem.²⁶⁵ In pursuing this objective, the Authority is focusing on the interaction of climate change and other kinds of stressors to the coral reef ecosystem, "such as degraded water quality, fishing and loss of biological diversity," because "[k]nowledge of the interactions between climate and other stresses helps identify actions that can restore and maintain resilience, and thereby minimise impacts of climate change on the GBR ecosystem."²⁶⁶ Specific actions in furtherance of this objective include addressing water quality issues, including land-based water pollution; assessing and improving the sustainability of Great Barrier Reef fisheries; protecting the species and habitats most vulnerable to climate change; incorporating expected impacts from climate change into environmental regulation, such as water quality targets and environmental health standards; and "[i]dentify[ing] and protect[ing] transition or alternative habitats that will provide for shifts in distribution and abundance of species and habitats (eg [sic] turtle nesting, seabird breeding and productivity zones) affected by climate change."²⁶⁷ Moreover, in pursuit of this objective, the GBRMPA intends to take steps to reduce impacts from climate change and other stressors, such as by investigating management responses to coral bleaching

²⁶⁰ *Id.* at 3.

²⁶¹ *Id.* at 6.

²⁶² *Id.*

²⁶³ *Id.*

²⁶⁴ *Id.*

²⁶⁵ *Id.* at 7.

²⁶⁶ *Id.*

²⁶⁷ *Id.*

events and taking steps to reduce the vulnerability of seabird and sea turtle nesting sites to climate change impacts.²⁶⁸

Pursuant to its third objective, the GBRMPA seeks to improve the adaptability of the communities and industries that depend upon the Great Barrier Reef.²⁶⁹ Most of the actions in pursuit of this objective revolve around assisting local governments and industries in understanding the risks that they face from climate change and helping them identify adaptation strategies and other ways of reducing their vulnerabilities.²⁷⁰

Finally, the GBRMPA seeks to use the Great Barrier Reef as a means of improving Australia's progress in climate change mitigation — that is, reducing greenhouse gas emissions.²⁷¹ As it recognizes, “[t]he fate of coral reefs will ultimately depend on the rate and extent of climate change,” and therefore “[t]he high sensitivity of coral reef ecosystems to climate change creates opportunities for linking emission reduction strategies to improvements in the long-term health of the GBR.”²⁷² Specific actions in pursuit of this objective include community education, community involvement in coral reef monitoring, and community efforts to identify ways to reduce greenhouse gas emissions.²⁷³

Many aspects of this Plan, especially the goals of increasing the Great Barrier Reef's resilience and the scientific studies that might illustrate how best to do that, could eventually influence the zoning plan for the Great Barrier Reef. For example, to protect areas of low resilience or high vulnerability to climate change, the GBRMPA may eventually expand the area of the Great Barrier Reef Marine Park covered by the most protective zones: Preservation Areas and Scientific Research Areas. To date, however, the GBRMPA has focused most of its energy on implementing the third and fourth objectives, working with local communities and industries to make them aware of their climate change vulnerabilities in connection with impacts to the reefs, beginning to pursue adaptation strategies, and working to reduce greenhouse gas emissions.²⁷⁴

For the reef itself, the GBRMPA has begun to implement its Climate Change Adaptation Plan by mapping the entire reef into Google EarthTM.²⁷⁵ This action, while a limited start, nevertheless emphasizes that spatial planning will remain an important tool for the Authority in a climate change era. As the Plan suggests, climate change impacts to particular places within the

²⁶⁸ *Id.*

²⁶⁹ *Id.* at 8.

²⁷⁰ *Id.*

²⁷¹ *Id.* at 9.

²⁷² *Id.*

²⁷³ *Id.*

²⁷⁴ *Climate Change Action Plan Activities Grouped by Action Plan Objective*, GREAT BARRIER REEF MARINE PARK AUTH., <http://www.gbrmpa.gov.au/outlook-for-the-reef/great-barrier-reef-outlook-report/outlook-online> (search “Climate Change Action Plan Activities Grouped by Action Plan Objective”) (last visited May 10, 2012) (on file with the Harvard Law School Library).

²⁷⁵ *Id.*

Great Barrier Reef ecosystem that serve particular functions — seabird nesting, turtle nesting, fish spawning, critical habitat, and so forth — will be the necessary foci of the Authority’s resilience thinking. They will also, however, become the critical indicators of when functionality is shifting and, unfortunately, when the reef’s resilience begins to fail. Thus, place-based awareness and management remain critical to climate change adaptation even though the Great Barrier Reef’s marine zoning plan has not yet fully incorporated climate change.

Notably, however, the GBRMPA is not the only government with authority over stressors to the Great Barrier Reef. In an unusual (for Australia) instance of cooperation between the commonwealth and state governments, the state of Queensland is now actively working to help implement the Action Plan’s second objective by addressing polluted runoff from terrestrial agricultural operations. The Great Barrier Reef thus now provides an example of how marine spatial planning can help to link both various levels of governments and governance of marine ecosystems to governance of the land-based stressors that reduce their resilience.

In 2009, the Commonwealth of Australia and Queensland jointly issued the *Reef Water Quality Protection Plan*.²⁷⁶ The Plan acknowledges that development in the relevant watersheds (“catchments”) “has led to significant pollutant loads entering the Reef, the largest contribution being from agricultural land use activities in the catchment areas.”²⁷⁷ Specifically, “[l]and-derived contaminants, including suspended sediments, nutrients and pesticides are still present in the Reef at concentrations likely to cause environmental harm.”²⁷⁸ The plan consciously balances the reef’s contribution of AUS\$5.4 billion to the Australian economy with the Queensland beef, sugar cane, and horticulture industries’ contributions of AUS\$3.7 billion²⁷⁹ and specifically seeks to enlist the farmers’ help in protecting the reef against the impacts of climate change:

By improving water quality, governments along with rural industry groups and landowners can help the Reef become more resilient and better able to withstand the impacts of climate change. Just as healthy humans are more able to resist and recover from diseases and injuries, healthy ecosystems can recover from acute disturbances or adapt to chronic stressors such as climate change.²⁸⁰

The Reef Water Quality Plan sets ambitious targets, widely acknowledged as unrealistic, for water quality improvements for the Great Barrier Reef. For example, the plan seeks to reduce the end-of-catchment nitrogen,

²⁷⁶ COMMONWEALTH OF AUSTRALIA & QUEENSLAND GOVERNMENT, REEF WATER QUALITY PROTECTION PLAN (2009), available at <http://www.reefplan.qld.gov.au/resources/assets/reef-plan-2009.pdf>.

²⁷⁷ *Id.* at 5.

²⁷⁸ *Id.*

²⁷⁹ *Id.* at 7.

²⁸⁰ *Id.* at 8.

phosphorus, and pesticide loads to the reef by fifty percent each by 2013 and to increase dry-season groundcover in dry tropical grazing land by fifty percent by 2013.²⁸¹ Slightly longer term is the goal of reducing sediment loads by twenty percent by 2020.²⁸²

Nevertheless, the on-the-ground measures to reduce pollutant loading from agricultural operations are likely to begin improving the quality of water running into the Great Barrier Reef. The Queensland Department of Environment and Resource Management (“QDERM”), supported by the Australian Commonwealth, is beginning to implement enforceable water quality requirements on agricultural sources of pollution in the watersheds that impact the reef. The Queensland Great Barrier Reef Protection Amendment Act 2009 amends the Queensland Environment Protection Act 1994 to “reduce the impact of agricultural activities on the quality of water entering the reef” and “contribute to achieving the targets about water quality improvement for the reef under agreements between the State and the Commonwealth from time to time.”²⁸³ Financially, implementation of the Act is being facilitated by an AUS\$50 million, five-year investment from the Queensland government and part of the Commonwealth’s AUS\$200 million Reef Rescue Plan.²⁸⁴ Queensland also announced that it would spend another AUS\$125 million on additional measures to protect and improve the Reef’s water quality.²⁸⁵

The 2009 Act begins the implementation of a regulatory program for agricultural sources of water pollution, specifying the agricultural sources that are regulated and imposing a limited number of water quality improvement requirements on them. In general, the Act targets cattle ranches of 2000 hectares or larger and commercial sugar cane operations.²⁸⁶ However, its requirements also apply to all agricultural properties in the Wet Tropics, Mackay-Whitsunday, and Burdekin dry tropics catchments.²⁸⁷

All farmers subject to the Act must comply, subject to penalties for violation, with fertilizer requirements. Specifically, before these farmers apply fertilizer, they must either comply with a number of conditions specified under the Act *or* have and operate pursuant to an accredited Environmental Risk Management Plan (“ERMP”) that provides an alternative nutrient application procedure to prevent over-fertilization of the property.²⁸⁸ The Act

²⁸¹ *Id.* at 16.

²⁸² *Id.*

²⁸³ *Great Barrier Reef Protection Amendment Act 2009* (Queensl.) s 6 (Austl.) (adding *Environmental Protection Act 1994* [“QEPA”] (Queensl.) s 74 (Austl.)).

²⁸⁴ *ReefWise Farming: Great Barrier Reef Protection Amendment Act 2009*, QUEENSL. DEP’T OF ENV’T & RES. MGMT., 2 (2010), <http://www.reefwise farming.qld.gov.au/pdf/gbrpa-act.pdf>; see also *Caring for Our Country — Reef Rescue*, COMMONWEALTH OF AUSTRALIA, <http://www.nrm.gov.au/funding/reef-rescue/index.html> (last visited May 10, 2012) (on file with the Harvard Law School Library) (discussing financial support at the Commonwealth level).

²⁸⁵ QUEENSL. DEP’T OF ENV’T & RES. MGMT., *supra* note 284, at 2.

²⁸⁶ *Great Barrier Reef Protection Amendment Act 2009* (Queensl.) s 6 (Austl.) (inserting QEPA s 75(1)(a)).

²⁸⁷ *Id.* (inserting QEPA s 75(1)(b)).

²⁸⁸ *Id.* (inserting QEPA s 78).

also requires ERMPs for some farmers, namely those growing sugar cane on more than seventy hectares in the Wet Tropics catchment and those grazing cattle on more than 2000 hectares in the Burdekin dry tropics catchment.²⁸⁹ The Minister can direct that a farmer complete an ERMP if he or she finds that it is necessary or desirable to improve the quality of water leaving the farm or if the farm is causing or may cause an illegal environmental harm.²⁹⁰ Farmers subject to this ERMP requirement had six months from the Act's effective date to comply.²⁹¹

The Act lays out numerous requirements and guidelines for an ERMP,²⁹² which the farmer must meet to receive accreditation. Notably, ERMPs must address *all* contaminants that the farm potentially releases to the reef, including sediments and pesticides as well as nutrients.²⁹³ All ERMPs, whether required or proposed as alternatives, must be submitted to QDERM for accreditation.²⁹⁴ In addition, all farmers working from accredited ERMPs must submit yearly reports to QDERM.²⁹⁵

These requirements appear modest and are probably unlikely to achieve immediately the water quality inputs that would most benefit the Great Barrier Reef. Nevertheless, the Commonwealth and Queensland's cooperative effort demonstrates how place-based ocean governance can incorporate terrestrial as well as marine management measures at the watershed scale, providing one model of a governance system that is explicitly trying to increase the marine ecosystem's resilience to climate change by addressing land-based stressors. Governments within the European Union are also using place-based management to reduce watershed-based stressors to coastal ecosystems.²⁹⁶

C. *Making Marine Spatial Planning Adaptable*

If the PMNM's contributions to climate change adaptation are so far largely accidental, the Great Barrier Reef Marine Park demonstrates a place-based governance system that has consciously incorporated climate change adaptation considerations and expanded actions on those considerations to land-based pollution. Moreover, the GBRMPA has demonstrated that zoning plans can both change — although the re-zoning process took almost a decade — and incorporate flexibility for interim responses, as in the Special Management Areas.

Nevertheless, the Great Barrier Reef Marine Park itself has largely remained stationary. Such stasis is unlikely to become a significant issue for

²⁸⁹ *Id.* (inserting QEPA s 88).

²⁹⁰ *Id.* (inserting QEPA s 89(a)).

²⁹¹ *Id.* s 18 (inserting QEPA s 657).

²⁹² *Id.* s 6 (inserting QEPA ss 94–96).

²⁹³ *Id.* (inserting QEPA s 94).

²⁹⁴ *Id.* (inserting QEPA s 97).

²⁹⁵ *Id.* (inserting QEPA s 105).

²⁹⁶ AGARDY, *supra* note 8, at 11 (discussing projects under the European Water Framework Directive and the Land-Ocean Interactions in the Coastal Zone Initiative).

coral reef ecosystem governance any time soon, because corals grow fairly slowly (generally in the range of centimeters per year). Indeed, coral growth on the Great Barrier Reef may be slowing.²⁹⁷ However, other marine ecosystems are more dynamic, and baseline marine conditions are likely to change in the face of climate change; sea-level rise, temperature increases, ocean acidification, and changing current patterns make fundamental changes in marine ecosystems inevitable at the large scale. In particular, as noted, species are already shifting their ranges poleward, and climate change may directly and irreversibly alter some marine ecosystems in other ways that also change human use patterns.

These climate change-driven alterations in marine ecosystem location and human access and use are likely to make additional dynamism and flexibility in place-based marine governance desirable in the climate change era. This section describes several possible governance responses, some of which are already being experimented with and some of which build on suggestions for increased flexibility in a slightly different marine governance context — fishery management.

1. *Anticipatory Zoning in the Arctic*

In our climate change era, place-based marine governance may increasingly eschew a limited focus on existing ecosystem locations, uses, and management needs in favor of management based on predictions for the future. This Article refers to this approach as “anticipatory zoning” — the implementation of governance regimes based on observed trends in ecological response to climate impacts and predictions about resulting management needs.

The United States has already engaged in climate change-based anticipatory zoning in the Arctic. The Arctic region is experiencing significant impacts from climate change, as the Arctic Climate Impact Assessment (“ACIA”) team documented in 2004.²⁹⁸ Among its findings, the ACIA concluded that “[r]educed sea ice is very likely to increase marine transport and access to resources” in the Arctic Ocean.²⁹⁹

This finding has been supported by actual observations of Arctic sea ice. The ACIA projected that the Arctic Ocean navigation season would be three to five times longer by 2080, increasing to 90 to 100 days for ordinary ships and to perhaps as much as 150 days for ice-breaking ships.³⁰⁰ By the next year, however, scientists were announcing that Arctic ice was melting faster than expected. In early 2011, the international Arctic Monitoring and Assessment Program projected nearly ice-free summers for the Arctic Ocean

²⁹⁷ James Randerson, *Slowdown of Coral Growth Extremely Worrying, Say Scientists*, GUARDIAN, Jan. 1, 2009, <http://www.guardian.co.uk/environment/2009/jan/01/1>.

²⁹⁸ ARCTIC CLIMATE IMPACT ASSESSMENT, IMPACTS OF A WARMING ARCTIC 8–12 (2004), available at <http://amap.no/acia/>.

²⁹⁹ *Id.* at 11.

³⁰⁰ *See id.* at 83.

by the middle of the twenty-first century.³⁰¹ The World Resources Institute concurs, noting that “Arctic perennial sea ice is disappearing at a rate of nearly nine percent per decade as a result of global warming. If this trend continues, summer ice could be completely melted as early as 2040, meaning that arctic ice would no longer be a year-long phenomenon.”³⁰²

One highly predictable result of the retreat of Arctic sea ice is vastly increased use of the Arctic Ocean by commercial fishers. Equally predictable is that unregulated fishing could devastate these newly accessible ecosystems. For example, Australia’s Boult Reef was closed to leopard grouper fishing for three and a half years to allow the population to recover, but when fishing reopened, “intensive fishing removed 25% of the stock within only two weeks”³⁰³

In recognition of the threat that quickly expanding fishing efforts could pose to the Arctic’s largely unstudied ecosystems,³⁰⁴ in August 2009, NOAA’s North Pacific Fishery Management Council established, pursuant to its authority under the Magnuson-Stevens Fishery Conservation and Management Act,³⁰⁵ the Arctic Management Area in the federal waters of the Chukchi and Beaufort Seas along the northwestern and northern coasts of Alaska.³⁰⁶ The Fishery Management Plan for this new management area is simple: “The Arctic Management Area is closed to commercial fishing until such time in the future that sufficient information is available with which to initiate a planning process for commercial fishery development.”³⁰⁷ As a result, the Arctic Management Area is an example of place-based governance, currently functioning as a large marine reserve, that was created explicitly in anticipation of human adaptation to climate change’s impacts in the Arctic Ocean — namely, the exploitation of marine resources that were previously inaccessible at a commercial scale.³⁰⁸

The Council’s anticipatory intervention is thus a climate change adaptation governance measure, designed to ensure that human adaptation responses do not destroy these newly exposed ecosystems. In addition, however, this anticipatory zoning should also ensure that evolving governance regimes — the Council does anticipate the potential allowance of at

³⁰¹ ARCTIC MONITORING & ASSESSMENT PROGRAM, SNOW, WATER, ICE AND PERMAFROST IN THE ARCTIC 7 (2011), available at <http://amap.no/swipa/>.

³⁰² Crystal Davis, *Melting Arctic Sea Ice Threatens Polar Bears*, WORLD RESOURCES INST. EARTHTRENDS (Jan. 8, 2007, 8:52 PM), <http://earthtrends.wri.org/updates/node/138>.

³⁰³ CALLUM M. ROBERTS & JULIE P. HAWKINS, FULLY PROTECTED MARINE RESERVES: A GUIDE 59 (2000) (citation omitted).

³⁰⁴ See N. PACIFIC FISHERY MGMT. COUNCIL, NOAA, FISHERY MANAGEMENT PLAN FOR FISH RESOURCES OF THE ARCTIC MANAGEMENT AREA 4, 9 (2009) [hereinafter 2009 ARCTIC FMP], available at <http://www.fakr.noaa.gov/npfmc/PDFdocuments/fmp/Arctic/ArcticFMP.pdf>.

³⁰⁵ 16 U.S.C. § 1801–1884 (2006).

³⁰⁶ 2009 ARCTIC FMP, *supra* note 304, at 1; *see also* 74 Fed. Reg. 56,734 (Nov. 3, 2009) (publishing final rule to implement the Fishery Management Plan).

³⁰⁷ 2009 ARCTIC FMP, *supra* note 304, at 2.

³⁰⁸ *See id.* at 4.

least some commercial fisheries in the future³⁰⁹ — are cognizant of the ecosystems' own needs to adapt to changing conditions. Notably, the Council viewed the Arctic Management Area “as an opportunity for implementing an ecosystem-based management policy that recognizes [the management] issues” that climate change is creating in the region.³¹⁰

Anticipatory zoning could become an increasingly important tool for marine governance in the climate change era, allowing governments to anticipate future needs and desired uses in light of changing environmental and ecological conditions. Commercial fishing dependent on patterns of upwelling is one obvious example: if ocean currents are changing, as appears to already have occurred in several important fishing grounds, governance regimes based on marine spatial planning should also anticipate shifts in the locations of commercial fishing efforts. Other potential beneficiaries of anticipatory zoning could be offshore wind farms. Climate change is predicted to change prevailing wind patterns in at least some areas, which may have direct consequences for the viability of offshore wind farms. Given the infrastructure investments involved, anticipating viable locations for wind turbines would benefit both the investors and the consumers seeking non-fossil-fuel sources of electricity.

2. *Dynamic Zoning*

As noted, all ocean zoning plans are (or should be) subject to amendment, and in that sense, all ocean zoning is dynamic. Nevertheless, “dynamic zoning,” as used in this Article, refers to zones that move *as a matter of zone design*. Such zones are already proving useful in places where key species in marine ecosystems continually shift locations through the course of the year; in the future, they could prove helpful (probably on longer time scales) in managing species assemblages or even ecosystems that are known to be shifting their ranges.

One example of dynamic zoning is TurtleWatch, a fisheries management tool designed to reduce loggerhead sea turtle bycatch in the long-line fisheries off of Hawai'i.³¹¹ Loggerhead sea turtles are listed for protection as a threatened species under the federal Endangered Species Act,³¹² which limits the allowable bycatch in the long-line fishery. Excessive interactions with loggerhead sea turtles in the last decade led to closures of the fishery, limited entry access, gear restrictions, and an annual shutdown once seven-

³⁰⁹ See *id.* at 12.

³¹⁰ *Id.* at 4.

³¹¹ Evan A. Howell et al., *TurtleWatch: A Tool to Aid in the Bycatch Reduction of Loggerhead Turtles *Caretta caretta* in the Hawaii-Based Pelagic Long-Line Fishery*, 5 ENDANGERED SPECIES RES. 267, 267 (2008), available at <http://www.int-res.com/articles/esr2008/5/n005p267.pdf>.

³¹² *Loggerhead Turtle (Caretta caretta)*, OFFICE OF PROTECTED RES., NOAA, <http://www.nmfs.noaa.gov/pr/species/turtles/loggerhead.htm> (last visited May 10, 2012) (on file with the Harvard Law School Library).

teen interactions that qualify as “takes” have occurred.³¹³ Because most interactions occur in the first quarter of the year, the long-line fishery can close down as early as March.³¹⁴

One problem in minimizing bycatch is that loggerhead turtles move around, hatching on nesting beaches in Japan, spending juvenile stages in the open ocean (pelagic zone), migrating to the coastal zone (neritic zone) later in life, and then returning to nesting beaches.³¹⁵ Moreover, juvenile sea turtles migrate within the Pacific Ocean, occupying a more northern range in the first quarter of the year.³¹⁶ There, sea turtle migration patterns follow the Transition Zone Chlorophyll Front, “an important migration and forage pathway for many pelagic animals,” which is in turn associated with the 65°F (about 18°C) isotherm.³¹⁷ In other words, if you want to know where loggerhead sea turtles are in the pelagic zone, temperature and chlorophyll are both important indicators, although the project focused on temperature.³¹⁸

TurtleWatch uses this knowledge to map, on a daily basis, the location of the 65.5°F (about 18.5°C) isotherm, recommending that long-line fishers not fish north of that line in recognition that most turtles like to stay in waters that are 65°F or colder.³¹⁹ The result, in effect, is a moving recommended fishing zone, which appears effective in reducing loggerhead sea turtle bycatch, especially in the first quarter of the year: “The majority (65%) of all loggerhead turtle bycatch in 2007 occurred in the area where fishing was discouraged by the TurtleWatch product.”³²⁰ Observation of TurtleWatch’s recommendations is not mandatory, but it is in the fishers’ collective best interests to observe them, because fewer bycatch incidents in the critical first quarter of the year potentially extends the long-line fishery season for everyone.³²¹

While TurtleWatch responds to normal variations in ocean temperature, similar kinds of dynamic zones could be created to respond to the longer-term needs of other temperature-sensitive species adapting to oceans that are, on average, warming. Ocean governance regimes might, for example, create no-take marine reserves whose boundaries shift automatically in response to species-significant changes in sea surface temperature, whether caused by phenomena such as El Niño and La Niña oscillations or longer-term climate change impacts.

³¹³ Howell et al., *supra* note 311, at 268.

³¹⁴ *Id.*

³¹⁵ *See id.* at 267.

³¹⁶ *Id.* at 268.

³¹⁷ *Id.* (citations omitted).

³¹⁸ *Id.* at 275.

³¹⁹ *Id.* at 275–76.

³²⁰ *Id.* at 276.

³²¹ *Id.* at 276–77. Notably, although the authors do not discuss this facet of their research, TurtleWatch at least potentially creates a host of collective action and commons management problems, which may help to explain why some fishers continue to “cheat” — although not illegally — and ignore the recommended boundary.

Commercial aquaculture operations might also benefit from dynamic zoning and the opportunity to shift locations. In Tasmania, Australia, for example, a group of offshore salmon farmers are located in “a climate change ‘hot spot’ where sea temperatures are increasing four times faster than the global average.”³²² They are hoping to benefit from predictions of sea temperatures three months in advance, which would allow them to shift the location of their operations and keep the temperature-sensitive salmon healthy.³²³

3. *Anticipatory Bidding for Future Use Rights: A Thought*

Anticipatory zoning and dynamic zoning could also be creatively combined to harness private resources to improve our collective scientific knowledge about actual climate change impacts on various marine environments while simultaneously limiting future uses made possible by those impacts, preventing damaging exploitation. Auctioning of potential future use rights within an anticipatory place-based marine governance regime, through mechanisms akin to how the federal government currently licenses offshore oil and gas exploration and drilling, is one potential mechanism for accomplishing this goal.

Josh Eagle, James Sanchirico, and Barton H. Thompson have already argued that more creative implementation of marine use rights could increase the flexibility of marine spatial planning with respect to fishery management.³²⁴ In these authors’ view, “[o]cean zoning . . . is not a panacea; rather, zoning creates a framework that can facilitate both the re-alignment of industry incentives as well as the attainment of the broader goal of healthier ocean ecosystems.”³²⁵ Zoning the oceans, they note, can be used to create group property rights, which allow for new kinds of inter-group bargaining.³²⁶ As they recognize, a completely static marine governance structure based on zoning does not allow uses to adjust to ecological changes.³²⁷

Eagle, Sanchirico, and Thompson advocate first for the establishment of dominant-use zones in marine spatial planning — zones that prioritize a single use, such as fishing or diving, but that also “permit non-priority uses where that use can be conducted in a manner consistent with the overall

³²² *Sea Temp Research Will Aid Tasmanian Aquaculture*, ABC RURAL (Feb. 17, 2011), <http://www.abc.net.au/rural/news/content/201102/s3141230.htm>.

³²³ *Id.*; see also *Marine Climate Impacts and Adaptation*, CSIRO MARINE & ATMOSPHERIC RESEARCH, <http://www.cmar.csiro.au/climateimpacts/projects.htm> (last visited May 10, 2012) (on file with the Harvard Law School Library) (describing its current project of forecasting ocean temperatures for salmon farming).

³²⁴ Josh Eagle, James N. Sanchirico, & Barton H. Thompson, Jr., *Ocean Zoning and Spatial Access Privileges: Rewriting the Tragedy of the Regulated Ocean*, 17 N.Y.U. ENVTL. L.J. 646, 651–54 (2008).

³²⁵ *Id.* at 651.

³²⁶ *Id.* at 653.

³²⁷ *Id.* at 666.

purpose of the zone.”³²⁸ Governing bodies can then assign use rights to particular entities or groups that engage in the priority use.³²⁹ Such assignment provides those entities and groups with both stewardship incentives, because they effectively control the area resource of interest, and a basis for bargaining with other potential users and rightsholders in other zones, because they hold recognized property rights in a system that allows for multiple uses in the different zones.³³⁰ In particular, these property rights and bargaining ability would allow the initial marine zoning scheme to accommodate alterations in fisheries resources by “[a]llowing the groups the right to negotiate and trade uses over space and time.”³³¹ Moreover, the negotiations themselves would also reveal groups’ preferences and valuation of particular uses and resources,³³² information that is important to ocean governance generally but traditionally difficult to obtain.

While new assignments of property rights and decisions to limit access should always be approached with caution, especially in commons resources like the oceans, several limitations could enhance the appeal of experimenting with these tradable use rights. First, just as few areas of the ocean are currently zoned as no-take marine reserves, zones implementing tradable use rights do not need to blanket the seas to improve marine governance. Initially, such zoning might be particularly useful in places where important economic uses of the relevant ecosystem are known to shift location, such as in response to changes in prevailing current patterns. Second, there is no reason that the proposed use rights would require the legal solidity (and potential compensability) of even an easement. Long-term licenses or permits, replete with conditions for revocation and precautionary and protective limitations on the use rights actually being granted, should ordinarily suffice.³³³ Third, when applied in ecosystems and to resources with acknowledged needs for increased management, these leased use rights would not significantly differ in principle from existing limited-entry fisheries³³⁴ and diving access restrictions.³³⁵

³²⁸ *Id.* at 654.

³²⁹ *Id.* at 663.

³³⁰ *Id.* at 663–64.

³³¹ *Id.* at 664; *see also id.* at 664 n.71 (describing how “many species in the ocean environment move over large areas, such as bluefin tuna and sharks, and El Nino and La Nina events shift ocean temperatures and species distributions across space”).

³³² *Id.* at 665.

³³³ Notably, even oil and gas leases under the Outer Continental Shelf Submerged Lands Act initially last only five to ten years, 43 U.S.C. § 1337(b)(2)(A)–(B) (2006), and allow the Secretary of the Interior to cancel the lease — admittedly with compensation — if environmental problems develop, *id.* § 1334(a)(2)(A).

³³⁴ NOAA’s Fishery Management Councils, for example, have created at least fifteen limited access fisheries. *Catch Shares*, OFFICE OF SUSTAINABLE FISHERIES, NOAA, http://www.nmfs.noaa.gov/sfa/domes_fish/catchshare/index.htm (last visited May 10, 2012) (on file with the Harvard Law School Library).

³³⁵ For example, in Hawaii’s Molokini Shoal Marine Life Conservation District, no anchoring is allowed, and commercial dive boats must have a permit to use one of the limited mooring sites. *Marine Life Conservation District: Maui — Molokini Shoal*, HAW. DIV. OF

With those precautionary caveats, the authors' flexible marine use rights system suggests several extensions that could make ocean zoning more flexibly adaptable to climate change and its impacts. For example, this Article has already discussed how the value of the Great Barrier Reef to Queensland and Australia as a whole have induced the two governments to work cooperatively to begin to address land-based water pollution that impacts the reef. A flexible use rights system could induce the same kinds of negotiations in the private sector by making the value of the marine ecosystem clear and identifiable in particular rights holders. As one fairly straightforward example, a group holding the dive use rights for a particular zone or a coalition of all the groups holding dive use rights for all the diving priority zones in a particular ecosystem's zoning plan might well find it worthwhile to bargain with land-based polluters to reduce the amount of pollution, such as runoff from farms or forestry operations or sewage system overflows, that reaches the dive sites. Such bargaining would increase the value of the diving use rights by ensuring divers consistently better dive experiences and cleaner and more healthful water to swim in. However, as with the Great Barrier Reef, it would also more generally increase the resilience of the marine ecosystem, at least potentially increasing that ecosystem's ability to absorb and recover from climate change-induced stresses. As such, this flexible bargaining authority would increase the ability of marine spatial planning to participate in and enhance climate change adaptability.

Even more expansively, marine spatial planners could anticipate future zoning needs, as the North Pacific Fishery Management Council did in Alaska, and build future use rights into a climate change-minded zoning plan. For example, as climate change increases ocean temperatures, kelp forests on the west coast may begin to shift north. Unlike coral reefs, many species of kelp grow very quickly.³³⁶ Marine spatial planners who can anticipate the migration of these highly productive marine ecosystems should consider including provisional "climate change zones" in their planning processes. Interested user groups could then bid for what is essentially a future interest in the use rights for these climate change zones, allowing the zoning/user group system to migrate with climate change impacts.

As with the static anticipatory marine zoning in the Arctic, this anticipation of climate change-induced shifts in marine ecosystem use could help to ensure that newly productive areas are not decimated before effective regulation can be enacted. However, unlike the complete (if temporary) elimination of access in the Arctic, the combination of anticipatory zoning (perhaps with dynamic zoning triggers in some circumstances) and auctioning of use rights assures future access, perhaps increasing political support for anticipatory protections.

AQUATIC RES., <http://hawaii.gov/dlnr/dar/mlcd/molokini.html> (last visited May 10, 2012) (on file with the Harvard Law School Library).

³³⁶ *Monterey Bay Sanctuary: Kelp Forests*, MONTEREY BAY NAT'L MARINE SANCTUARY, <http://www.sanctuariesimon.org/monterey/sections/kelpForests/overview.php?sec=kf> (last visited May 10, 2012) (on file with the Harvard Law School Library).

The combined approach might also induce increased private investment in basic climate change research. In offshore oil and gas leasing, government auctions of designated plots of submerged lands drive private entities — the oil and gas companies — to invest in basic research to try to anticipate which lease areas are likely to contain commercially profitable oil and gas reserves.³³⁷ In the process, overall understanding of these offshore areas improves dramatically.³³⁸ While some of this information is deemed proprietary, well owners have to report proven reserves to the Securities and Exchange Commission.³³⁹ Moreover, the federal government receives revenues from the leasing program in the forms of bonus bids, rents, and royalties.³⁴⁰

Anticipatory marine zoning plans that allow for auctioning of future use rights need not be structured in exactly the same manner as oil and gas leasing; for example, minimum bids might be proportionately lower, but the bidding process might require successful bidders to disclose all relevant climate change projections and ecosystem modeling. Nevertheless, marine spatial planning that anticipates climate change, coupled with auctions of future use rights, could help to induce private entities to engage in research that would help to fill that most basic of climate change adaptation knowledge gaps: what are the local impacts of climate change likely to be? Moreover, the accumulation of such private research could help more generally to improve marine governance in this climate change era.

CONCLUSION

Current approaches to ocean governance in the United States suffer from acknowledged limitations, particularly regulatory fragmentation and a resource-by-resource focus in management programs. Marine spatial planning and ocean zoning offer a more holistic approach to marine governance that can help to overcome these limitations.

However, as governments increasingly rely upon marine spatial planning in the twenty-first century, they should be cognizant that they employ this governance tool in a climate change era. To be sure, the PMNM demonstrates that some of the goals of specific kinds of marine zones are inherently climate change adaptive because they function (if rationally established and adequately enforced) to reduce marine ecosystems' existing stressors — overfishing, habitat destruction, and some forms of marine pollution — and

³³⁷ See David R. Baker, *The Lowdown on Offshore Oil Reserves*, S.F. CHRON., July 22, 2008, at A-1, available at <http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2008/07/21/MN6M11SN60.DTL> (noting that offshore oil exploration “is slow and costly,” with uncertain results until wells are actually drilled).

³³⁸ MARC HUMPHRIES, ROBERT PIROG, & GENE WHITNEY, CONG. RESEARCH SERV., R40645, U.S. OFFSHORE OIL & GAS RESOURCES: PROSPECTS AND PROCESSES 11 (2010), available at <http://fpc.state.gov/documents/organization/142736.pdf> (“Exploration and production proceed in stages during which increasing data provide increasing certainty about volumes of oil and gas present.”).

³³⁹ *Id.*

³⁴⁰ *Id.* at 17.

hence to increase the resilience and adaptive capacity of those ecosystems. Conversely, it must never be forgotten that marine spatial planning is not a panacea that can resolve all marine governance issues. In particular, the root causes of climate change, emissions of greenhouse gases, cannot be addressed (except in very limited fashion) through place-based marine ecosystem management; instead, climate change mitigation requires different and more international solutions.

Nevertheless, in between these two extremes — climate change obliviousness and climate change futility — marine spatial planning techniques could do much to enhance climate change adaptation programs and ocean governance. Increased use of MPAs is already promoted as a climate change adaptation strategy in threatened marine ecosystems like the reefs of the Coral Triangle; governance regimes might also increasingly prioritize the place-based protection of likely climate change survivors — those marine ecosystems that, because of relative health, location, or other factors, are more likely to survive expected climate change impacts as functional (if altered) ecosystems than other ecosystems of the same type. Fishery managers are already experimenting with anticipatory and dynamic zoning; use of these techniques could be extended to pursue broader ecosystem and climate change adaptation goals. Finally, carefully implemented and initially limited use rights auctions, coupled with other innovations in marine zoning, could result in flexible and climate change-cognizant marine spatial planning that both anticipatorily manages expected future uses of the oceans and generates increased understanding of what climate change actually means for local adaptation and governance.