Re-Valuing the Ocean in Law: Exploiting the Panarchy Paradox of a Complex System Approach

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The United States controls more ocean territory than land territory, and it depends upon marine resources for fuel, transportation, food, and recreation, among other things. U.S. law and policy currently address marine resources on a resource-by-resource and often species-by-species basis, leading to valuations of the ocean's parts rather than a more comprehensive appreciation for its multiple roles in supporting human well-being. While marine valuation is shifting to the ecosystem level as a result of the increasing importance of marine tourism, the development of ecosystem services valuation and its incorporation into natural resources damages, and adoption of ecosystem-based management, it remains very difficult to value the ocean as a complex system. Nevertheless, the attempt to do so becomes increasingly critical, because the entire ocean is changing pervasively in ways that threaten all the aspects of the ocean

that humans already value, as well as services like oxygen production that humanity should value but generally does not.

Unlike most single-issue ocean law scholarship, this Article steps back to argue that we need to re-value the ocean in law as a complex adaptive system. The failure to recognize our increasing vulnerability from the ocean's complex and changing system leaves law fundamentally unable to cope with those changes. In contrast, a broader perspective, such as that provided by the Planetary Boundaries Project, illuminates the increasing importance of governance measures that are both less intuitively obvious and less difficult to address than climate change, such as promoting resilience-enhancing marine food security and more effectively regulating nutrient pollution. Thus, re-valuing the ocean as a complex adaptive system empowers adaptation governance to exploit this panarchy paradox by pursuing immediately possible, politically palatable, and technologically achievable governance interventions into ocean management.

> "I hope you will abandon the urge to simplify everything, to look for formulas and easy answers, and begin to think multidimensionally, to glory in the mystery and paradoxes of life, not to be dismayed by the multitude of causes and consequences that are inherent in each experience—to appreciate the fact that life is complex."
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> — M. Scott Peck, *Further Along the Road Less Traveled* (1993)

I. INTRODUCTION

There is no question that humans have valued the ocean[1]—and particularly the coastal parts of the ocean—for centuries. "Estuaries and coastal seas have been focal points of human settlement and marine resource use throughout history,"[2] largely because "[c]oastal ecosystems are among the most rich and diverse in the world, providing important global functions (ecosystem services) for marine ecosystems and atmospheric composition."[3] Indeed, the sea has supported humanity since prehistoric times, and marine fishing continues to tie us to our ancestors: fishing "not only survived but expanded to provide rations for

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[1] This Article refers to the planet's marine realm as the "ocean" rather than "oceans" to emphasize that the bodies of water that humans choose to refer to as separate entities, such as the Atlantic Ocean, the Pacific Ocean, the Southern Ocean, the Mediterranean Sea, and so forth, are in fact components of one complex and intimately connected system. Thus, it uses the plural "oceans" only within quotations.

[2] Heike K Lotze et al., *Depletion, Degradation, and Recovery Potential of Estuaries and Coastal Seas*, 312 SCI. 1806, 1806 (2006).

[3] Sara Curran et al., *Interactions Between Coastal and Marine Ecosystems and Human Population Systems: Perspectives on How Consumption Mediates this Interaction*, 31 AMBIO 264, 264 (2002).

pharaohs, provisions for Norse sailors, and, today, food for millions of us."[4] Although the deeper parts of the ocean have been more difficult to access throughout much of human history, "[t]he oceans have long been recognized as one of humanity's most important natural resources."[5]

Beyond its immediate importance to humanity, the ocean, which covers 71% of the planet's surface, also dominates the biosphere and the surface systems of Planet Earth. It drives the hydrological cycle, stores and distributes solar heat, provides the water vapor that helps to determine daily weather, interacts with the atmosphere to modulate the planetary climate system, supporting a variety of ecosystems and biodiversity more generally, and acts as a sink for both carbon dioxide and land-based nutrients.[6] Life itself almost certainly began in the sea, and, "[e]ven now, almost all life on earth, both on land and in the seas, takes place in an internal aqueous medium, not much different from the chemical composition of the oceans. In several very real senses, the oceans are the source of all life on earth."[7]

At this larger scale, the ocean plays a principal role in both dampening and mediating the changes of the Anthropocene,[8] especially those wrought by the anthropogenic increase in greenhouse gas (especially carbon dioxide) concentrations in the atmosphere. Climate perhaps can be best understood as the conditions that result primarily from the atmosphere's and the ocean's combined efforts to redistribute solar radiation, in the form of heat, from the Earth's equator to the poles.[9] As such, even as the ocean itself experiences the impacts of increasing greenhouse gas concentrations, such as warming waters and

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[4] BRIAN FAGAN, FISHING: HOW THE SEA FED CIVILIZATION, at ix (2017).

[5] Robert Costanza, *The Ecological, Economic, and Social Importance of the Oceans*, 31 ECOLOGICAL ECON. 199, 199 (1999).

[6] *Id.* at 200.

[7] *Id.*

[8] The term "Anthropocene" has both a stricter geological meaning and a more colloquial meaning, but both acknowledge that humanity has become the primary driver of planetary change through habitat destruction, biodiversity loss, and, of course, climate change and ocean acidification. MELINDA HARM BENSON & ROBIN KUNDIS CRAIG, THE END OF SUSTAINABILITY: RESILIENCE AND THE FUTURE OF ENVIRONMENTAL GOVERNANCE IN THE ANTHROPOCENE 4-7 (2017) (collecting references). The official geological designation remains a work-in-progress, although the Anthropocene Working Group voted overwhelmingly in 2019 to recommend the new designation to the International Commission on Stratigraphy. *See* Meera Subramanian, *Anthropocene Now: Influential Panel Votes to Recognize Earth's New Epoch*, NATURE (May 21, 2019), https://www.nature.com/articles/d41586-019-01641-5.

[9] *How Does the Ocean Affect Climate and Weather on Land?*, NOAA OCEAN EXPLORATION, https://oceanexplorer.noaa.gov/facts/climate.html (last visited July 12, 2021).

ocean acidification, it also helps to define what climate change means for every social-ecological system on the planet.[10]

At the same time, the ocean itself is changing.[11] Increased greenhouse gas concentrations in the atmosphere have five principal impacts on the ocean.[12] All but one of these impacts derive primarily from global warming—that is, the increase in global average temperature as a result of the atmosphere trapping more heat;[13] the last results from an independent chemical reaction of carbon dioxide in seawater.[14] Together, the synergistic interactions of these changes with each other and with already existing anthropogenic stressors (like marine pollution) underscore a fact that humans have known but largely ignored in law: the ocean is a complex adaptive system of systems that responds to multiple anthropogenic stressors in cascading and often unpredictable ways.[15] While this fact cautions against management hubris,[16] it also paradoxically empowers ocean governance in the Anthropocene by increasing the importance and potential impact of reducing those other stressors.[17]

This Article, rather than address individual marine legal issues, as is the norm in ocean law scholarship,[18] instead discusses the failure of U.S.

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[10] We know, for example, that the El Niño/La Niña oscillation that starts in the southern Pacific Ocean is part of a global complex of ocean temperature oscillations that has dramatic effects on yearly weather. *What Are El Niño and La Niña?*, NAT'L OCEAN SERV., https://oceanservice.noaa.gov/facts/ninonina.html (last visited Jun. 4, 2021). Longer-term changes to ocean temperature and ocean currents could drive significant adjustments to what we consider "normal" climate. *See Climate Change Indicators: Oceans*, U.S. ENV'T PROT. AGENCY, https://www.epa.gov/climate-indicators/oceans (last updated May 12, 2021).

[11] *See, e.g.*, Intergovernmental Panel on Climate Change, *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* 9-10, 12-14 (2019), https://www.ipcc.ch/site/assets/uploads/sites/3/2019/12/SROCC_FullReport_FINAL.pdf [hereinafter *2019 IPCC Ocean & Cryosphere Report*].

[12] See discussion *infra* Part I.

[13] *See What Are Climate and Climate Change?*, NAT'L AERONAUTICS & SPACE ADMIN., https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-climate-change-58.html (last updated Aug. 7, 2017).

[14] For a more expansive discussion of ocean acidification, see Robin Kundis Craig, *Dealing with Ocean Acidification: The Problem, the Clean Water Act, and State and Regional Approaches*, 90 WASH. L. REV. 1583, 1589-1602 (2015).

[15] *See* discussion *infra*, Part III.

[16] *See, e.g.*, BENSON & CRAIG, *supra* note 8, at 69-78, 104-134 (discussing the need to incorporate resilience theory into environmental law and policy, as well as the challenges of this approach).

[17] *Id.* at 73-74; *see also* discussion *infra* Part IV.

[18] The most popular topics recently are President Obama's National Ocean Policy, fishing regulation, marine pollution, marine mammals, marine protected areas/marine spatial planning, climate change, and ocean acidification. *See, e.g.*, Audrey Nichols, *Bidding Adieu to the National Ocean Policy: Exploring Offshore Drilling Policies and the Need for Integrated Coastal and Marine Spatial Planning in the Trump Era*, 11 GEO. WASH. J. ENERGY & ENV'T L. 1 (2020);

ocean law and policy[19] to value (or, often, even to acknowledge) this complex—and now actively changing—system *as* a system. It offers some initial and non-intuitive suggestions as to how the United States' domestic ocean law might actively begin to re-value the ocean as the planetary life support system that it is.

Importantly, this Article does not advocate for major legal revision, preferring to emphasize instead what the United States can accomplish within existing legal authorities, a pragmatic approach to ocean re-valuation that allows for immediate action.[20] While climate change and the accompanying phenomenon of ocean acidification pose the greatest long-term threats to the global ocean system,[21] flailing global climate change mitigation efforts since 1992 have yet to significantly address either problem even as their impacts become ever more obvious.[22] As a result, human, ecological, and social-ecological adaptation to a changing ocean—the system that has been absorbing the brunt of anthropogenic climate change so far[23]—has become a reality. What might be considered purely *human adaptation* efforts generally respond to the

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Xiaoduo Liu, *Protecting Marine Animals: Domestic and International Regulation on Ocean Plastic Dumping*, 8 CHI.-KENT J. ENV'T & ENERGY L. 1 (2018); Robin Warner, *Oceans in Transition: Incorporating Climate-Change Impacts into Environmental Impact Assessment for Marine Areas Beyond National Jurisdiction*, 45 ECOLOGY L.Q. 31 (2018); Amanda M. Carr, *Continuing to Lead: Washington State's Efforts to Address Ocean Acidification*, 6 WASH. J. ENV'T L. & POL'Y 543 (2016); Scott C. Doney, Victoria J. Fabry, Richard A. Feely & Joan A. Kleypas, *Ocean Acidification: The Other CO_2 Problem*, 6 WASH. J. ENV'T L. & POL'Y 213 (2016); Julia Wyman, *Effects of Sound on Marine Mammals: Acoustic Permitting of Ocean Activities*, TRENDS: ABA SECTION OF ENVIRONMENT, ENERGY, AND RESOURCES NEWSLETTER, Mar.-Apr. 2015, at 11; Emily Migliaccio, *The National Ocean Policy: Can It Reduce Marine Pollution and Streamline Our Ocean Bureaucracy?*, 15 VT. J. ENV'T L. 629 (2014); Andrew Rakestraw, Note, *Open Oceans and Marine Debris: Solutions for the Ineffective Enforcement of MARPOL Annex V*, 35 HAST. INTL. & COMP. L. REV. 383 (2012).

[19] Many of the observations in this article also apply to the laws of other developed nations and the European Union and to the international law that governs the ocean, most notably the United Nations Convention on the Law of the Sea and the United Nations Convention on Biological Diversity. However, because these international regimes are slowly evolving in the right direction, as current negotiations on a new United Nations treaty for the open ocean ("high seas") attest, and because the United States is not a party to these international agreements, this article focuses on United States law.

[20] Indeed, readers should view this Article as a specific application of the argument presented more generally in Ahjond Garmestani et al., *Untapped Capacity for Resilience in Environmental Law*, 116 PROC. NAT'L ACAD. SCIS. 19899, 19899-19904 (2019).

[21] Isabella Lövin, *Climate Change Poses a Threat to Our Oceans*, UN CHRON., https://www.un.org/en/chronicle/article/climate-change-poses-threat-our-oceans (last visited July 12, 2021).

[22] *See generally* J.B. Ruhl & Robin Kundis Craig, *4°C*, 106 MINN. L. REV. 191, 191-282 (2021).

[23] *See infra* Part I.

changing physicality of the Anthropocene ocean, such as sea level rise[24] and increasing numbers of worsening coastal storm events,[25] but also the physical manifestations of the ocean's influence on global climate, from flooding to drought.[26] *Ecological adaptation* refers to the responses of non-human marine and coastal species to the physical, chemical, and biological changes occurring in their environments, most graphically represented in the multiple documented species range shifts, mostly toward the North and South Poles.[27] Finally, *social-ecological adaptation* acknowledges that humans live within and depend upon ecosystems, forming linked social-ecological systems[28] that respond in complex ways to the changing ocean. For example, as commercially important and, hence, regulated fish and shellfish species in U.S. coastal waters shift northwards or to deeper waters, fishing-dependent coastal communities must either adapt to the increasing cost of their traditional fisheries or shift to new species (assuming that option is legally possible and economically viable).[29]

All three categories of adaptation response require U.S. ocean agencies and officials to appreciate the ocean as a complex adaptive system—a system that, by definition, has never been subject to complete and perfect human control and that now is actively changing in ways that undermine and threaten human needs and desires.[30] Therefore, a complex systems view of the ocean immediately deflates some of the certainty and expectations of stationarity incorporated into traditional marine resource laws and management.[31] Paradoxically, however, the acknowledgement of marine interactivity through a broader systems approach also reveals that a variety of different governance strategies—not just getting anthropogenic greenhouse gas emissions under control—can help the ocean system to become more ecologically resilient, and as a result can ease the adaptation burdens that marine ecosystems and social-ecological systems currently face. This Article argues, therefore,

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[24] *See infra* Part I.

[25] *See 2019 IPCC Ocean & Cryosphere Report*, *supra* note 11, at 27-28.

[26] *Id.* at 15, 25, 27-28.

[27] *Id.* at 12, 26.

[28] The term "social-ecological system" acknowledges that human societies are embedded within and dependent upon ecosystems and that the two systems influence each other. *E.g.*, *Social-Ecological Systems*, RESILIENCE ALL., https://www.resalliance.org/concepts-social-ecological-systems (last visited July 12, 2021); *Social-Ecological Systems*, S. AM. INST. FOR RESILIENCE & SUSTAINABILITY STUD. (2021), https://saras-institute.org/social-ecological-systems/ (last visited July 12, 2021).

[29] *See 2019 IPCC Ocean & Cryosphere Report*, *supra* note 11, at 26.

[30] *See* BENSON & CRAIG, *supra* note 8, at 56, 63-65.

[31] *See id.* at 29-30.

that system-conscious improvements in ocean governance should focus on two problems that the United States is eminently capable of addressing immediately, in terms both of the effectiveness of unilateral national action and of political feasibility: nutrient pollution and marine food security.

This Article begins in Part II with an overview of the changes occurring in the ocean and their implications for human well-being, drawing primarily from the Intergovernmental Panel on Climate Change's (IPCC's) 2019 report on climate change and the ocean. Part III then explores the current resource-specific focus of U.S. ocean laws, illuminating this country's truly fragmented approach to ocean management and its recurring emphasis on individual marine goods and species. This fragmentation, in turn, has immediate consequences for how both government officials and individual citizens value the ocean, because it focuses both regulatory and economic attention on the parts rather than on the system. As the first step in a transition to systems thinking, Part IV examines some initial attempts to value the ocean as a collection of economically important ecosystems. It looks at the several drivers of marine ecosystem protection and the many tools that have arisen to articulate the value of functional marine ecosystems, from ecosystem-dependent marine recreation industries (snorkeling, diving, whale watching), to ecosystem service valuations and natural resource damages, to ecosystem-based management and marine protected areas. Part V, in turn, looks to the next step: the challenge of valuing the entire global ocean as one complex adaptive system. This Part argues that the Planetary Boundaries Project provides one avenue both for comprehending the importance of the ocean's status as a system and for identifying starting focal areas for improving implementation of ocean law and policy in the United States—namely, nutrient pollution and biodiversity loss. This Article concludes by suggesting that, while both a fully systemic legal approach to the ocean and comprehensive action on climate change mitigation are unlikely in the near future, new attention to the ocean's complex role in securing both human health and human food supply would provide salutary and politically feasible starting points for significantly improving marine management in the United States, increasing the resilience to climate change of both marine ecosystems and American communities.

II. THE CHANGING OCEAN

Anthropogenic emissions of greenhouse gases, especially carbon dioxide, are causing significant changes in the ocean and its sub-systems that in turn negatively affect the marine goods and services that humans value. This Part provides an overview of five of the most important of those changes, relying primarily on the IPCC's 2019 *Special Report on the Ocean and Cryosphere in a Changing Climate*,[32] which represents the most recent consensus scientific evaluation of changes occurring in the ocean. The increasing concentrations of greenhouse gases in the atmosphere have resulted in global warming, which in turn causes four of these five important changes: (1) rising ocean temperatures; (2) changing salinity; (3) loss of dissolved oxygen; and (4) sea level rise. Increased atmospheric concentrations of carbon dioxide directly cause the fifth important change: the decrease in the ocean's pH through a process known as ocean acidification.

Importantly, these changes do not occur in isolation, either from each other or from non-climate change-related stressors like habitat destruction, overfishing, or marine pollution. Because the ocean is a system, these changes interact with each other, and the first victims of these synergies are marine food webs and ecosystems. Thus, this Part concludes with a discussion of the profound synergistic and cumulative changes that are already occurring in marine ecosystems.

A. *Warming Ocean Temperatures*

The ocean absorbs much of the excess heat produced by global warming.[33] In its 2019 report, the IPCC concluded that: (1) the ocean has experienced continuous and unabated warming since 1970; (2) the ocean has absorbed more than 90% of anthropogenically induced heat in the climate system; (3) the rate of ocean warming has more than doubled since 1993; (4) ocean warming now reaches to depths over 2000 meters; and (5) marine heatwaves have doubled in frequency and increased in intensity since 1982.[34]

Whether through the massive fish kills that can accompany heatwaves or the slower damage of gradually rising temperatures, ocean warming can devastate marine fisheries, compounding the effects of existing overfishing for certain fish stocks.[35] This synergy is already creating global climate change winners and (mostly) losers among fishing-dependent communities.[36] The impacts of being on the losing side tend to be

[32] *2019 IPCC Ocean & Cryosphere Report*, *supra* note 11.

[33] *2019 IPCC Ocean & Cryosphere Report*, *supra* note 11, at 9.

[34] *Id.*

[35] *Id.* at 12.

[36] For more comprehensive discussions of climate change winners and losers, see generally J.B. Ruhl, *The Political Economy of Climate Change Winners*, 97 MINN. L. REV. 206 (2012);

particularly acute in indigenous communities and other communities highly dependent on fish and seafood.[37] Nevertheless, in some areas—at least for now—"changing ocean conditions have contributed to the expansion of suitable habitat and/or increases in the abundance of some species."[38] Even for these "winner" communities, however, the more abundant catch likely includes unusual species of fish or non-traditional mixes of species,[39] flummoxing cultural norms and potentially rendering existing fishing licenses unusable.

B. *Changes to Ocean Salinity*

Salinity is an important aspect of the ocean's chemistry. Salinity differences across the ocean's vast expanse help to drive marine currents, while local salinity is important to marine species.[40] Salinity affects water evaporation from the ocean and hence is a component of the climate system. As a result, changes in ocean salinity can help to change the climate itself.[41]

The salinity of the ocean is changing in response to both increased evaporation (leading to higher salinity) and more runoff and ice melt (leading to lower salinity).[42] For the United States and Canada, such changes mean that the waters of most of the Pacific are becoming significantly saltier, while the North Atlantic has experienced a slight but noticeable trend toward increased freshness.[43]

Increased marine salinity, which is itself often the end result of the synergistic interactions of ocean warming, sea level rise, and changes in local tidal patterns, will create "high risks" for some marine species under high emissions scenarios, "leading to migration, reduced survival, and local extinction."[44] Changes in salinity also affect critical ocean currents,

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Robin Kundis Craig, *The Social and Cultural Aspects of Climate Change Winners*, 97 MINN. L. REV. 1416 (2013); Victor B. Flatt, Response, *More than Winners and Losers: The Importance of Moving Climate and Environmental Policy Debate to a More Transparent Process*, 97 MINN. L. REV. HEADNOTES 26 (2013).

[37] *See 2019 IPCC Ocean & Cryosphere Report*, *supra* note 10, at 12, 15-17.

[38] *Id.* at 12.

[39] *Id.*

[40] *2013 State of the Climate: Ocean Salinity*, NOAA (July 12, 2014), https://www.climate.gov/news-features/understanding-climate/2013-state-climate-ocean-salinity.

[41] *See id.* ("Any changes in salinity and ocean currents can affect regional climates and marine life.")

[42] Intergovernmental Panel on Climate Change, *Climate Change 2014: Synthesis Report* 40 (2014) [hereinafter *2014 IPCC Synthesis Report*].

[43] Deke Arndt, *2013 State of the Climate: Ocean Salinity*, NOAA (updated July 9, 2021), https://www.climate.gov/news-features/understanding-climate/2013-state-climate-ocean-salinity.

[44] *2019 IPCC Ocean & Cryosphere Report*, *supra* note 10, at 25.

especially global thermohaline circulation,[45] and retards sea ice formation, exacerbating positive warming feedback loops.[46] Thus, in the regions where ocean salinity is increasing, those rising salinity concentrations can positively reinforce global warming itself.

C. *Decreased Dissolved Oxygen*

Animal life in the ocean depends on the presence of sufficient dissolved oxygen.[47] Ocean warming, however, is decreasing the ocean's dissolved oxygen content.[48] In 2019, the IPCC concluded that the near-surface marine layer (from the surface to a depth of 1000 meters) has lost, on average, 0.5% to 3.3% of its normal oxygen concentration.[49] As with most of the ongoing changes to the ocean, these global averages mask the often-significant changes occurring in specific places: Oxygen levels in several tropical regions, for example, have dropped almost 40% over the last fifty years.[50]

Dropping oxygen concentrations in the ocean are associated with a number of damaging consequences. Most obviously, lack of dissolved oxygen affects species and ecosystems,[51] sometimes in surprising ways, such as by reducing fertility.[52] Zooplankton, the small animals at the base of most ocean food webs, are particularly sensitive to changes in dissolved

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[45] *See generally* Jodie Cullum et al., *The Importance of Ocean Salinity for Climate and Habitability*, 113 PROC. NAT'L ACAD. SCI. (PNAS) 4278, 4278-83 (2016); https://doi.org/10.1073/pnas.1522034113 (discussing the importance of marine salinity to assessing whether other planets are potentially habitable).

[46] *Id.* at 4281 (citations omitted).

[47] *See* Craig Welch, *Oceans Are Losing Oxygen—and Becoming More Hostile to Life*, NAT'L GEOGRAPHIC (Mar. 12, 2015), https://www.nationalgeographic.com/science/article/150313-oceans-marine-life-climate-change-acidification-oxygen-fish (describing documented impacts of the loss of dissolved oxygen on particular species and the potential fate of ocean life more generally).

[48] *2014 IPCC Synthesis Report*, *supra* note 42, at 41. "A warming ocean loses oxygen for two reasons: First, the warmer a liquid becomes, the less gas it can hold." Laura Poppick, *The Ocean Is Running Out of Breath, Scientists Warn*, SCI. AM. (Feb. 25, 2019), https://www.scientificamerican.com/article/the-ocean-is-running-out-of-breath-scientists-warn/. Second, a warming ocean stratifies, preventing ocean currents from mixing surface oxygen into the depths. *Id.*

[49] 2019 IPCC OCEAN AND CRYOSPHERE REPORT, *supra* note 11, at 10.

[50] Lothar Stramma et al., *Expanding Oxygen-Minimum Zones in the Tropical Oceans*, 320 SCI. 655, 655-58 (2008).

[51] *Id.* at 655 (citations omitted).

[52] Poppick, *supra* note 48. In addition, "[o]cean animals large and small . . . respond to even slight changes in oxygen by seeking refuge in higher oxygen zones or by adjusting behavior. . . . These adjustments can expose animals to new predators or force them into food-scarce regions." *Id.*

oxygen concentrations.[53] At a larger scale, in the geological record, significantly reduced ocean oxygen levels are associated with mass extinction events.[54]

Finally, "[o]ceanic dissolved-oxygen concentrations [also] have major impacts on the global carbon and nitrogen cycles," meaning that dissolved oxygen is an important parameter for understanding the ocean's role in climate.[55] Specifically, reductions in the ocean's dissolved oxygen content signal changes in the ocean's circulation patterns and changes in the ocean's ability to absorb carbon dioxide, potentially requiring adjustments to humanity's remaining carbon budget to effectively mitigate climate change itself.[56] As such, the observed changes in oceanic dissolved oxygen are signs that the climate system itself is changing.[57]

D. *Sea Level Rise*

Globally, sea level is rising.[58] Melting terrestrial ice and warming seas combine to drive sea level rise, which over the decade from 2006 to 2015 reached a rate of 3.6 millimeters (0.14 inches) per year on average globally—a rate unprecedented in the last century and 2.5 times the rate occurring from 1901 to 1990.[59] Ice melt has surpassed thermal expansion as the predominant driver of sea level rise,[60] and the rates of melting in the Greenland and Antarctic ice sheets have doubled and tripled, respectively.[61] The melting rate of both ice sheets is expected to accelerate throughout the 21st century,[62] and the Antarctic ice sheet may already have become irreversibly destabilized, which could lead to several meters of sea level rise over the next few centuries.[63] As with salinity and dissolved oxygen, however, what sea level rise means for a particular place varies considerably, with regional sea level rise as much as 30% above or below the global mean.[64] The effects of sea level rise are compounded by

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[53] K.F. Wishner et al., *Ocean Deoxygenation and Zooplankton: Very Small Oxygen Differences Matter*, 4 SCI. ADVANCES eaau5180, at 1 (2018), https://doi.org/10.1126/sciadv.aau5180.

[54] Stramma, *supra* note 50, at 655 (citations omitted).

[55] *Id.*

[56] Fortunat Joos et al., *Trends in Marine Dissolved Oxygen: Implications for Ocean Circulation Changes and the Carbon Budget*, 84 EOS 197, 197-98 (2003).

[57] Andreas Oschlies et al., *Drivers and Mechanisms of Ocean Deoxygenation*, 11 NATURE GEOSCI. 467, 467-68 (2018).

[58] *2014 IPCC Synthesis Report*, *supra* note 42, at 42.

[59] *2019 IPCC Ocean & Cryosphere Report*, *supra* note 11, at 10.

[60] *Id.*

[61] *Id.*

[62] *Id.* at 17.

[63] *Id.* at 10.

[64] *Id.*

increasing wave heights, especially during severe storms.[65]

E. *Ocean Acidification*

The ocean is the world's largest carbon sink, and absorbed carbon dioxide is reacting chemically in the ocean to reduce the ocean's pH, a phenomenon known as ocean acidification.[66] According to the IPCC in 2019, "[b]y absorbing more CO_2, the ocean has undergone increasing surface acidification (*virtually certain*)."[67] It concluded that the ocean has been absorbing 20% to 30% of anthropogenic carbon dioxide emissions and that global ocean pH has already dropped 0.017 to 0.027 pH units—enough to exceed natural background variability in 95% of the ocean's surface area.[68]

The pH scale is logarithmic, so these changes mean that the ocean is now at least 30% more acidic than it was 200 years ago.[69] Ocean acidification is currently occurring "faster than any known change in ocean chemistry in the last 50 million years."[70] Ocean acidification will likely only get worse throughout the 21st century, and "by the end of this century the surface waters of the ocean could have acidity levels nearly 150 percent higher, resulting in a pH that the oceans haven't experienced for more than 20 million years."[71]

Ocean acidification initially interferes with shell forming in organisms such as clams, oysters, and corals, and even small changes in marine pH can affect these organisms.[72] Fish experience a condition known as acidosis that disrupts the chemical reactions that normally occur with their bodies, directly threatening their survival.[73] More ominously, the geological record suggests that the ocean is already approaching truly catastrophic acidification levels. The ocean acidified rapidly after the meteor impact at the Cretaceous-Paleogene boundary 66 million years ago, helping to cause the extinction of the dinosaurs—and 75% of marine

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[65] *Id.* at 10-11.

[66] *2014 IPCC Synthesis Report*, *supra* note 42, at 41.

[67] *2019 IPCC Ocean & Cryosphere Report*, *supra* note 11, at 9.

[68] *Id.*

[69] *What Is Ocean Acidification?*, PMEL CARBON PROGRAM, NOAA (viewed Feb. 17, 2020), https://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F.

[70] *Ocean Acidification*, SMITHSONIAN (viewed Feb. 17, 2020), https://ocean.si.edu/ocean-life/invertebrates/ocean-acidification.

[71] *What Is Ocean Acidification?*, PMEL CARBON PROGRAM, NOAA (viewed Feb. 17, 2020), https://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F.

[72] *Id.*; *Ocean Acidification*, SMITHSONIAN (viewed Feb. 17, 2020), https://ocean.si.edu/ocean-life/invertebrates/ocean-acidification.

[73] *Ocean Acidification*, SMITHSONIAN, https://ocean.si.edu/ocean-life/invertebrates/ocean-acidification (last visited Feb. 17, 2020).

species—with only a 0.25 drop in marine pH.[74] "[T]he resulting ecological collapse in the oceans had long-lasting effects for global carbon cycling and climate."[75]

F. *Synergistic Effects on Marine Ecosystems: Transitioning to an "Unprecedented" Ocean*

Each of the changes described above is already having multiple effects on the ocean, which the IPCC summarized in 2019.[76] Together, and especially in combination with other stressors such as commercial fishing, habitat destruction, and marine pollution, these climate change- and acidification-induced effects are causing large-scale marine food web alterations.[77] Moreover, these changes signal that marine ecosystems may be on the brink of enormous transformations, probably with significant losses of ecosystem goods and services that humans depend upon.[78] As one example, species in the first 200 meters of the marine water column are currently shifting their ranges, on average, about 52 kilometers (more than 32 miles) per decade, while species closer to the bottom shift on average about 29 kilometers (18 miles) per decade.[79] "Warming-induced species range expansions have led to altered ecosystem structure and functioning such as in the North Atlantic, Northeast Pacific, and Arctic."[80]

As the discussions of the five important changes indicate, stressors to the ocean often interact synergistically to exacerbate or accelerate the changes occurring. At the planet's poles, the cascading effects of multiple climate-related drivers on zooplankton, the base of polar food chains, have already affected food webs, marine biodiversity, and commercial fisheries.[81] In addition, "[o]cean warming, oxygen loss, acidification and a decrease in flux of organic carbon from the surface to the deep ocean are projected to harm habitat-forming cold-water corals, which support high biodiversity, partly through decreased calcification, increased dissolution

[74] Damian Carrington, *Ocean Acidification Can Cause Mass Extinctions, Fossils Reveal*, GUARDIAN (Oct. 21, 2019, 15:00 EDT), https://www.theguardian.com/environment/2019/oct/21/ocean-acidification-can-cause-mass-extinctions-fossils-reveal.

[75] Michael J. Henehan et al., *Rapid Ocean Acidification and Protracted Earth System Recovery Followed the End-Cretaceous Chicxulub Impact*, 116 PROC. NAT'L ACAD. SCI. 22,500, 22,500 (2019), https://doi.org/10.1073/pnas.1905989116.

[76] *2019 IPCC Ocean & Cryosphere Report*, *supra* note 11, at 14 fig. SPM.2.

[77] *Id.* at 13, 52.

[78] *Id.*

[79] *Id.* at 12.

[80] *Id.*

[81] *Id.*

of skeletons, and bioerosion."[82] Multiple climate change impacts are also affecting the highly productive upwelling systems of the world's ocean.[83] Finally, ocean warming and ocean acidification negatively affect shellfish production, and "[i]n many regions, declines in the abundance of fish and shellfish stocks due to direct and indirect effects of global warming and biogeochemical changes have already contributed to reduced fisheries catches (*high confidence*)."[84]

Acute events that decimate large portions of the ocean are becoming regular phenomena. The death of large sections of Australia's Great Barrier Reef in 2015 and 2016[85] may be the most widely reported evidence of marine ecosystem stress, but record-setting temperatures in the western North Atlantic in 2012[86] and the Pacific "warm blob" of 2013-2016[87] each wreaked plenty of havoc on marine ecosystems off the coasts of the United States and Canada. The latter event, for example, is credited with killing about 1 million seabirds in less than 12 months in 2015-2016.[88]

Ongoing scientific research increasingly suggests that ocean ecosystems also suffer from chronic problems resulting from synergistic

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[82] *Id.* at 22.

[83] *Id.* at 12.

[84] *Id.*

[85] Terry P Hughes et al., *Global Warming and Recurrent Mass Bleaching of Corals*, 543 NATURE 373, 373 (2017).

[86] Philip Bump, *The Atlantic Ocean Off the East Coast Was the Warmest Ever Recorded in 2012*, ATL., https://www.theatlantic.com/national/archive/2013/04/atlantic-ocean-east-coast-was-warmest-ever-recorded-2012/315707/ (April 30, 2013).

[87] Nicholas A. Bond, *What Is the 'Warm Blob' in the Pacific and What can it Tell us About our Future Climate?*," CONVERSATION (May 15, 2015), https://theconversation.com/what-is-the-warm-blob-in-the-pacific-and-what-can-it-tell-us-about-our-future-climate-40140; Jessie Yeung, *A Blob of Hot Water in the Pacific Ocean Killed a Million Seabirds, Scientists Say*, CNN (updated Jan. 16, 2020, 4:06 AM ET), https://www.cnn.com/2020/01/16/world/blob-seabird-study-intl-hnk-scli-scn/index.html.

[88] Yeung, *supra* note 87. Notably, the northern Pacific heat blob recurred in 2019, becoming by September 2019 the second-largest marine heatwave in the last 40 years and stretching from the Arctic to California. *"The Blob" is Back: Pacific Heat Wave Already Second-Largest in Recent History,* MONGABAY (Sept. 24, 2019), https://news.mongabay.com/2019/09/the-blob-is-back-pacific-heat-wave-already-second-largest-in-recent-history/. In the worst-affected areas, the ocean was 5˚F warmer than normal, enough to spur harmful algal blooms, shut down fisheries, strand seals, change whale migrations, and alter weather. *Id.*; *New Marine Heatwave Emerges off West Coast; Resembles "The Blob"*, NOAA FISHERIES (Sept. 5, 2019), https://www.fisheries.noaa.gov/feature-story/new-marine-heatwave-emerges-west-coast-resembles-blob. While that blob retreated by November, in December 2019 another marine heatwave appeared off the eastern coast of New Zealand, with ocean temperatures 6˚C (10.8˚F) warmer than normal over an area of 400,000 square miles, making the phenomenon visible from space. Yeung, *supra*; Adam Morton, *Hot Blob: Vast Patch of Warm Water off New Zealand Coast Puzzles Scientists*, GUARDIAN (Dec. 26, 2019, 22:29 EST), https://www.theguardian.com/world/2019/dec/27/hot-blob-vast-and-unusual-patch-of-warm-water-off-new-zealand-coast-puzzles-scientists.

and intensifying stressors and that these chronic issues ultimately are likely to become more important than the acute crises. For example, a 2015 meta-analysis of 632 peer-reviewed experiments related to ocean biodiversity concluded that warming ocean waters will likely increase some forms of primary production in the ocean (phytoplankton growth in certain regions) while simultaneously disrupting marine ecosystems overall and starving both herbivores and carnivores farther up marine food chains, while the combination of warming and ocean acidification is likely to greatly simplify marine ecosystem structure and function.[89] By the end of the century on the current trajectory, primary production in the ocean could decrease by 10% and total fish biomass by 25%.[90]

The IPCC concurs that, by 2100, we likely will not recognize the world's ocean.[91] Even under a low emissions scenario, ocean heat waves will likely occur 20 times more often than they do now (which is already an increase over pre-climate change conditions); under a business-as-usual scenario, they will likely occur 50 times more often.[92] Most coastal ecosystems, including kelp forests, sea grass meadows, and salt marshes, face an increasing risk of destruction because of this heat, ocean acidification, and sea level rise.[93] By the end of the 21st century, again assuming business as usual, 60% of the ocean will be experiencing all five of the IPCC's drivers of ecosystem change—surface warming, acidification, oxygen loss, nitrate pollution, and change in net primary production (growth of marine plants and zooplankton).[94] Among other things, these synergistic interactions will make existing marine pollution more toxic, undermining species' capacity to adapt,[95] and threaten the world's tropical coral reefs with destruction.

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[89] Ivan Nagelkerken & Sean D. Connell, *Global alteration of ocean ecosystem functioning due to increasing human CO_2 emissions*, 112 PROC. NAT'L ACAD. SCIS. 13,272, 13,273-75 (2015), http://www.pnas.org/cgi/doi/10.1073/pnas.1510856112. According to the United Nations' May 2019 biodiversity report, "almost 33% of reef-forming corals and more than a third of all marine mammals are threatened" with extinction, and the planet has already lost about 30% of seagrass meadows and 50% of coral reefs—two highly productive marine habitats—since 1970 and 1870, respectively. *UN Report: Nature's Dangerous Decline 'Unprecedented'; Species Extinction Rates 'Accelerating'*, UNITED NATIONS (May 6, 2019), https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report/.

[90] *UN Report*, *supra* note 89; *see also 2019 IPCC Ocean & Cryosphere Report, supra* note 11, at 22 (projecting nearly identical losses).

[91] *2019 IPCC Ocean & Cryosphere Report*, *supra* note 11, at 18.

[92] *Id.* at 19.

[93] *Id.* at 24.

[94] *Id.* at 18-19.

[95] Henrique Cabral et al., *Synergistic Effects of Climate Change and Marine Pollution: An Overlooked Interaction in Coastal and Estuarine Areas*, 16 INT'L J. ENV'T RSCH. & PUB. HEALTH 273, at 5-6 (2019) (citations omitted), https://doi.org/10.3390/ijerph16152737.

Importantly for U.S. marine governance, many of the changes occurring in the ocean generally are directly relevant to the United States and its reliance on marine productivity—for example, heat waves in the northern Pacific and Atlantic Oceans, changes in salinity (in opposite directions) in both oceans, a rapidly changing Arctic Ocean and consequent impacts to Alaska and its fisheries, changes to the California current, greater-than-average sea level rise in the Gulf of Mexico, and increasingly violent hurricanes affecting the Gulf of Mexico and the Atlantic coast. In other words, the changes to the world's ocean are not (just) a generic global issue but also a specifically American issue.

So far, however, the losses that U.S. citizens are already starting to feel tend to remain framed in terms of the individual marine goods and services that Americans value most—such as fisheries,[96] coastal protection, cultural resources and services, and marine recreation[97]—not in terms of larger marine system function. Not coincidentally, these individual goods and services also dictate the focus of many U.S. ocean laws. The next Part illuminates the dominant tendency of current law to regulate individual goods and species in isolation from the larger ocean system.

III. THE TRADITIONAL LEGAL PERSPECTIVE: VALUING INDIVIDUAL MARINE GOODS, SERVICES, AND USES

The ocean is a classic example of an environmental commons. Traditionally subject to an international law regime based on "freedom of the seas,"[98] private property rights in open ocean resources were (and still are) generally limited to and by the commodity-focused rule of capture—i.e., in general, no private property rights accrue in fish or other ocean resources (such as deep sea minerals) until an individual effectively brings those resources under his or her dominion and control.[99] Private ownership, community ownership,[100] and even cooperative management of

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[96] *See* Steven L. Chown, *Marine Food Webs Destabilized*, 369 SCI. 770, 770-71 (2020) (discussing the impacts of climate change on fisheries and ocean ecosystems).

[97] *2019 IPCC Ocean & Cryosphere Report*, *supra* note 11, at 16.

[98] *See generally*, *e.g.*, HUGO GROTIUS, THE FREE SEA (1609) (David Armitage ed., Richard Hakluyt trans., Liberty Fund 2004).

[99] Anastasia Telesetsky, *Rule of Marine Capture Versus Rule of Cooperation in the East China Sea: Exploring Options for Regional Ecosystem Restoration*, 28 CHINESE (TAIWAN) Y.B. INT'L L. & AFFS. 114, 117-120 (2010).

[100] I rely here on Professor Daniel H. Cole's typology of properties. Professor Cole distinguishes five types of property regimes: public property, which is property owned or regulated by governments or the international community; private property, typified by individual private property; common property (*res communes*), which describes a situation where there are "at least two groups, one of which collectively controls the resource with the authority and the ability to exclude the other"; mixed property, where public, common, and private property rights

areas of the sea remain rare and limited.[101]

Otherwise, in the United States, marine waters and submerged lands are usually public spaces. As a result of a somewhat complicated history of U.S. Supreme Court decisions, congressional actions, international law, and presidential declarations, *states* own the submerged lands of internal bays, tidal estuaries, and navigable coastal rivers, control the waters above them, and generally have primary authority over the first three miles of the ocean, while the *federal government* has sovereign authority over the submerged lands and water column out to 200 nautical miles from shore.[102]

Complicating the United States' regulation of the marine commons is a significant lack of needed information. In 2000, Colin Woodward proclaimed that "[w]e are better informed about the Moon and Mars than about the bottom of the ocean floor; we know more about the life cycle of stars than those of the sperm whale, giant squid, and many of the creatures sought by the world's fishing fleets."[103] The situation has improved somewhat in the intervening two decades as a result of sometimes herculean scientific efforts such as the 10-year-long Census of Marine Life,[104] the data from which are still contributing to international understanding of marine biodiversity.[105] At the same time, however, the newly recognized and ongoing changes to ocean chemistry,[106] currents,[107]

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exist simultaneously, in proportions that can vary; and nonproperty/open access/*res nullius*, where no individual, government, or group has the right to exclude. DANIEL H. COLE, POLLUTION & PROPERTY 9-13 (2002). Most important, and especially critical for the oceans and coasts, is Professor Cole's recognition that "all existing property regimes are more or less admixtures [of] individual, group, and public rights." *Id.* at 13.

[101] Teletsetsky, *supra* note 99, at 116-121.

[102] U.S. COMM'N ON OCEAN POLICY, AN OCEAN BLUEPRINT FOR THE 21ST CENTURY 70-71 (2004) [hereinafter 2004 USCOP REPORT].

[103] COLIN WOODWARD, OCEAN'S END: TRAVELS THROUGH ENDANGERED SEAS 30 (2000).

[104] *A Decade of Discovery*, CENSUS OF MARINE LIFE, http://www.coml.org (last visited July 17, 2021).

[105] Many of the publications from this project, for example, have been collected within PLOS. Search for "Census of Marine Life" at *Browse Collections*, PLOS, https://collections.plos.org/s/coml (last visited July 17, 2021). In addition, the Census helped to create a global database of marine life, currently incorporating over 122,000 species. *OBIS: Ocean Biographic Information System*, https://obis.org (last visited July 17, 2021). In the United States, NOAA notes that "[t]he data and information collected by the Census—30 million records and 2,600 papers contributed to the scientific literature—will serve as a baseline in the coming years, as researchers strive to measure changes to ocean habitats due to sea level rise and climate change, extreme weather events, hazardous spills, and other factors." NOAA, *What Is the Census of Marine Life?*, NAT'L OCEAN SERV., https://oceanservice.noaa.gov/facts/marine-census.html (last updated Feb. 26, 2021).

[106] *E.g.*, *Changing Ocean Chemistry*, AM. MUSEUM NAT. HIST., https://www.amnh.org/exhibitions/climate-change/changing-ocean/changing-ocean-chemistry (last visited July 17, 2021).

thermal dynamics,[108] and species ranges[109] discussed in Part I make achieving a settled understanding of the ocean for any purpose, but particularly for effective marine law and policy, an elusive, if not impossible, goal.[110]

This continued ignorance has contributed to a complicated and divisive ocean regulatory regime in the United States. This regulatory fragmentation arises primarily because the United States divides authority over living and nonliving marine resources geographically, among regulating agencies, and among regulatory regimes.[111] No one entity is charged with oversight of the entirety of the nation's marine jurisdiction.[112] This Part explores the United States' geographically and substantively fragmented approaches to ocean law and policy. It concludes with prominent examples of the sector-by-sector valuation analyses that result from such fragmentation—monetary "bottom lines" that effectively elide the complex drivers of change in the ocean system.

A. *The United States' Geographically Fragmented Management of the Ocean*

Until relatively recently, coastal nations controlled only a narrow three-mile-wide band of "territorial seas" off their coasts.[113] Beginning in the mid-20th century, however, nations began to assert increasing control over the world's ocean.[114] The 1982 United Nations Convention on the Law of the Sea (LOSC) came into force on November 16, 1994,[115] and divides the oceans into six zones. The band of ocean closest to shore remains the territorial sea, where coastal nations can exercise full

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[107] *E.g.*, *Arctic Ice Melt Is Changing Ocean Currents*, NASA GLOB. CLIMATE CHANGE (Feb. 6, 2020), https://climate.nasa.gov/news/2950/arctic-ice-melt-is-changing-ocean-currents/.

[108] *E.g.*, LuAnn Dahlman & Rebecca Lindsey, *Climate Change: Ocean Heat Content*, NOAA (Aug. 17, 2020), https://www.climate.gov/news-features/understanding-climate/climate-change-ocean-heat-content.

[109] *E.g.*, Malin L. Pinsky et al., *Climate-Driven Shifts in Marine Species Ranges: Scaling from Organisms to Communities*, 12 ANN. REV. MARINE SCI. 153, 153-79 (2020), https://doi.org/10.1146/annurev-marine-010419-010916.

[110] *See* BENSON & CRAIG, *supra* note 8, at 104-134 (discussing the implications of these changes for marine fisheries regulation in the United States).

[111] 2004 USCOP REPORT, *supra* note 102, at 108.

[112] *Id.* at 77-78 & fig.4-1.

[113] U.N. on the Territorial Sea and Contiguous Zone, *opened for signature* Apr. 29, 1958, 516 U.N.T.S. 205, art. 1 (entered into force Sept. 10, 1964).

[114] Robin Kundis Craig, *Treating Offshore Public Lands as Submerged Lands: An Historical Perspective*, 34 PUB. LANDS & RES. L. REV. 51, 57-69 (2013).

[115] U.N. Convention on the Law of the Sea, Dec. 10, 1982, https://www.un.org/depts/los/convention_agreements/texts/unclos/closindx.htm [hereinafter LOSC].

sovereignty over the waters, airspace, seabed, and subsoil, subject to ships' rights of innocent passage.[116] However, LOSC extends the territorial sea to 12 nautical miles, expanding nations' sovereign authority over the ocean.[117] Immediately beyond the territorial sea, stretching to 24 nautical miles offshore, is the contiguous zone, in which nations can enforce laws relating to activities in their territorial seas.[118] A coastal nation can also claim a 200-nautical-mile-wide exclusive economic zone (EEZ), within which it has "sovereign rights to explore, exploit, conserve, and manage" the natural resources in the waters, seabed, and subsoil, "whether living or non-living," as well as jurisdiction over marine research and conservation.[119] Underlying the EEZ is the continental shelf, which extends throughout "the natural prolongation of [the nation's] land territory to the outer edge of the continental margin, or to a distance of 200 miles," giving signatory nations control of at least 200 nautical miles of the continental shelf and its subsoil resources.[120] The water column beyond the EEZ is the high seas, in which nations continue to enjoy "freedom of the seas."[121] Finally, the ocean floor beyond nations' continental shelves is The Area, subject to an international permitting regime for deep seabed mining and a requirement that mining nations share the profits gained from this "common heritage of mankind."[122]

Although the United States has not ratified the LOSC, it has claimed for itself, through customary international law and presidential proclamations, the same regulatory zones that the convention establishes.[123] As a result of its long coastlines, Alaska, and its various island states and territories, the United States' adoption of a 200-nautical-mile EEZ means that this country now controls more ocean space than terrestrial land.[124]

More important for the United States' internal regulation of its marine resources is the division of the ocean between the federal government and the states. Under the Submerged Lands Act of 1953, coastal states received title to the lands beneath, and consequently regulatory control over the waters of, the first three miles of sea, subject to the federal government's

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[116] *Id.* § 2.
[117] *Id.* arts. 2.1, 2.2, 3, 17-25.
[118] *Id.* art. 33.
[119] *Id.* arts. 57, 56.1.
[120] *Id.* art. 76.1.
[121] *Id.* art. 87.
[122] *Id.* arts. 133-158.
[123] Proclamation No. 2667, 10 Fed. Reg. 12,305 (Sept. 28, 1945); Proclamation No. 5030, 48 Fed. Reg. 10,605 (Mar. 10, 1983); Proclamation No. 5928, 54 Fed. Reg. 777 (Dec. 27, 1988); Proclamation No. 7219, 64 Fed. Reg. 48,701 (Aug. 2, 1999).
[124] 2004 USCOP REPORT, *supra* note 102, at i.

power to regulate "commerce, navigation, national defense, and international affairs."[125] As a result, states generally regulate marine resources in the first three miles of ocean, while the federal government regulates marine resources in the next 197 miles of the United States' EEZ and continental shelf.[126] In addition, the various coastal states divide regulation of marine resources in the first three miles of ocean among themselves by extending the borders between states out to sea.

When combined, therefore, the United States' adoption of international law and the Submerged Lands Act create 33 regulatory jurisdictions for its marine resources under the control of 30 governments. The federal government controls the EEZ, continental shelf, contiguous zone, and territorial sea more than three miles out to sea. In turn, 24 coastal states (not including the Great Lakes states) and five island territories—the Virgin Islands, Puerto Rico, Guam, American Samoa, and the Northern Mariana Islands—control the three-mile bands of ocean extending from their shores. More difficult to count are the growing number of Tribes that also manage marine resources and territories, but at least four Tribes in each of Washington and Oregon have that authority,[127] and California Tribes are also pursuing management agreements with the state.[128]

B. *The United States' Substantively Fragmented Regulation of the Ocean*

The various sovereigns that manage the United States' ocean territory have further fragmented that authority along subject matter lines, in the process handing different aspects of regulatory authority over the ocean to a plethora of federal, state, regional, and local authorities. For the sake of brevity, this overview focuses on the federal level of regulation, but the twenty-four coastal states and five coastal territories generally replicate the federal government's subject matter fragmentation for their three-mile ocean zones. This fragmented authority encourages regulatory agencies to consider the ocean through the lens of specific resources, species, or geographies, rather than valuing the ocean as a complex system.

Congress has divided the federal government's regulatory authority over the ocean among a rather large number of federal agencies. These agencies include the U.S. Environmental Protection Agency (EPA), the

[125] 43 U.S.C. §§ 1301(a), 1314(a) (2012).

[126] 2004 USCOP REPORT, *supra* note 102, at 98.

[127] *Coastal Tribes*, WASH. MARINE SPATIAL PLAN., https://www.msp.wa.gov/learn/tribes/ (last visited July 17, 2021).

[128] *E.g.*, *Tribal Co-Managed Marine Protected Areas*, WISHTOYO CHUMASH FOUND. (2020), https://www.wishtoyo.org/marine-protected-areas-1.

U.S. Fish and Wildlife Service (USFWS), the National Oceanic and Atmospheric Administration (NOAA), NOAA Fisheries (formerly the National Marine Fisheries Service or NMFS), the Bureau of Ocean Energy Management (BOEM) and Bureau of Safety and Environmental Enforcement (BSEE) (formerly the Minerals Management Service), the U.S. Army Corps of Engineers, the Coast Guard, and eight regional Fisheries Management Councils (FMCs), among others.[129] These agencies are not even housed within a single department of the federal government. Instead, as the U.S. Commission on Ocean Policy recognized in its 2004 report to Congress, "eleven of fifteen cabinet-level departments and four independent agencies play important roles in the development of ocean and coastal policy."[130] By the Commission's count, "more than 55 congressional committees and subcommittees oversee some 20 federal agencies and permanent commissions in implementing at least 140 federal ocean-related statutes."[131] "These agencies interact with one another and with state, territorial, tribal, and local authorities in sometimes haphazard ways."[132]

The multiplicity of agencies involved in ocean management often reflect legislative decisions to regulate different aspects of the ocean in different way. Nevertheless, of this plethora of regulatory regimes, two federal statutes—the Coastal Zone Management Act (CZMA)[133] and the Clean Water Act (CWA or Federal Water Pollution Control Act)[134]—and the state laws that implement them are of particular importance for coastal development and marine pollution. The Coastal Zone Management Act bribes states with federal grants,[135] technical assistance,[136] and a guarantee that federal agencies will conform to state requirements,[137] to enact Coastal Zone Management Plans to govern coastal development and resource use, including land use planning and zoning, protection of critical areas, and

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[129] 2004 USCOP REPORT, *supra* note 102, at 5, 78 fig.4.1.

[130] *Id.*

[131] *Id.* at 55.

[132] *Id.* at 5.

[133] Pub. L. No. 92-583, 86 Stat. 1280 (1972) (codified as amended at 16 U.S.C. §§ 1451-1464).

[134] Pub. L. No. 92-500, 86 Stat. 816 (1972) (codified as amended at 33 U.S.C. §§ 1251-1388).

[135] Coastal Zone Management Act §§ 1455, 1455a, 1455b, 1456b.

[136] *Id.* § 1456(c).

[137] *Id.* § 1456(c). The "federal consistency" requirement has played a prominent role in the history of oil and gas development in the federal waters off the coast of California. *See*, *e.g.*, Secretary of the Interior v. California, 464 U.S. 312, 330-43 (1984) (holding that the Department of the Interior's sales of oil and gas leases off the coast of California did not "directly affect" the state's coastal zone and hence did not trigger the CZMA).

additional investment in coastal pollution control.[138] The Clean Water Act, in turn, seeks to "restore and maintain the . . . integrity of the Nation's waters,"[139] including the ocean.[140] States generally take the lead in protecting water quality in the first three miles of ocean,[141] while the federal Environmental Protection Agency (EPA) regulates discharges of pollutants (such as from oil and gas platforms) farther out to sea.[142] In addition, special provisions of the Act regulate discharges from vessels (including vessels of the Armed Forces),[143] impose liability for oil spills,[144] and establish special protections for marine habitats.[145]

Only a handful of federal statutes directly regulate nonliving marine resources in the U.S. ocean like offshore oil and gas: the Outer Continental Shelf Lands Act (OCSLA),[146] the Outer Continental Shelf Deep Water Royalty Relief Act,[147] and the Deep Seabed Hard Mineral Resources Act.[148] Notably, as a result of early attempts to use federal mining laws offshore, regulation of offshore mineral development ended up in the U.S. Department of the Interior, not NOAA.[149] In contrast, there are over 45 federal statutes governing *living* marine resources. Congress tends to regulate on a species-by-species basis, with different statutes addressing specific species and geographies. The very titles of the 45 or so federal statutes that govern these resources evidence this tendency.[150] In addition,

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[138] 16 U.S.C. §§ 1452, 1455(a).

[139] 33 U.S.C. § 1251(a).

[140] *Id.* § 1362(7)-(10), (12).

[141] *See id.* § 1342(a)-(b) (federal and state regulatory programs); *see also id.* § 1344(g) (state regulatory program for dredged or fill material).

[142] *See id.* § 1362(7)-(8) (defining the territorial sea).

[143] *Id.* § 1322.

[144] *Id.* § 1321.

[145] *Id.* § 1330.

[146] 43 U.S.C. §§ 1331-1356(b).

[147] Pub. L. No. 104-58, 109 Stat. 563 (1995) (amending *id.* § 1337).

[148] Pub. L. No. 96-283, 94 Stat. 553 (1980) (codified as amended at 30 U.S.C. §§ 1401-1473, 40 U.S.C. §§ 4495- 4498).

[149] *See About BOEM*, BUREAU OF OCEAN ENERGY MGMT., U.S. DEP'T OF THE INTERIOR, https://www.boem.gov/about-boem (last visited July 17, 2021).

[150] *See, e.g.*, Anadromous Fish Conservation Act of 1965, Pub. L. No. 89-304, 79 Stat. 1125 (codified as amended at 16 U.S.C. §§ 757a-757f); Atlantic Salmon Convention Act of 1982, Pub. L. No. 97-389, 96 Stat. 1951 (codified as amended at 16 U.S.C. §§ 3601-3608); Atlantic Striped Bass Conservation Act, Pub. L. No. 98-613, 98 Stat. 3187 (1984) (codified as amended at 16 U.S.C. §§ 5151-58); Atlantic Tuna Convention Act of 1975, Pub. L. No. 94-70, 89 Stat. 385 (codified as amended at 16 U.S.C. § 971-971k); Act of Sept. 26, 1970, Pub. L. No. 91-427, 84 Stat. 884 (codified as amended at 16 U.S.C. §§ 1211-1213) (allocating funds to study and control the crown-of-thorns starfish); Fur Seal Act Amendments of 1983, Pub. L. No. 98-129, 97 Stat. 835 (codified as amended in scattered sections of 16 U.S.C. ch. 24); International Dolphin Conservation Program Act, Pub. L. No. 105-42, 111 Stat. 1122 (1977) (codified as amended in scattered sections of 16 U.S.C.); Northern Pacific Halibut Act of 1982, Pub. L. No. 97-176, 96 Stat. 78 (codified as amended at 16 U.S.C. § 773-773k); South Pacific Tuna Act of 1988, Pub. L.

many federal statutes governing living marine resources evidence an underlying consumption-promoting policy, such as the Central, Western, and South Pacific Fisheries Development Act,[151] the Fish and Seafood Promotion Act of 1986,[152] the Fisheries Financing Act of 1996,[153] and the Fisherman's Protective Act of 1967.[154]

Geographic division, biological division, and a consumption-oriented policy all help to structure one of the most important of the federal statutes regulating living marine resources: the Magnuson-Stevens Fishery Conservation and Management Act.[155] Although Congress recognized in this Act that "a national program for the conservation and management of the fishery resources of the United States is necessary to prevent overfishing, to rebuild overfished stocks, to insure conservation, to facilitate long-term protection of essential fish habitats, and to realize the full potential of the Nation's fishery resources,"[156] it did not enact a comprehensive ecosystem-based regulatory regime to achieve those goals. Instead, geographically, the Magnuson-Stevens Act leaves fisheries regulation in the first three miles of ocean largely to the states,[157] then divides management in the federal EEZ among eight regional Fisheries Management Councils, which enact fishery management plans for each troubled fishery within their respective jurisdictions.[158] Moreover, even after Congress enacted the Sustainable Fisheries Act of 1996[159] to address continued problems of overfishing and bycatch (the incidental catching of non-target species in commercial fishing), federal fishery management plans tend to remain focused on individual fisheries and stocks of fish, and the statutory goal for fisheries management remains "optimum yield"[160]—that is, the maximum sustainable yield from such fishery "which will provide the greatest overall benefit to the Nation."[161]

The other two major federal statutes regulating living marine

No. 100-330, 102 Stat. 591 (codified as amended at 16 U.S.C. § 973-973r); Sponge Act, ch. 253, 38 Stat. 692 (1914) (codified as amended at 16 U.S.C. §§ 781-785); Whaling Convention Act of 1949, ch. 653, 64 Stat. 421 (1950) (codified as amended at 16 U.S.C. § 916).

[151] Pub. L. No. 92-444, 86 Stat. 744 (1972) (codified as amended at 16 U.S.C. § 758e).

[152] Pub. L. No. 99-659, 100 Stat. 3715 (1986) (codified as amended at 16 U.S.C. §§ 4001-4017).

[153] Pub. L. No. 104-297, 110 Stat. 3615 (codified as amended at 46 U.S.C. §§ 1274, 1279f, 1279g).

[154] Ch. 1018, 68 Stat. 883 (1954) (codified as amended at 22 U.S.C. §§ 1971-1980).

[155] 16 U.S.C. §§ 1801-1883.

[156] *Id.* § 1801(a)(6).

[157] *Id.* § 1856; 43 U.S.C. §§ 1311-12.

[158] 16 U.S.C. § 1852.

[159] Pub. L. No. 104-297, 110 Stat. 3559 (1996).

[160] *See* 16 U.S.C. § 1851(a)(1), (3).

[161] *Id.* § 1802(33).

resources, the Marine Mammal Protection Act (MMPA) of 1972[162] and the Endangered Species Act (ESA) of 1973,[163] focus on species already in crisis and thus underscore the federal species-specific approach to living marine resources. By the time Congress enacted the MMPA, many marine mammals such as whales and seals had already been hunted to crisis levels.[164] The MMPA imposes a general moratorium on the taking and importing of these species, subject to exceptions for scientific research, public display, incidental takings, gear protection in commercial fishing, importation of specified products, actions by certain Alaska natives, and self-defense.[165] In addition, NOAA can designate any marine mammal as depleted and limit the availability of incidental take permits for that species if its stock is below its optimum sustainable population or if the species has been listed for protection under the ESA.[166] Under the ESA, USFWS, in consultation with NOAA Fisheries (also known as the National Marine Fisheries Service), can list a marine species as either threatened or endangered if that species is in danger of becoming extinct.[167] The ESA prohibits takings, importation, and exportation of listed species, including those in the oceans.[168] In addition, federal agencies must ensure that their actions and the activities that they permit, fund, or regulate do not jeopardize the continued existence of a listed species or destroy its critical habitat.[169]

The point of this very quick overview is simple: the current structure of ocean law in the United States encourages agencies, consumers, and politicians to value the ocean on the basis of specific resources, species, or geographic locations and through the lens of human use. Not surprisingly, therefore, most official marine valuation studies in the United States focus on these individual resources or, at broadest, commercial sectors.

Fisheries provide one prominent example. In its 2004 report, the U.S. Commission on Ocean Policy noted that "[t]he commercial fishing

[162] 16 U.S.C. §§ 1361-1421h.

[163] 16 U.S.C. §§ 1531-1544.

[164] Lauren L. Lones, Note, *The Marine Mammal Protection Act and International Protection of Cetaceans: A Unilateral Attempt to Effectuate Transnational Conservation*, 22 VAND. J. TRANSNAT'L L. 997, 998-99 (1989). *See also Status of Marine Mammal Species and Populations*, MARINE MAMMAL COMM'N, https://www.mmc.gov/priority-topics/species-of-concern/status-of-marine-mammal-species-and-populations/ (last visited July 17, 2021) (listing the marine mammal species considered "depleted" under the Marine Mammal Protection Act, most of which are also listed for protection under the Endangered Species Act).

[165] 16 U.S.C. §§ 1371-1374.

[166] *Id.* § 1373(c).

[167] 16 U.S.C. § 1533(a).

[168] *Id.* § 1538(a).

[169] *Id.* § 1536(a).

industry's total value exceeds $28 billion annually, with the recreational saltwater fishing industry valued at around $20 billion, and the annual U.S. retail trade in ornamental fish worth another $3 billion."[170] On the other side of the process, "Americans consume more than 4 billion pounds of seafood at home or in restaurants and cafeterias every year," amounting to "about $54 billion in consumer expenditures."[171]

Each year, generally in late fall, NOAA Fisheries releases its latest *Fisheries Economics of the United States* report. The current report, released in December 2018, is based on 2016 data.[172] Ironically, however, NOAA historically has known more about the economic value of U.S. fisheries and specific fish species than it has about the health of the fish stocks themselves. NOAA Fisheries does not fully monitor all fished stocks. The 2018 *Status of Fisheries* report, for example, noted that "NOAA Fisheries manages 479 stocks or stock complexes in 46 fishery management plans."[173] NOAA, however, performed sustainability analyses on only 175 of the most important of them, representing approximately 80% of the value of U.S. marine fisheries, and it actually knew the overfished status of only 151 of those.[174] As for the other 304 regulated species, NOAA Fisheries did not know whether 193 of these stocks were overfished or not.[175] Notably, despite some progress during the Obama Administration in reducing the number of overfished stocks, that

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[170] 2004 USCOP REPORT, *supra* note 102, at 31-32.

[171] *Id.* at 32.

[172] *Fisheries Economics of the United States, 2016*, NOAA FISHERIES, https://www.fisheries.noaa.gov/content/fisheries-economics-united-states-2016 (last visited July 9, 2021). As of July 2021, NOAA Fisheries has not released any subsequent fisheries economic reports. However, in its 2020 fish stocks assessment report to Congress, it noted that "U.S. commercial fisheries landed 9.3 billion pounds of seafood valued at $5.5 billion in 2019. Saltwater recreational fishing remains a key contributor to the national economy with anglers taking more than 187 million trips in 2019." NOAA FISHERIES, STATUS OF STOCKS 2020: ANNUAL REPORT TO CONGRESS ON THE STATUS OF U.S. FISHERIES 2 (2021), https://media.fisheries.noaa.gov/2021-05/2020%20Status%20of%20Stocks%20RtC_5-18-21_FINAL.pdf?null [hereinafter 2020 NOAA STOCK STATUS REPORT]. The COVID-19 pandemic hit the U.S. fisheries industry particularly hard, and "commercial fish landings revenues declined an average of 29 percent through the first half of 2020." *Id.* at 10.

[173] *2018 Report to Congress on the Status of U.S. Fisheries*, NOAA FISHERIES, https://www.fisheries.noaa.gov/national/2018-report-congress-status-us-fisheries (last visited Feb. 17, 2020).

[174] NOAA FISHERIES, 2019 QUARTER 4 UPDATE THROUGH DECEMBER 31, 2019, at 1 (Feb. 2020) [hereinafter NOAA QUARTER 4 UPDATE]; *Status of U.S. Fisheries*, NOAA FISHERIES, https://www.fisheries.noaa.gov/national/population-assessments/status-us-fisheries (last visited Oct. 31, 2021).

[175] NOAA QUARTER 4 UPDATE, *supra* note 174, at 2

number is increasing again,[176] reaching 22 of the fully assessed stocks by the end of 2019,[177] the highest level in the last ten years. At the same time, NOAA Fisheries proudly reported to Congress that "[i]n 2018, in conjunction with the councils, we reviewed all of our fishery regulations to identify those that should be removed or revised to further reduce regulatory constraints and optimize fishery benefits. As a result, we finalized 10 deregulatory actions that resulted in $695 million in cost-savings."[178]

The federal government also keeps a steady eye on the value of offshore oil and gas resources. In federal offshore waters, the Bureau of Ocean Energy Management (BOEM) leases submerged lands for oil and gas development pursuant to OCSLA, charging for the lease itself and then earning annual royalties for the United States.[179] Like NOAA Fisheries, BOEM keeps close tabs on the economic value of the industry it regulates.[180] For FY2016, for example, BOEM calculated that federally regulated offshore oil and gas production created "[a]pproximately 315,000 U.S. jobs," contributed "$30 billion to the U.S. economy," generated "$2.7 billion in leasing revenues to the U.S. Treasury," contributed "$11 million in revenue sharing programs" to Texas, Louisiana, Mississippi, Alabama, Alaska, and California,[181] and promoted domestic energy security.[182]

Finally, ocean-based shipping and other kinds of transportation have long been important to the U.S. economy. As the U.S. Commission on Ocean Policy noted in 2004, "[m]ore than thirteen million jobs are related to trade transported by the network of inland waterways and ports that support U.S. waterborne commerce," and, "[a]nnually, the nation's ports

[176] *2018 Report to Congress on the Status of U.S. Fisheries*, NOAA Fisheries, https://www.fisheries.noaa.gov/national/2018-report-congress-status-us-fisheries (last visited Feb. 17, 2020).

[177] NOAA QUARTER 4 UPDATE, *supra* note 180, , at 1.

[178] NOAA FISHERIES, STATUS OF STOCKS 2018: ANNUAL REPORT TO CONGRESS ON THE STATUS OF U.S. FISHERIES 11 (2019).

[179] *Lease Sales and Fair Market Value*, BUREAU OF OCEAN ENERGY MGMT., https://www.boem.gov/oil-gas-energy/energy-economics/lease-sales-and-fair-market-value (last visited July 17. 2021); *BOEM Completes Analysis Of Royalty Rates For Offshore Oil And Gas Leases*, BUREAU OF OCEAN ENERGY MGMT. (July 6, 2017), https://www.boem.gov/newsroom/notes-stakeholders/boem-completes-analysis-royalty-rates-offshore-oil-and-gas-leases.

[180] *Oil and Gas Energy*, BUREAU OF OCEAN ENERGY MGMT., https://www.boem.gov/oil-gas-energy (last visited July 9, 2021).

[181] BUREAU OF OCEAN ENERGY MGMT., OFFSHORE OIL AND GAS ECONOMIC CONTRIBUTIONS 1 (2016), https://www.boem.gov/sites/default/files/oil-and-gas-energy-program/Leasing/Five-Year-Program/2019-2024/DPP/NP-Economic-Benefits.pdf.

[182] *Id.* at 2.

handle more than $700 billion in goods."[183] Prior to the COVID-19 pandemic, cruise passengers accounted for another $12 billion in spending,[184] while "[n]ationwide retail expenditures in recreational boating exceeded $30 billion in 2002."[185]

Maritime transportation has only increased in its economic importance to the United States since 2004. Again focusing on pre-COVID reporting, according to the Maritime Administration of the U.S. Department of Transportation in 2019, "about 99% of overseas trade enters or leaves the U.S. by ship. This waterborne cargo and associated activity contributes more than $500 billion dollars to the U.S. GDP, generates over $200 billion in annual port sector federal/state/local taxes and sustains over 10 million jobs."[186] According to NOAA, U.S. ports are involved in 76% of *all* trade in the United States, seaports alone support 13 million jobs, and "[t]he volume of traffic for marine ports is expected to double by 2021 and double again shortly after 2030."[187]

C. *A Summary of Current U.S. Marine Economics and Valuation*

The importance of the economic figures in Subpart B is twofold. First, they demonstrate that the ocean is immensely valuable to the United States, and hence worth protecting. Second, however, they project that valuation only in terms of specific facts of the ocean's functioning, giving no sense that the ocean is a complex system. NOAA tacitly admits to this sector-by-sector valuation of the U.S. marine economy even in its overall assessments. Before COVID, NOAA noted of the U.S. marine economy overall that "[i]t's big. And it grew a lot. The marine economy's contribution to gross domestic product grew by 5.7 percent between 2014 and 2015. This was twice as fast as the U.S. economy as a whole (which

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[183] 2004 USCOP REPORT, *supra* note 102, at 31.

[184] *Id.*

[185] *Id.* at 32.

[186] *Maritime Transportation System (MTS): Improving the U.S. Marine Transportation System*, MARITIME ADMINISTRATION, U.S. DEPARTMENT OF TRANSPORTATION, https://www.maritime.dot.gov/outreach/maritime-transportation-system-mts/maritime-transportation-system-mts (last updated Jan. 8, 2021). Notably, the U.S. Coast Guard is even more enthusiastic about the maritime sector's contributions to the U.S. economy, noting in 2018 that "[t]he Marine Transportation System (MTS) is an integrated network that consists of 25,000 miles of coastal and inland waters and rivers serving 361 ports. The MTS supports $4.6 trillion of economic activity each year and accounts for the employment of more than 23 million Americans." U.S. COAST GUARD, MARITIME COMMERCE STRATEGIC OUTLOOK 4 (Oct. 2018) (citations omitted), https://media.defense.gov/2018/Oct/05/2002049100/-1/-1/1/USCG%20MARITIME%20COMMERCE%20STRATEGIC%20OUTLOOK-RELEASABLE.PDF.

[187] *Fast Facts: Ports*, NOAA OFF. FOR COASTAL MGMT., https://coast.noaa.gov/states/fast-facts/ports.html (last updated July 14, 2021).

grew by 2.7 percent)."[188]

Nevertheless, tensions are emerging from this sector-by-sector approach. The U.S. ocean economy is complex and diverse, and not all sectors co-exist peacefully.[189] As NOAA noted, "Some sectors have strong economic ties, such as ship building, marine construction, and marine transportation. Other sectors, such as tourism and recreation and living resources, benefit from healthy ecosystems. Some sectors compete for coastal and offshore space."[190] However, the marine economy's diversity also contributes to the resilience (in the engineering or "bounce back" sense[191]) of the U.S. economy: "The marine economy rebounded from the 2007 recession much faster than the U.S. economy. Employment options range from entry level to highly technical positions, and these skill levels are reflected in wages. This includes seasonal and part-time work options."[192] New marine industries will both strengthen the marine economy's resilience and increase the competition for ocean space. As NOAA noted, "[s]everal industries that are economically significant in other countries are just now breaking ground in the U.S., such as offshore renewable energy and aquaculture. There is great growth potential here."[193]

This increasingly crowded and high-tech maritime sector is already becoming a governance challenge for the U.S. Coast Guard.[194] This agency concluded in 2018 that, "[g]iven the competing uses and growing demands for commerce, energy, food, resources, and recreation in U.S. waters, the Coast Guard must optimize maritime planning."[195] The Coast Guard thus suggests one reason why marine spatial planning, discussed in more detail in Part III, may have continuing legal and policy importance for the United States.

Moreover, hidden in NOAA's bright vision of an engineered future for U.S. coasts are hints that the ocean's life support systems are already stressed. Thus, "[a]fter seeing a decline in its fishery over the last 30 years, Gloucester, Massachusetts, recognized the need to diversify its marine economy. The city used NOAA-supplied methods and assistance to

[188] NOAA OFF. FOR COASTAL MGMT., DISCOVER AN OCEAN OF BUSINESS OPPORTUNITY: NOAA AND THE MARINE ECONOMY 1 (2019), https://coast.noaa.gov/data/nationalfacts/pdf/hand-out-marine-economy.pdf.

[189] *Id.*

[190] *Id.*

[191] *See* discussion *infra* nn. 367 & 368 & accompanying text.

[192] NOAA OFF. FOR COASTAL MGMT., *supra* note 188, at 1.

[193] *Id.*

[194] U.S. COAST GUARD, *supra* note 186, at 6.

[195] *Id.* at 7.

quantify economic impacts and better position itself to take advantage of emerging markets"[196]—presumably *not* related to fisheries. In the Gulf of Mexico, NOAA has been using its marine economics data to "examine how environmental problems, such as the *Deepwater Horizon* oil spill, affect business and employment in the marine economy."[197] BOEM is studying "how offshore wind energy affects recreation and tourism. The federal agency is using this information to help local decision makers understand potential impacts when considering this alternative energy source."[198]

Again, pulling back to view the various economic sectors of the ocean more comprehensively, increasing competition for space and mutual interference are becoming the dominant characteristics of U.S. marine space, especially closer to the coast. Moreover, it is the industries based on living marine resources and healthy ecosystems—fishing, whale watching, snorkeling and diving, and other forms of coastal recreation and tourism—that are the most stressed: ships don't depend as strongly on a stable set of chemical, physical, and biological parameters as coral reefs, kelp forests, and various other marine ecosystems do.

The realization that marine valuation and economics tends to elide the value of healthy marine ecosystems helped to promote new ways of valuing the ocean, especially as specific forms of marine recreation became increasingly important components of various state economies and the national one. The next Part explores some of these ecosystem-focused valuation techniques.

IV. THE BEGINNING OF A CHANGE: VALUING MARINE ECOSYSTEMS

One of the major problems with the current regulatory regime for the United States' ocean is that it largely ignores the fact that fish, shellfish, crustaceans, and marine mammals live in interconnected and interdependent marine ecosystems, not as isolated populations. However, the importance of this interdependence can no longer be denied. For example, large-scale slaughter of the sea otter populations on the west coast of the United States led to widespread destruction of the kelp forests that grow there because the otters fed on sea urchins, which in turn fed on kelp.[199] Even though the law has since protected sea otters, their recovery has been uneven because of the more-complex-than-expected feeding

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196 NOAA OFF. FOR COASTAL MGMT., *supra* note 188, at 2.

197 *Id.*

198 *Id.*

199 Jeremy B.C. Jackson et al., *Historical Overfishing and the Recent Collapse of Coastal Ecosystems*, 293 SCI. 629, 630-31 (2001).

choices that orcas make among seals, sea lions, and otters.[200] Without comprehensive consideration of these interactions, regulation of individual species—even to *protect* that species—is likely to produce suboptimal results, such as minimally sustainable populations with little resilience to the changes occurring in the ocean that Part I described.

Ecosystem approaches to marine management both attempt to correct the shortcomings of species-by-species and sector-by-sector management and broaden the regulatory ken to larger marine support systems—habitat, predator-prey relationships and food webs, and anthropogenic stressors. While these approaches do not (yet) attempt to encompass the entire ocean as a system, they *do* focus on ocean subsystems—ecosystems—and can sometimes define quite large areas of the ocean as functional units of governance. For example, "Large Marine Ecosystems (LMEs) are relatively large areas of ocean space of approximately 200,000 km^2 [kilometers squared] or greater, adjacent to the continents in coastal waters where primary productivity is generally higher than in open ocean areas."[201] As NOAA notes, "there are 64 LMEs defined globally, of which 11 are located within the US Exclusive Economic Zone."[202] Similarly, several marine protected areas in the United States govern large expanses of the ocean. For example, the four Marine National Monuments in the Pacific—in order of creation, Papahānaumokuākea (2006), Marianas Trench (2009), Pacific Remote Islands (2009), and Rose Atoll (2009) Marine National Monuments—now "encompass a total area of 600,684 square miles (1,555,764 square kilometers)."[203]

This Part examines the various ways in which U.S. ocean law and policy both incorporate and value marine ecosystems. It begins with the transition from extractive recreation, like recreational fishing, to marine ecosystem-based recreation, which includes snorkeling, diving, and whale watching. Other important milestones include the development of ecosystem services and their incorporation into the Clean Water Act, the Comprehensive Environmental Response, Compensation, and Liability Act, and the Oil Pollution Act, and place-based marine regulation,

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[200] *Id.*

[201] *Introduction to the LME Portal: The Large Marine Ecosystem Approach to the Assessment and Management of Coastal Ocean Waters*, UNIV. OF R.I. ENV'T DATA CTR., https://web.archive.org/web/20200120172806/http://lme.edc.uri.edu/index.php/lme-introduction (archived Jan. 20, 2020).

[202] *Science and Research Activities*, NOAA ECOSYSTEM-BASED MANAGEMENT, https://ecosystems.noaa.gov/ScienceandResearch/ScienceandResearchActivities.aspx (last visited Oct. 31, 2021).

[203] *Marine National Monuments in the Pacific*, NOAA FISHERIES, https://www.fisheries.noaa.gov/pacific-islands/habitat-conservation/marine-national-monuments-pacific (last visited July 9, 2021).

including marine protected areas, marine reserves, and marine spatial planning.

A. *A Starting Point for Wider Appreciation and Valuation: Marine Ecosystem-Based Recreational Tourism as an Important Marine Industry*

When the U.S. Commission on Ocean Policy produced figures for the ocean's economic contribution in 2004, it noted that "[r]oughly three-quarters of the jobs and half the economic value were produced by ocean-related tourism and recreation."[204] While some of this value came from recreational fishing, much of this tourism and recreation supports a transition to governance based on ecosystem-based regulation and an increased valuation of intact ecosystems that attract tourists. At that time, non-extractive ocean-related tourism and recreation provided approximately $38.5 billion in annual economic value to the United States.[205] According to NOAA, by 2021, the United States' marine-related tourism and recreation sector employed almost 2.5 million people, generated almost $66 billion in annual wages, contributed about $143 billion to the U.S. GDP, and was growing faster than the U.S. economy as a whole.[206]

Globally, the shift to ecosystem-based valuation has been most obvious for coral reef ecosystems in countries where snorkeling- and diving-based tourism is an important component of national economic well-being. Coral reef ecosystems are some of the most productive ecosystems on the planet, often compared to rainforests in terms of biodiversity.[207] Traditionally, nations with tropical reefs have valued them for their fishery resources.[208] However, overfishing placed a strain on many of the world's coral reefs long before climate change became an issue for them. In 2002, for example, researchers concluded that "'overfishing has affected 95 percent'" of the world's coral reefs, and coral reef fish species are far more likely than other marine species to become or

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[204] 2004 USCOP FINAL REPORT, *supra* note 102, at 31.

[205] *See id.* (providing the bases for the author's calculations).

[206] *Fast Facts: Tourism and Recreation*, NOAA OFF. FOR COASTAL MGMT., https://coast.noaa.gov/states/fast-facts/tourism-and-recreation.html (last updated July 7, 2021).

[207] Richard Stone, *A World Without Corals?*, 316 SCI. 678, 678 (2007); THOMAS E. SVARNEY & PATRICIA BARNES-SVARNEY, THE HANDY OCEAN ANSWER BOOK 169 (2000); DIRK BRYANT ET AL., REEFS AT RISK: A MAP-BASED INDICATOR OF THREATS TO THE WORLD'S CORAL REEFS 7 (1998).

[208] Stone, *supra* note 207, at 678.

be at risk of extinction.[209] Indeed, in 2006 in the United States, the NMFS listed two species of *Acropora* coral (elkhorn and staghorn coral) as threatened species under the federal ESA,[210] and several more species have been added to the list since then.[211]

Despite this historical emphasis on coral reefs' fishery resources, coral reef tourism has become equally as valuable as fishing in many of these countries—and snorkelers and divers want healthy reefs. Coral reefs are some of the most valuable ecosystems on the planet, contributing over US$375 billion each year to the global economy.[212] Many of these benefits derive from tourism.[213] For example, the economic benefits from recreation on Australia's Great Barrier Reef alone have been valued at US$710 million to $1.6 billion.[214] A study in the Maldives calculated that each shark tourists could see while diving or snorkeling was worth $33,500, while a similar study in Palau calculated that each shark was worth $1.9 million over the course of its lifetime in reef tourism revenue—far exceeding its paltry value in a fishery.[215] In Indonesia, the tourism industry attached to shark and ray (such as manta rays) diving was worth at least $22 million in 2017, dwarfing the export value of the Indonesian shark fishery ($10 million), and is expected to increase dramatically over the next decade if Indonesia invests in these species' conservation.[216] More comprehensively, a study in support of marine spatial planning in Wales found that "the economic importance of non-extractive recreational uses of marine biodiversity," such as "diving, kayaking, wildlife watching from boats and seabird watching . . . is comparable to that of marine fisheries for

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[209] Robin Kundis Craig, *Taking Steps Toward Marine Wilderness Protection? Fishing and Coral Reef Marine Reserves in Florida and Hawaii*, 34 MCGEORGE L. REV. 155, 187 (2003) (citation omitted).

[210] Endangered and Threatened Species: Final Listing Determinations for Elkhorn Coral and Staghorn Coral, 71 Fed. Reg. 26,852 (May 9, 2006) (codified at 50 C.F.R. pt. 223); *see also* Robin Kundis Craig, Acropora *spp.: Water Flow, Water Quality, and Threatened Florida Corals*, 22 NAT. RES. & ENV'T. 8, 8-10 (Fall 2007) (discussing the *Acropora* listing).

[211] *E.g.*, Adding 20 Coral Species to the List of Endangered and Threatened Wildlife, 79 Fed. Reg. 67,356 (Nov. 13, 2014) (codified at 50 C.F.R. pt. 17).

[212] J.M. Pandolfi et al., *Are U.S. Coral Reefs on the Slippery Slope to Slime?*, 307 SCI. 1725, 1725 (2005); *see also* 2004 USCOP FINAL REPORT, *supra* note 102, at 321; CORAL REEF TASK FORCE, THE NATIONAL ACTION PLAN TO CONSERVE CORAL REEFS 1 (2000) [hereinafter 2000 CORAL NATIONAL ACTION PLAN].

[213] *See* Stone, *supra* note 207, at 680.

[214] Liam Carr & Robert Mendelsohn, *Valuing Coral Reefs: A Travel Cost Analysis of the Great Barrier Reef*, 32 AMBIO 353, 356 (2003).

[215] David Jolly, *Priced Off the Menu? Palau's Sharks Are Worth $1.9 Million Each, A Study Says*, N.Y. TIMES (May 2, 2011), https://www.nytimes.com/2011/05/02/science/earth/02shark.html.

[216] Putu Liza Kusuma Mustika et al., *The Economic Value of Shark and Ray Tourism in Indonesia and Its Role in Delivering Conservation Outcomes*, 7 FRONTIERS MARINE SCI. art. 261, at 1-2, 8-9 (2020).

the same region," arguing that these interests should be given equal weight to fishing in marine planning.[217]

In 2002, NOAA "calculated that annually 45 million visitors come to seaside and live-aboard accommodations to dive, fish, and otherwise enjoy U.S. coral reefs," generating about $17.5 billion a year for local communities and state and territorial governments.[218] Over 90 million U.S. residents "frequent coral reefs for some sort of recreation."[219] In 2007, NOAA more specifically reported (based on 2002 data) that the Main Hawaiian Islands received an annual economic benefit of over $360 million from marine tourism,[220] while southeastern Florida received "$4.4 billion in local sales, almost $2 billion in local income, and 71,300 full- and part-time jobs."[221] Even in American Samoa, where tourism is limited, coral reefs provide approximately $5 million in annual economic value.[222] More recent figures indicate that coral reef tourism and recreation in the United States is worth $1.028 billion per year.[223] In contrast, coral reefs'

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[217] A. Ruiz-Frau et al., *Spatially Explicit Economic Assessment of Cultural Ecosystem Services: Non-extractive Recreational Uses of the Coastal Environment Related to Marine Biodiversity*, 38 MARINE POL'Y 90, 90 (2013), https://doi.org/10.1016/j.marpol.2012.05.023.

[218] DONNA D. TURGEON ET AL., NAT'L OCEAN SERV., THE STATE OF CORAL REEF ECOSYSTEMS OF THE UNITED STATES AND PACIFIC FREELY ASSOCIATED STATES 4 (2002).

[219] *Id.* at 35 (citations omitted).

[220] NOAA CORAL REEF ECOSYSTEM RESEARCH PLAN FOR FISCAL YEARS 2007 TO 2011, at 1 (K.A. Puglise & R. Kelty eds., 2007) [hereinafter 2007 CORAL RESEARCH PLAN] (citing H.P. CESAR ET AL., ECONOMIC VALUATION OF THE CORAL REEFS OF HAWAII: FINAL REPORT (FY 2001-2002) (2002) (calculating the $360 million per year figure)).

[221] *Id.* at 1. Data for Florida vary considerably, however. For example, the U.S. Commission on Ocean Policy reported in 2004 that "[i]n 2001, coral reefs in the Florida Keys alone supported $105 million in income and more than 8,000 jobs." 2004 USCOP FINAL REPORT, *supra* note 102, at 321-22. In contrast, in 2005, Pandolfi et al. reported in *Science*, relying on 1998 calculations, that "[a]nnual revenues from reef tourism are $1.6 billion, but the economic future of the Keys is gloomy owing to accelerating ecological degradation." Pandolfi et al., *supra* note 212, at 1725. Richard Dodge, executive director of the National Coral Reef Institute, reportedly stated that "[r]eef-related activities generate more than $4 billion for the economy of southeast Florida alone." Brian Skoloff, *Florida Officials Try to Shield Coral Reefs*, USA TODAY (June 15, 2007), http://www.usatoday.com/tech/science/2007-06-14-889661944_x.htm. It seems reasonable, therefore, to assert that coral reefs generate tourism benefits worth significantly more than $1 billion annually to Florida.

[222] 2007 CORAL RESEARCH PLAN, *supra* note 220, at 1.

[223] *See* LUKE BRANDER & PETER VAN BEUKERING, NOAA CORAL REEF CONSERVATION PROGRAM, THE TOTAL ECONOMIC VALUE OF U.S. CORAL REEFS: A REVIEW OF THE LITERATURE 5 tbl.1, 6 tbl.2, 7 tbl.3, 8 tbl.4, 9 tbl.5, 10 tbl.6 & tbl.7 (2013), https://data.nodc.noaa.gov/coris/library/NOAA/CRCP/other/other_crcp_publications/TEV_US_Coral_Reefs_Literature_Review_2013.pdf. The figures presented in the accompanying text represent the totals of each territory's or state's "recreation" and "tourism" columns. While there is some overlap with recreational fishing, even if one subtracts the entire $100 million in recreational fishing that coral reefs provide (see *infra* note 243 and accompanying text), the United States' coral reefs are still worth $928 million in tourism and non-fishing recreation.

value for commercial and recreational fisheries is far less: "In the United States, about half of all federally managed fisheries depend on coral reefs. NOAA's National Marine Fisheries Service estimates the annual commercial value of U.S. fisheries from coral reefs to be over $100 million."[224] While significant, this is 10 times *less* valuable than coral reef-related tourism. Thus, the increasing value of marine tourism to local and natural economies can help to shift public and political valuation of the ocean from specific fished species to the health of the relevant ecosystems as a whole.

B. *Ecosystem Services*

Coral reef tourism and recreation are examples of *ecosystem services*, but the concept of ecosystem services provides a broader mechanism for valuing intact and functional marine ecosystems that incorporates more than just these two human uses. Ecosystem services acknowledge that ecosystems provide for human needs in a variety of ways that have real economic value but that are not always traded in markets.[225] The Millennium Ecosystem Assessment defined ecosystem services broadly as "the benefits people obtain from ecosystems."[226] More specifically, according to Gretchen Daily, "*[e]cosystem services* are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life."[227] In 1997, Robert Costanza and several colleagues estimated that the world's ecosystem services were worth $16 to $54 *trillion* each year,[228] underscoring the economic importance of ecosystem services to human well-being.

While researchers classify ecosystem services in a variety of ways, these classification systems are broadly similar.[229] For convenience, this Article adopts the Millennium Ecosystem Assessment's four categories of

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[224] *Coral Reefs Support Jobs, Tourism, and Fisheries*, FLA. KEYS NAT'L MARINE SANCTUARY, https://floridakeys.noaa.gov/corals/economy.html (last visited July 17, 2021).

[225] Gretchen C. Daily, *Introduction: What Are Ecosystem Services?*, *in* NATURE'S SERVICES: SOCIETAL DEPENDENCE ON NATURAL ECOSYSTEMS 1, 2 (Gretchen C. Daily ed., 1997) [hereinafter NATURE'S SERVICES].

[226] MILLENNIUM ECOSYSTEM ASSESSMENT, ECOSYSTEMS AND HUMAN WELL-BEING: A FRAMEWORK FOR ASSESSMENT 49, 53 (2003) [hereinafter MEA FRAMEWORK].

[227] NATURE'S SERVICES, *supra* note 225, at 3.

[228] Robert Costanza et al., *The Value of the World's Ecosystem Services and Natural Capital*, 387 NATURE 253, 253 (1997).

[229] *See*, *e.g.*, Camino Liquete et al., *Current Status and Future Prospects for the Assessment of Marine and Coastal Ecosystem Services: A Systematic Review*, 8 PLOS ONE e67737, at 4-5 fig.3 (2013), https://doi.org/10.1371/journal.pone.0067737 (comparing various classification systems for ecosystem services and explaining why the differences can be important in the marine environment).

ecosystem services.[230] The first category, and often the most obvious and most likely to be valued in markets, is *provisioning services*, or "the products obtained from ecosystems."[231] Sometimes referred to as "ecosystem goods," these services include food, fiber, fuel, fresh water, genetic resources, biochemicals, natural medicines, pharmaceuticals, and ornamental resources.[232] In the ocean, provisioning services and ecosystem goods include fish and shellfish for food, mangroves for timber, seaweed for food and food ingredients, biofuels, cosmetic ingredients, and the raw materials of marine-based pharmaceuticals and other biochemical products.[233]

The other three categories of ecosystem services are generally less obvious and traditionally less likely to have economic or political value. The second category is *regulating services*, or the "benefits obtained from the regulation of ecosystem processes."[234] Regulating services include air quality maintenance, climate regulation, storm protection, water regulation, erosion control, water purification and waste treatment, regulation of human diseases, biological control, and pollination.[235] Third, ecosystems provide *cultural services*, which the Millennium Ecosystem Assessment defines as "the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences."[236] Cultural services include cultural diversity, spiritual and religious values, knowledge systems, educational values, inspiration, aesthetic values, social relations, sense of place, cultural heritage values, and recreation and ecotourism.[237] Finally, *supporting services* are those ecosystem services that "are necessary for the production of all other ecosystem services" but that "are either indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people."[238] Given this definition, the Millennium Ecosystem Assessment considers the production of oxygen to be a supporting service, because such production

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230 MEA FRAMEWORK, *supra* note 226, at 49, 56.

231 *Id.* at 56.

232 *Id.* at 56-57.

233 *Mapping Ocean Wealth: Ecosystem Services*, NATURE CONSERVANCY (2020), https://oceanwealth.org/ecosystem-services/; *E-Learning Module 1.2.3.3: Marine Provisioning Services*, VALMER, https://www.marine-ecosystem-services.eu/en/Section-1/Section-1-2/1-2-3-marine-ecosystem-services/1-2-3-3-marine-provisioning-services (last visited July 10, 2021).

234 MEA FRAMEWORK, *supra* note 226, at 57.

235 *Id.* at 57-58.

236 *Id.* at 58.

237 *Id.* at 58-59.

238 *Id.* at 59.

occurs over "an extremely long time."[239] Other supporting services include "soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat."[240]

The ocean provides a significant portion of the Earth's ecosystem services. As the IPCC summarized in 2019, "[i]n addition to their role within the climate system . . . services provided to people by the ocean and/or cryosphere include food and water supply, renewable energy, and benefits for health and well-being, cultural values, tourism, trade, and transport."[241] In their 1997 *Nature* article, Robert Costanza and his colleagues estimated that about 63% of the total world value of ecosystem services—about US$20.9 trillion—comes from marine environments,[242] and about 60% of the value of marine ecosystem services derives from coastal ecosystems.[243] These researchers emphasized that the ocean is particularly important as a source of gas regulation, disturbance regulation, nutrient cycling, biological control, habitat, food production, raw materials, recreation, and cultural services.[244]

Thus, the ocean provides a variety of valuable ecosystem services spread across all four of the Millennium Ecosystem Assessment's categories. Nevertheless, it is worth emphasizing some of the more important of the non-provisioning services, given that provisioning services like fisheries are likely to already be part of ocean law and policy. First, the ocean provides the critical supporting service of oxygen production. Tiny plants that float near the ocean's surface throughout the world, known as phytoplankton, produce this oxygen.[245] Some of the oxygen remains dissolved within the ocean itself for use by where fish and other marine animals (but not marine mammals or sea turtles, which breathe atmospheric oxygen). Most of the oxygen, however, is released into the atmosphere. In fact, marine phytoplankton produce half of the world's atmospheric oxygen[246]—the oxygen upon which terrestrial animals, including humans, depend.

Second, the ocean provides regulating services related to air quality,

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[239] *Id.* at 60.

[240] *Id.*

[241] *2019 IPCC Ocean & Cryosphere Report*, *supra* note 11, at 5 (startup box).

[242] Costanza et al., *supra* note 228, at 259; *see also* Liquete et al., *supra* note 229, at 1 ("According to Costanza et al. and Martinez et al. the oceans and especially the coastal zone contribute more than 60% of the total economic value of the biosphere.").

[243] Costanza et al., *supra* note 228, at 256 tbl.2.

[244] *Id.*

[245] John Roach, *Source of Half Earth's Oxygen Gets Little Credit*, NAT'L GEOGRAPHIC NEWS (June 7, 2004), http://news.nationalgeographic.com/news/2004/06/0607_040607_phytoplankton.html.

[246] *Id.*

water purification, and climate and weather modulation, among others.[247] As noted above, the ocean is significantly dampening the terrestrial impacts of climate change by absorbing most of the heat generated by anthropogenic greenhouse gas emissions. In addition, marine ecosystems "both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality."[248] Indeed, scientists have noted that "[g]iven time, the oceans can absorb most of what we can throw into the atmosphere."[249]

Ocean ecosystems, especially coastal ecosystems, also provide regulating services in terms of storm protection, and "[t]he presence of coastal ecosystems such as mangroves and coral reefs can dramatically reduce the damage caused by hurricanes or large waves."[250] In the United States, loss of coastal wetlands and marshes allows storms in the Gulf of Mexico—like Hurricanes Katrina and Harvey—to inflict more damage than they would have had those coastal ecosystems remained intact.[251] In contrast, "[c]oastal wetlands saved more than US$ 625 million in avoided flood damages from Hurricane Sandy across the northeastern USA. For census tracts with wetlands, there was on average a 10% reduction in property damages across the region."[252] Recognizing these concrete values has recently inspired financial institutions to explore creative approaches to financing coastal ecosystem protection and enhancement.[253]

The ocean's cultural services are some of the least-researched aspects of the ocean's value.[254] Nevertheless, they too are highly valuable,[255] a value that is particularly evident in coastal areas closely linked to natural features such as beaches, coral reefs, and kelp forests.[256] Coastal and

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[247] For a more recent and more complete list of the ocean's regulating and maintenance services, see Liquete et al., *supra* note 229, at 5 fig.3.

[248] MEA FRAMEWORK, *supra* note 226, at 57.

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

[250] MEA FRAMEWORK, *supra* note 226, at 58.

[251] *See, e.g.*, John Tibbetts, *Louisiana's Wetlands: A Lesson in Nature Appreciation*, 114 ENV'T HEALTH PERSP. A40-A43 (2006), https://doi.org/10.1289/ehp.114-a40.

[252] SIDDHARTH NARAYAN ET AL., LLOYD'S TERCENTENARY RSCH. FOUND., COASTAL WETLANDS AND FLOOD DAMAGE REDUCTION: USING RISK INDUSTRY-BASED MODELS TO ASSESS NATURAL DEFENSES IN THE NORTHEASTERN USA (2016).

[253] CHARLES S. COLGAN ET AL., LLOYD'S TERCENTENARY RSCH. FOUND., FINANCING NATURAL INFRASTRUCTURE FOR COASTAL FLOOD DAMAGE REDUCTION 6-20 (2017).

[254] João Garcia Rodrigues et al., *Marine and Coastal Cultural Ecosystem Services: Knowledge Gaps and Research Priorities*, 2 ONE ECOSYSTEM e12290, at 2 (2017), https://doi.org/10.3897/oneeco.2.e12290; Carol L. Martin et al., *A Systematic Quantitative Review of Coastal and Marine Cultural Ecosystem Services: Current Status and Future Research*, 74 MARINE POL'Y 25, 25-26 (2016), https://doi.org/10.1016/j.marpol.2016.09.004.

[255] Rodrigues et al., *supra* note 254, at 4.

[256] Liquete et al., *supra* note 229, at 6:

fishing communities have their own identities, and recreation and tourism values have already been discussed. In addition, ocean resources have cultural and religious significance for Native Hawaiians, Native Alaskans, and many coastal Native American tribes,[257] a fact that multiple federal agencies with jurisdiction over the U.S. ocean acknowledge.[258] As Rodrigues et al. (2017) observed, however:

> Research targeted specifically at CES [cultural ecosystem services] has been focusing mostly on the economic valuation of nature-based recreation, tourism, and landscape or seascape scenic beauty. These CES classes are more amenable to monetary metrics, are seemingly easier to quantify, and often generate high revenues in the global economy. On the other hand, there is insufficient knowledge on CES related to spiritual interactions, inspirational experiences, cultural identity, sense of place, bequest, and existence values. These services generate non-material benefits that are usually not subject to market exchange and thus are not amenable to monetary quantification.[259]

Whatever one thinks of the precise monetary figures that Costanza and his colleagues suggested, or even of the whole attempt to assign economic values to services that are indispensable to life and human culture, the fact that the ocean makes such a significant contribution, in both economic and social terms, to human well-being suggests that law and policy should be paying more attention to keeping the ocean healthy. In particular, as Costanza has emphasized elsewhere, "[c]oastal environments, including estuaries, coastal wetlands, beds of sea grass and algae, coral reefs, and continental shelves are of disproportionately high value. They cover only 6.3% of the world's surface, but are responsible for 43% of the estimated

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> Coastal communities have always shown strong bonds to the sea due to the local identity. Natural and cultural sites linked to traditions and religion are numerous in the coastal zone. Both coastal and inland societies value the existence and beauty of charismatic habitats and species such as coral reefs or marine mammals.

[257] *See generally, e.g.*, *Makah Tribe History*, MAKAH TRIBE (viewed Aug. 21, 2020), https://makah.com/makah-tribal-info/; JOSHUA L. REID, THE SEA IS MY COUNTRY: THE MARITIME WORLD OF THE MAKAHS, AN INDIGENOUS BORDERLANDS PEOPLE (2015) (both describing the Makah Tribe's cultural connections to the ocean).

[258] For example, NOAA highlights the involvement of coastal tribes in many National Marine Sanctuaries. *Native Cultures and the Maritime Heritage Program*, NOAA (revised July 31, 2017), https://sanctuaries.noaa.gov/maritime/cultures.html. BOEM has a Tribal Engagement Program for offshore oil and gas and, more recently, wind farm development. *Tribal Engagement*, Bureau of Ocean Energy Mgmt., https://www.boem.gov/about-boem/tribal-engagement.

[259] Rodrigues et al., *supra* note 254, at 3 (citations omitted).

value of the world's ecosystem services."[260] It follows that loss of coastal and open ocean ecosystems, which is occurring throughout the world, represents a significant loss to the natural capital of both individual coastal nations and the world.

C. *Operationalizing Ecosystem Services in U.S. Ocean Law: Natural Resources Damages (NRDs)*

One of the general problems in valuing ecosystem services is that, usually, no one pays for them. As Costanza has noted, "If ecosystem services were actually paid for, in terms of their value contribution to the global economy, the global price system would be very different than it is today. The price of commodities utilizing ecosystem services directly or indirectly would be much greater."[261]

In the United States, Congress has adopted, in three ocean-related federal statutes, a mechanism to make those who damage ecosystem services and other natural resource amenities pay for their value: natural resource damages (NRDs).[262] NRDs are one way to place a price tag on the value of ecosystems and their services. Under federal law, NRDs are available under the federal Clean Water Act for oil spills,[263] the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) for releases of hazardous substances,[264] and the federal Oil Pollution Act of 1990 (OPA) for marine oil spills.[265] The EPA implements the Clean Water Act and CERCLA and has a single set of NRD assessment regulations for both statutes.[266] NOAA implements the OPA and has promulgated its own NRD regulations.[267] However, if an oil spill contains multiple constituents that trigger the OPA *and* either or both of the other two statutes, the OPA's NRD Assessment rules apply to any assessment that began after February 5, 1996.[268] Because of that primacy,

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[260] Costanza, *supra* note 5, at 201.

[261] *Id.*

[262] For more extensive discussions of NRDs and their uses and problems in restoring ecosystem functions and services, see generally Karen Bradshaw, *Settling for Natural Resource Damages*, 40 HARV. ENV'T L. REV. 211 (2016); Sanne H. Knudsen, *The Long-Term Tort: In Search of a New Causation Framework for Natural Resource Damages*, 108 NW. U. L. REV. 475 (2014); Itzchak E. Kornfeld, *Of Dead Pelicans, Turtles, and Marshes: Natural Resources Damages in the Wake of the BP Deepwater Horizon Oil Spill*, 38 B.C. ENV'T AFFS. L. REV. 317 (2011).

[263] 33 U.S.C.§ 1321.

[264] 42 U.S.C. § 9607.

[265] 33 U.S.C. §§ 2701-2762.

[266] 43 C.F.R. Part 11 (2021).

[267] 15 C.F.R. Part 990 (2021).

[268] 15 C.F.R. § 990.20(a), (b) (2021).

and because the most significant marine NRD assessments to date have involved oil spills (the 1989 *Exxon Valdez* oil spill in Prince William Sound, Alaska, and the 2010 *Deepwater Horizon* blowout in the Gulf of Mexico), this section focuses on the OPA to illustrate how NRDs operationalize ecosystem services concepts in the U.S. marine environment.

1. *NRDs under the Oil Pollution Act of 1990.*

Congress enacted the OPA in response to the 1989 *Exxon Valdez* oil spill in Alaska.[269] The main effect of the OPA is to expand responsible parties' potential liability for oil spills from what existed in the Clean Water Act.[270] "Responsible parties" subject to the OPA include:

> [T]he lessee or the permittee of the area in which the facility is located or the holder of a right of use and easement granted under State law or the Outer Continental Shelf Lands Act (43 U.S.C. § 1301-1356) for the area in which the facility is located (if the holder is a different person than the lessee or permittee), except a Federal agency, State, municipality, commission, or political subdivision of a State, or any interstate body, that as owner transfers possession and right to use the property to another person by lease, assignment, or permit.[271]

A "discharge" of oil is "any emission (other than natural seepage), intentional or unintentional, and includes, but is not limited to, spilling, leaking, pumping, pouring, emitting, emptying, or dumping."[272] Defenses are limited to "an act of God"; "an act of war"; and acts or omissions of unrelated third parties.[273]

Once a responsible party triggers the OPA, liability revolves primarily around removal costs and statutorily designated "damages." Responsible parties are liable for "all removal costs incurred by the United States, a State, or an Indian tribe" under federal or state law, and for "any removal costs incurred by any person for acts taken by the person which are consistent with the National Contingency Plan."[274] "Removal costs" are "the costs of removal that are incurred after a discharge of oil has occurred" or the costs of preventing, minimizing, or mitigating a

[269] S. REP. NO. 101-99, at 1-2 (Aug. 1, 1989), *reprinted in* 1990 U.S.C.C.A.N. 749, 750-51.
[270] 33 U.S.C. § 2702(a).
[271] *Id.* § 2701(32)(C).
[272] *Id.* § 2701(7).
[273] *Id.* § 2703(a).
[274] *Id.* § 2702(b)(1).

threatened oil spill.[275] "Removal," in turn, means "containment and removal of oil or a hazardous substance from water and shorelines or the taking or other actions as may be necessary to minimize or mitigate damage to the public health or welfare, including, but not limited to, fish, shellfish, wildlife, and public and private property, shorelines, and beaches."[276] Under the OPA, there is no limit on a responsible party's liability for removal costs in connection with an oil spill at an offshore facility.[277]

OPA damages include several forms of public and private damages.[278] Most relevant to this Article, however, the OPA explicitly provides for natural resource damages—that is, "[d]amages for injury to, destruction of, loss of, or loss of use of, natural resources, including the reasonable costs of assessing the damage."[279] Only public entities can recover natural resource damages—specifically, "a United States trustee, a State trustee, an Indian tribe trustee, or a foreign trustee."[280] "Natural resources" include:

> [L]and, fish, wildlife, biota, air, water, ground water, drinking water supplies, and other such resources belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by the United States (including the resources of the exclusive economic zone), any State or local government or Indian tribe, or any foreign government.[281]

The OPA designates NOAA as the agency responsible for promulgating natural resource damages regulations and dictates that damage assessments

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[275] *Id.* § 2701(31).

[276] *Id.* § 2701(30).

[277] *Id.* § 2704(a)(3) (designating that an offshore facility is liable for "all removal costs").

[278] These include: "[d]amages for injury to, or economic losses resulting from destruction of, real or personal property"; "[d]amages for loss of subsistence use of natural resources"; "[d]amages equal to the net loss of taxes, royalties, rents, fees, or net profit shares due to the injury, destruction, or loss of real property, personal property, or natural resources"; "[d]amages equal to the loss of profits or impairment of earning capacity due to the injury, destruction, or loss of real property, personal property, or natural resources"; and "[d]amages for net costs of providing increased or additional public services during or after removal activities, including protection from fire, safety, or health hazards, caused by a discharge of oil." *Id.* § 2702(b)(2)(B)-(F).

[279] *Id.* § 2702(b)(2)(A).

[280] *Id. See also id.* § 2706 (clarifying how natural resource trustees are appointed). Although natural resource damages claims in response to the *Deepwater Horizon* oil spill have so far focused on the United States and the Gulf states, several tribes are also potential claimants. For an overview of the relation of the oil spill to Gulf tribes, see Erick Rhoan, Comment, *The Rightful Position: The BP Oil Spill and Gulf Coast Tribes*, 20 SAN JOAQUIN AGRIC. L. REV. 173, 184-92 (2010-2011); Diane Courselle, *We (Used to?) Make a Good Gumbo—The BP* Deepwater Horizon *Disaster and the Heightened Threats to the Unique Cultural Communities of the Louisiana Gulf Coast*, 24 TUL. ENV'T L.J. 19, 26-28, 37-39 (2010).

[281] 33 U.S.C. § 2701(20).

done in accordance with the regulations "shall have the force and effect of a rebuttable presumption on behalf of the trustee in any administrative or judicial proceeding under this Act."[282]

The OPA generally caps the responsible parties' liability for statutory damages resulting from a release of oil at an offshore facility at $75 million, including NRDs.[283] However, the cap does not apply if the spill was "proximately caused by" the "gross negligence or willful misconduct of," or "the violation of an applicable Federal safety, construction, or operating regulation by, the responsible party," its agents or employees, or its contractors.[284] The cap also does not apply if the responsible party does not report the incident as required, does not cooperate with the removal activities, or does not comply with orders.[285]

2. *The OPA NRD regulations.*

NOAA's OPA NRD regulations emphasize that NRDs "make the environment and public whole" by returning "the injured natural resources *and services* to baseline and compensation for interim losses of such natural resources *and services* from the date of the incident until recovery."[286] As such, ecosystem services are built into the NRD Assessment's goals and purposes, which include both ultimate restoration of the ecosystems that the spill affected and compensation for interim losses—including losses, again, of those ecosystem services. "Restoration" under the regulations means:

> [A]ny action (or alternative), or combination of actions (or alternatives), to restore, rehabilitate, replace, or acquire the equivalent of injured natural resources and services. Restoration includes:
>
> (a) Primary restoration, which is any action, including natural recovery, that returns injured natural resources and services to baseline; and
>
> (b) Compensatory restoration, which is any action taken to compensate for interim losses of natural resources and services that occur from the date of the incident until recovery.[287]

In turn, "[s]ervices (or natural resource services) means the functions

[282] *Id.* § 2706(e) (2006).
[283] *Id.* § 2704(a)(3) (2006).
[284] *Id.* § 2704(c)(1).
[285] *Id.* § 2704(c)(2).
[286] 15 C.F.R. § 990.10 (2021) (emphasis added).
[287] *Id.* § 990.30.

performed by a natural resource for the benefit of another natural resource and/or the public."[288]

Ecosystem services are accounted for throughout the NRD assessment process. For example, determining injuries from the oil spill includes determining whether "impairment of a natural resource service has occurred as a result of response actions or a substantial threat of a discharge of oil."[289] Similarly, ecosystem services are prominent in the quantification phase, when "[t]rustees may quantify injuries in terms of . . . [t]he degree, and spatial and temporal extent of injury to a natural resource, with subsequent translation of that adverse change to a reduction in services provided by the natural resource" or "[t]he amount of services lost as a result of the incident," in addition to quantifying the damages to the natural resources themselves.[290] Thus, while NRD assessments do not absolutely require NOAA and the trustees to value ecosystem services, they clearly allow for the possibility. Moreover, such valuations may be particularly important in quantifying the interim losses from an oil spill, as the NRD assessment for the *Deepwater Horizon* blowout demonstrates.

3. *NRDs for ecosystem services losses resulting from the* Deepwater Horizon *blowout.*

On Tuesday, April 20, 2010, BP's $350 million, 33,000-ton *Deepwater Horizon* platform was drilling the Macondo well in water 5000 feet deep when the well blew out.[291] Eleven of the crew died in the ensuing explosion, which sank the rig two days later.[292] For three months, oil poured into the Gulf of Mexico's deepwater environment—nearly five million barrels before the well was finally capped on July 15.[293] The legal consequences were many. By June 2010, the Minerals Management Service—the federal agency that used to oversee offshore drilling in federal waters—had ceased to exist,[294] irrevocably tainted by conflicts of interest.[295] Two new agencies, including BOEM, replaced it, with revenue-

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[288] *Id.*
[289] *Id.* § 990.51(b)(2)(ii).
[290] *Id.* § 990.52(b).
[291] NAT'L COMM'N ON THE BP DEEPWATER HORIZON OIL SPILL & OFFSHORE DRILLING, DEEP WATER: THE GULF OIL DISASTER AND THE FUTURE OF OFFSHORE DRILLING 1-3 (2011) [hereinafter 2011 DEEPWATER HORIZON COMMISSION REPORT].
[292] *Id.* at 55.
[293] *Id.* at 87.
[294] *Id.* at 55.
[295] *Id.* at 77-79, 254-55.

making and regulatory functions better separated.[296] All of the companies involved were eventually held liable to the U.S. Government: MOEX Offshore 2007 LLC settled its civil liability in 2012 for $90 million; BP Exploration & Production entered a $4 billion criminal plea agreement later that year, followed by a $14.9 billion civil settlement in 2015; Transocean entered into a $1 billion civil settlement and $400 million criminal plea agreement in early 2013; and the federal courts imposed a $159.5 million civil penalty on Anadarko Petroleum in 2015.[297] Environmental damages concluded in 2016 with a $20.8 billion settlement.[298]

Neither scientists nor state and federal agencies could readily assess all the ecological impacts from the *Deepwater Horizon* spill because baseline information about these ecosystems was simply unavailable.[299] However, the economic impacts occasioned by the loss of the region's ecosystem services were both immediate and obvious, especially to tourism and fishing, the two industries that "were highly sensitive to both direct ecosystem harm and, indirectly, public perception and fears of tainted seafood and soiled beaches."[300] Fishing-dependent minority and tribal communities—most still recovering from the 2005 hurricane season—were particularly hard hit.[301]

Thus, the *Deepwater Horizon* spill presented a situation in which the ecosystem services damages to surrounding communities were often easier to assess than damages to the natural resources themselves, particularly with respect to the deepest Gulf ecosystems affected. Indeed, a 2013 National Academy of Sciences study on the use of ecosystem services in connection with the spill concluded that "the ecosystem services approach will add value along several dimensions."[302] Noting that "[o]ne of the strengths of the ecosystem services concept is that it highlights the ways in which healthy ecosystems support healthy economies,"[303] it concluded that

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[296] *Organizational History*, BUREAU OF SAFETY & ENV'T ENF'T, https://www.bsee.gov/about-bsee/our-organization/organizational-history (last visited July 10, 2021).

[297] *Deepwater Horizon – BP Gulf of Mexico Oil Spill*, U.S. ENV'T PROT. AGENCY, https://www.epa.gov/enforcement/deepwater-horizon-bp-gulf-mexico-oil-spill (last updated Dec. 4, 2020).

[298] *Deepwater Horizon Oil Spill Settlements: Where the Money Went*, NOAA, https://www.noaa.gov/explainers/deepwater-horizon-oil-spill-settlements-where-money-went (last updated Apr. 20, 2017).

[299] 2011 DEEPWATER HORIZON COMMISSION REPORT, *supra* note 291, at 184.

[300] *Id.* at 185.

[301] *Id.* at 193-94.

[302] NAT'L ACAD. OF SCIS., AN ECOSYSTEM SERVICES APPROACH TO ASSESSING THE IMPACTS OF THE *DEEPWATER HORIZON* OIL SPILL IN THE GULF OF MEXICO 1 (2013).

[303] *Id.* at 1-2.

"an ecosystem services approach can change the public's perception of natural resources and the ways agencies manage for healthy ecological systems" and "will contribute to public understanding of the relationships between humans and the environment."[304] Emphasizing the importance of ecological resilience to marine ecosystems' continued ability to provide ecosystem services, the Academy noted that "[e]cosystems are also subject to slowly changing long-term stresses, such as nutrient enrichment and changes in sediment supply, as observed in the [Gulf]. These long-term stresses can affect the ability of the system to respond to a shock such as the [*Deepwater Horizon*] oil spill."[305] Finally, it concluded that, given the then-current state of science, the oil spill's impacts to coastal wetlands and Gulf of Mexico fisheries provided the most promising foci for an ecosystem services-based NRD assessment.[306]

Ecosystem services were very much part of the *Deepwater Horizon* NRD assessment, a fact that is easiest to identify in Chapter 4 of the February 2016 combined Final Programmatic Damage Assessment and Restoration Plan (PDARP) and Final Programmatic Environmental Impact Statement (PEIS).[307] Given the massive scale of the oil spill, the Trustees "employed an ecosystem approach to the assessment by evaluating injuries to a suite of representative habitats, communities, and species, *as well as select human services*, ecological processes, and ecological linkages."[308] Lost recreational use was the most obvious ecosystem service they assessed,[309] and the Trustees "estimated that the public lost 16,857,116 user days of boating, fishing, and beach-going experiences as a result of the spill."[310] These losses occurred across multiple years; after the final estimates were compounded to 2015 using a 3 percent interest rate and adjusted to 2015 price levels, total recreational use damages resulting from the spill were "estimated to be $693.2 million."[311]

Ecosystem services informed other aspects of the NRD assessment as well. For example, observed changes in the deepwater (benthic)

[304] *Id.* at 2.
[305] *Id.* at 5.
[306] *Id.* at 6-9.
[307] The entire assessment is available at *A Comprehensive Restoration Plan for the Gulf of Mexico*, GULF SPILL RESTORATION, https://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan (last visited July 10, 2021). Chapter 4 alone is nearly 700 pages long, so this discussion is necessarily summary.
[308] DEEPWATER HORIZON NAT. RES. DAMAGE ASSESSMENT TRS., *DEEPWATER HORIZON* OIL SPILL: FINAL PROGRAMMATIC DAMAGE ASSESSMENT AND RESTORATION PLAN AND FINAL PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT 4-9 (2016) (emphasis added).
[309] *Id.* at 4-25.
[310] *Id.* at 4-648.
[311] *Id.*

ecosystems around the wellhead included toxic sediments and changes in species assemblages, and "such changes in the food web have the ability to change some of the most important ecological services that the deep benthos provides, principally the recycling of energy and nutrients from detritus falling to the sea floor back up into the water column."[312] Similarly, as the National Academy of Sciences suggested, damage to coastal salt marshes and other nearshore habitats directly impacted ecosystem services values, because "[m]any of the region's most important commercial and recreational fisheries include species that spend all or part of their lives in the nearshore environment."[313] In its conclusion, the Trustees emphasized three categories of lost ecosystem functions and services in particular:

> Marsh plants contribute several important ecosystem functions and services. They produce biomass through photosynthesis and form the basis of wetland and estuarine food webs. They help stabilize shorelines by holding, retaining, and accumulating marsh sediments. They also contribute to coastal flood protection by reducing storm surge and waves, and they provide critical structural habitat (as refuge and forage) for a wide variety of organisms. Injuries to marsh vegetation resulted in losses of these important ecosystem functions and associated services.
>
> The Trustees documented accelerated erosion rates along heavily oiled marsh shorelines in Louisiana where injuries to vegetation and intertidal oysters were observed. This increased erosion exacerbates Louisiana's already critical coastal erosion problem.
>
> Other examples of ecosystem function injuries include impaired cycles of organic matter and nutrients from the water column to oil-contaminated bottom sediments; altered transfer of energy and nutrients from coastal to offshore ecosystems where estuarine-dependent fish and shrimp were injured; and water filtration and nutrient cycling where oysters were injured.[314]

The federal government settled the *Deepwater Horizon* NRDs in 2016, as is common in NRD cases.[315] The settlement figure provides the best comprehensive valuation available for the totality of ecosystem services lost: BP paid $8.1 billion in NRDs to the federal government and an additional $700 million to cover unknown injuries and adaptive

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[312] *Id.* at 4-268.
[313] *Id.* at 4-291.
[314] *Id.* at 4-683 to 4-684.
[315] Bradshaw, *supra* note 262, at 215-16.

management.[316] As Karen Bradshaw observed, this settlement was "the largest natural resource damages settlement in history. The *Deepwater Horizon* consent decree alone exceeds the Environmental Protection Agency's ("EPA") 2015 budget and triples the total of all other settlements collected by agencies in the 35-year history of the remedy."[317] The Trustees concluded that the settlement would "make the public whole," as the OPA requires.[318] Nevertheless, there is reason to suspect that the settlement did not capture the full amount of the injury to Gulf ecosystem services[319]—let alone other aspects of marine function that do not directly benefit humans.

D. *Ecosystem-Based Management, Marine Protected Areas, and Marine Reserves*

As the *Deepwater Horizon* NRD assessment demonstrates, an ecosystem services approach forces the assessors to identify values—whether quantified and economic (e.g., lost recreation) or narrative and qualitative (e.g., lost wetlands)—that intact and functional marine ecosystems provide to humans. As the National Academy of Sciences pointed out, such assessments can also help the public appreciate the value of a healthy ocean system. Notably, the sheer scale of the oil spill encouraged the Trustees to think in terms of larger ecosystems rather than individual species or habitats, further underscoring the system-level functions and values at stake in the Gulf of Mexico.

Nevertheless, while ecosystem service assessments can suggest important foci for governance, they do not create a governance or management strategy or policy. Instead, ecosystem-based management (EBM) has become the dominant approach for governing marine ecosystems *as* ecosystems. NOAA, for example, has adopted EBM for many of its programs in the United States, describing that approach as follows:

> Ecosystem-based management (EBM) is an integrated management approach that recognizes the full array of interactions within an ecosystem, including humans, rather than considering single issues, species, or ecosystem services in isolation. The current and future environmental challenges facing ocean, coastal, and Great Lakes

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[316] U.S. Dep't of Justice, *Fact Sheet: Proposed Consent Decree with BP for the Deepwater Horizon/Macondo Well Oil Spill* 2 (2016), https://www.justice.gov/enrd/file/834511/download.

[317] Bradshaw, *supra* note 262, at 212-13.

[318] DEEPWATER HORIZON NAT. RES. DAMAGE ASSESSMENT TRS., *supra* note 308, at 1-25.

[319] Bradshaw, *supra* note 262, at 241-42.

> ecosystems benefit from EBM by utilizing a broad management approach that considers cumulative impacts on marine environments; an approach that works across sectors to manage species and habitats, economic activities, conflicting uses, and the sustainability of resources. EBM allows for consideration of resource tradeoffs that help protect and sustain diverse and productive ecosystems and the services they provide.[320]

The goal of EBM is "to sustain the long-term capacity of marine ecosystems to deliver a range of ecosystem services, such as seafood, clean water, renewable energy (e.g., wave, tidal, and biofuels), protection from coastal storms, and recreational opportunities, with a focus on both ecosystem health and human well-being."[321]

Thus, by definition, EBM moves beyond the species-by-species and resource-by-resource approaches to marine management that dominate U.S. ocean law and policy to focus on particular places and the ecosystems therein.[322] It also better addresses the dynamism of marine ecosystems by incorporating adaptive management[323] and better allows agencies like

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[320] *What is Ecosystem-Based Management?*, NOAA, https://ecosystems.noaa.gov/EBM101/WhatisEcosystem-BasedManagement.aspx (last visited July 11, 2021).

[321] Benjamin S. Halpern et al., *Placing Marine Protected Areas onto the Ecosystem-Based Management Seascape*, 107 PROC. NAT'L ACAD. SCIS. 18312, 18312 (2010), www.pnas.org/cgi/doi/10.1073/pnas.0908503107.

[322] As NOAA itself notes:

> EBM is cross-sectoral, explicitly considering the interactions between sectors of human activity (e.g. fishing and off-shore energy development) that overlap in the coastal and marine environment. *Most resource management (whether by federal, state, local or tribal governments) is of a single sector and is often called for by a statute (state or federal or both) specific to that sector, which may or may not guide how interactions with other sectors should be handled. EBM differs from conventional approaches that focus on a single species, sector, activity or concern*; EBM works at multiple levels and considers the cumulative impacts of different sectors.
>
> For example, the Magnuson-Stevens Act (MSA) currently states that overfishing shall not be allowed and sets quantitative definitions of what constitutes overfishing. However, MSA does not address the harm to fisheries from activities in other sectors, with the exception of calling for consultation on activities authorized by federal agencies that may impact essential fish habitat. An EBM approach would include cross-sectoral and cross-agency consideration of impacts along with development of management measures to address those impacts.

What is Ecosystem-Based Management, *supra* note 320 (emphasis added).

[323] Often described as "learning by doing," in the marine environment adaptive management is:

NOAA to openly and publicly address management tradeoffs among different sectors and concerns, including the full complement of stakeholders and collaborators.[324]

EBM thus potentially helps both ocean governance entities and the public understand that the ocean is a complex of resources and amenities that interact with one another in sometimes complicated ways. Like all

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> [A] way of managing the dynamic nature of ecosystems in the face of uncertainty by considering a broad range of influences within a region, including external influences, factors, and stressors. To increase effectiveness, adaptive management is often based on an open and mutually agreed upon process for monitoring and assessing the outcome of management actions; a process that allows for mid-course corrections to achieve desired outcomes.
>
> Adaptive management also takes into account socioeconomic considerations, stakeholder participation, conflict resolution, legal and policy barriers, and institutional challenges. Being adaptive requires people and institutions to be flexible, innovative, and highly responsive to new information and experiences. Adaptive management succeeds when there are clear linkages among information, actions, and results and a strong climate of trust among partners. Considering local, state, federal, and international actions and sharing data are also critical to success.

Id. However, while adaptive management can be an improvement over more static approaches to management, U.S. administrative law requirements make it difficult for federal and state agencies to engage in the iterative decision-making that true adaptive management requires, making it a relatively rare management technique in the United States. Jonathan H. Adler, *Dynamic Environmentalism and Adaptive Management: Legal Obstacles and Opportunities*, 11 J.L. ECON. & POL'Y 133, 151-56 (2015); Robin Kundis Craig & J.B. Ruhl, *Designing Administrative Law for Adaptive Management*, 67 VAND. L. REV. 1, 27-38 (2014); J.B. Ruhl & Robert L. Fischman, *Adaptive Management in the Courts*, 95 MINN. L. REV. 424, 436-43 (2010); J.B. Ruhl, *Regulation by Adaptive Management—Is It Possible?*, 7 MINN. J.L. SCI. & TECH. 21, 39-53 (2005); Warren T. Coleman, Note, *Legal Barriers to the Restoration of Aquatic Systems and the Utilization of Adaptive Management*, 23 VT. L. REV. 177, 193-98 (1998).

[324] As NOAA recognizes:

> It is rarely possible to optimize all activities at once without some tradeoff in uses and goals. For example, increased energy development might result in some loss or degradation of habitats, recreational areas, or fishing grounds, yet [is] often necessary to meet the nation's energy demand. Under current management practices these tradeoffs still exist but are not explicitly dealt with, and the interaction between sectors is often contentious and difficult to resolve. In practice, tradeoffs and conflicts are often dealt with after the initial activity planning or permitting occurs, frequently resulting in long delays or lawsuits. Using an EBM approach, tradeoffs are explicit and become part of the planning and permitting efforts, ensuring that all stakeholders have the opportunity to engage and resolve issues proactively.

What is Ecosystem-Based Management?, *supra* note 320; *see also* Halpern et al., *supra* note 321, at 18312 (noting that "management at any particular location will have many goals, and a key aspect of EBM is to explicitly assess the necessary tradeoffs in achieving multiple, often competing, goals.").

management tools, however, it is not a panacea. Particularly in degraded marine ecosystems where the primary management goal is restoration, EBM may not be up to the task. Restoring degraded marine ecosystems through active management and technological intervention has often proven difficult, even when the value of the system's services is recognized and political will to restore those services exists, as is often true in the case of eroding beaches and other coastal barrier features or charismatic ecosystems such as coral reefs.[325]

More generally, marine ecosystems are not subject to the same level of human control as terrestrial ecosystems. The coastal zone is an ecologically open system, to a much greater degree than other biomes. As NOAA notes, marine "ecosystems and managed resources often cross traditional political boundaries. In addition, resources are influenced by drivers, such as oceanographic and climatic conditions and socioeconomic factors."[326] Pollution and nutrients reach the ocean directly from the land, through rivers and streams, via the atmosphere, and from other coastal and open-ocean systems. Larvae and larger forms of potentially invasive species arrive on normal currents, through storm events, in ships' ballast tanks, or after escape or dumping from aquariums. These multiple and largely uncontrollable influences pose enormous challenges for managers trying to keep marine ecosystems productive in terms of goods and services.[327]

On top of these challenges, few marine ecosystems are well understood scientifically, even in "isolation,"[328] and they interact physically, chemically, and biologically across time and space in ways that are barely documented, let alone understood.[329] Thus, active management of marine ecosystems is always, at some level, an experiment. However, because of the spatial and temporal connections among marine ecosystems that make human control difficult, many marine ecosystems can restore

[325] *See*, *e,g.*, Fredrik Moberg & Patrik Rönnbäck, *Ecosystem Services of the Tropical Seascape: Interactions, Substitutions and Restoration*, 46 OCEAN & COASTAL MGMT. 27, 34-41 (2003) (describing the inadequacies of marine restoration efforts in tropical coastal ecosystems).

[326] *What is Ecosystem-Based Management?*, *supra* note 320.

[327] Tundi Agardy et al., *Population, Consumption, and Environment: Lessons Learned and Future Research about Coastal and Marine Ecosystems: Roundtable Discussion*, 31 AMBIO 377, 379 (2002).

[328] Robin Kundis Craig, *Taking the Long View of Ocean Ecosystems: Historical Science, Marine Restoration, and the Oceans Act of 2000*, 29 ECOLOGY L.Q. 649, 688 (2002), and sources cited therein.

[329] Robin Kundis Craig, *Taking Steps Toward Marine Wilderness Protection? Fishing and Coral Reef Marine Reserves in Florida and Hawaii*, 34 MCGEORGE L. REV. 155, 173-74, 177-79 (2003); Craig, *Taking the Long View*, *supra* note 328, at 689-98.

themselves if simply left alone.[330] As a result, putting a degraded marine ecosystem legally out of bounds—or at least severely limiting the use of its marine resource commodities[331]—can be an effective way to improve that ecosystem's resilience and productivity. By the end of the first decade of the 21st century, these "[m]arine protected areas, including no-take marine reserves, ha[d] become key ocean conservation strategies around the world."[332] Studies show that marine reserves completely closed to fishing and other extractive uses harbor more fish, larger fish, and healthier habitats than are found outside of protected areas.[333]

Nevertheless, while marine protected areas ("MPAs") and marine reserves can become tools within a larger EBM approach, the MPA approach grew out of biodiversity conservation efforts rather than resource management, and the two approaches do not always align as well as managers might like.[334] Indeed, the whole purpose of a marine reserve is to severely limit or prohibit human resource uses such as fishing, not to "manage" them in the more traditional sense.[335]

Thus, for purposes of this Article, MPAs and especially marine reserves daylight the values conflicts between individual goods and services, on the one side, and broader biodiversity and ecosystem goals, on the other, that continue to exist within U.S. ocean law and policy. Indeed, marine reserves bring these conflicts into sharp relief in ways that EBM and its tool of marine spatial planning,[336] with their shared goals of mediating tradeoffs and potential conflicts, do not. Virtually no marine

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[330] *See*, *e.g.*, Lotze et al., *supra* note 2, at 1809 ("Despite some extinctions, most species and functional groups persist, albeit in greatly reduced numbers. Thus, the potential for recovery remains, and where human efforts have focused on protection and restoration, recovery has occurred, although often with significant lag times.").

[331] *See*, *e.g.*, Craig, *Taking Steps*, *supra* note 329, at 166-222 (discussing the value of MPAs and marine reserves in the context of coral reef ecosystems); Craig, *Taking the Long View*, *supra* note 328, at 681-97 (discussing MPAs as a general regulatory strategy for restoring and protecting marine ecosystems).

[332] Halpern et al., *supra* note 321, at 18312.

[333] *Id.*

[334] *Id.*

[335] *Id.* at 18313 (noting that the "holistic focus of EBM represents an important distinction from the typical approach and intent of MPAs.). As the authors explain, MPAs are commonly "designed to exclude or limit some types of fishing and, in the case of no-take reserves, prohibit all fishing and extractive or destructive activities, except as necessary for scientific monitoring." *Id.* This focus, they argue, reflects only "a small subset of what EBM is intended to address." *Id.*

[336] Marine spatial planning, often referred to as "marine zoning," helps to operationalize EBM by identifying where human uses are in conflict with each other and with the needs of the ecosystem itself. Management of the Great Barrier Reef, for example, is often held out as the "gold standard" of marine governance that combines marine spatial planning, MPAs, and marine reserves into an effective EBM approach. Ruckelshaus et al., *Marine Ecosystem-Based Management in Practice: Scientific and Governance Challenges*, 58 BIOSCI. 53, 59-61 (2008).

reserve created for biodiversity purposes[337] has come into existence in the United States without significant opposition, often from fishers[338] or indigenous groups.[339] These conflicts manifest as political machinations,[340] litigation,[341] and/or lengthy negotiations and collaborations.[342] Creatively, in a policy decision to make lemonade, the Oregon Department of Fish & Wildlife reframed the conflicts over Oregon's marine reserves precisely as an opportunity to understand the different ways that people value the ocean, with the goal of better enhancing the future resilience of *all*

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337 The U.S. Department of Defense, most notably, has created a number of *de facto* biodiversity reserves by prohibiting entry to the waters next to coastal facilities for security purposes. For example, it did not create the 15-mile security zone in the waters surrounding the Kennedy Space Center at Cape Canaveral, Florida, as a biodiversity reserve. Nevertheless, this area, established in 1962, is now considered the United States' oldest fully protected marine reserve, protecting sportfish at significantly greater abundance and to much larger size than outside its boundary. Eric A. Reyier et al., *Residency and Dispersal of Three Sportfish Species from a Coastal Marine Reserve: Insights from a Regional-scale Acoustic Telemetry Network*, 23 GLOB. ECOLOGY & CONSERVATION e1057, at 1-2 (2020), https://doi.org/10.1016/j.gecco.2020.e01057.

338 *See* ELIZABETH MARINO, OR. DEP'T OF FISH & WILDLIFE, CAPE FALCON MARINE RESERVE: A PILOT STUDY OF IMPACTS, OUTCOMES AND EFFORT SHIFT OF COMMERCIAL AND CHARTER FISHERS 11-14 (2015).

; Bret Yager, *Fishermen Protest Marine Reserve at Kaupulehu*, W. HAW. TODAY (June 5, 2016, 3:33 PM), https://www.westhawaiitoday.com/2016/06/05/hawaii-news/fishermen-protest-marine-reserve-at-kaupulehu/; *cf.* Tim Langlois, *Opposition Keen to Stop Marine Parks, but will Fishers Benefit?*, CONVERSATION (June 4, 2013, 11:08 PM EDT) (illustrating opposition in Australia), https://theconversation.com/opposition-keen-to-stop-marine-parks-but-will-fishers-benefit-14955..

339 *See* Heidi Walters, *Scenes from Tribes' MLPA Protest*, N. COAST J. (June 30, 2010, 3:58 PM), https://www.northcoastjournal.com/NewsBlog/archives/2010/06/30/scenes-from-tribes-mlpa-protest.

340 *See* Craig, *Taking Steps*, *supra* note 329, at 224-60 (discussing the creation of the Dry Tortugas marine reserve within the Florida Keys National Marine Sanctuary and the lengthy process that preceded President George W. Bush's establishment of the Papahānaumokuākea Marine National Monument).

341 Most recently, for example, the Massachusetts Lobstermen's Association, Atlantic Offshore Lobstermen's Association, Long Island Commercial Fishing Association, Garden State Seafood Association, and Rhode Island Fishermen's Alliance unsuccessfully challenged President Obama's 2016 creation of the Northeast Canyons & Seamounts National Marine Monument in the Atlantic Ocean roughly 130 miles off the coast of Massachusetts. Mass. Lobstermen's Ass'n v. Ross, 349 F. Supp. 3d 48, 68 (D.D.C. 2018), *aff'd* 945 F.3d 535 (D.C. Cir. 2019), *cert. denied sub nom* Mass. Lobstermen's Ass'n v. Raimondo, 141 S. Ct. 979 (2021). Nevertheless, President Trump purported to reopen the Monument to fishing by Executive Order in 2020. Proclamation No. 10049, 85 Fed. Reg. 35,793, 35, 793 (June 11, 2020). The Conservation Law Foundation, Natural Resources Defense Council, and Center for Biological Diversity are challenging the legality of this Executive Order in the U.S. District Court for the District of Columbia. Complaint, Conservation L. Found. v. Trump, No. 20-cv-1589 (D.D.C. June 17, 2020), https://www.nrdc.org/sites/default/files/complaint-necanyons-20200617.pdf.

342 *See generally* STEVEN L. YAFFEE, BEYOND POLARIZATION: PUBLIC PROCESS AND THE UNLIKELY STORY OF CALIFORNIA'S MARINE PROTECTED AREAS (2020) (detailing the long and convoluted public collaboration process in creating marine protected areas in California).

Oregonians.[343] More commonly, the dual vision of the ocean's value embodied in marine reserve conflicts—ocean-as-source-of-goods versus ocean-as-life-supporting-system—has promoted studies to demonstrate the value of areas closed to fishing to the fishers themselves, generally through "spillover" improvements to fishing as fish move out of the highly productive reserves and into fishable areas.[344]

The political appeal of these studies is clear enough: agencies and governments do not have to choose between improved marine biodiversity and profitable fisheries. However, the studies linking no-fishing reserves to improved fisheries provide some of the first inklings that ocean management potentially can exploit spatial and temporal paradoxes: the prevention of fishing *here* and *now* can lead to more robust fisheries *there* and *later*—and perhaps even overall gains in fish catch. Studies of the dispersal of tropical coral reef fish species similarly evidence that healthy reefs in one place can ultimately contribute to the recovery of damaged reefs many thousands of miles away.[345] Understanding the full potential of these marine management paradoxes in the Anthropocene, however, requires a greater understanding of the ocean's function as a complex adaptive system, to which this Article now turns.

V. WHAT WE NEED TO VALUE: THE OCEAN AS A COMPLEX ADAPTIVE SYSTEM

The ocean is a complex of marine ecosystems, and "marine ecosystems are complex adaptive systems linked across multiple scales by flow of water and species movements."[346] The many calls for increased use of EBM arose in part because, "[d]espite their adaptive character and often redundant linkages, marine ecosystems are vulnerable to rapid changes in diversity and function."[347] "In short, marine ecosystems are in trouble, indicating that many previous attempts to manage individual threats in the absence of a system-wide approach have not worked."[348]

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343 *A Natural Laboratory for Social Science Research*, OR. DEP'T OF FISH & WILDLIFE (April 29, 2020), https://oregonmarinereserves.com/2020/04/29/human-dimensions-research/.

344 *E.g.*, MARGARET COONEY ET AL., CTR. FOR AM. PROGRESS, HOW MARINE PROTECTED AREAS HELP FISHERIES AND OCEAN ECOSYSTEMS 5-6 (2019), https://cdn.americanprogress.org/content/uploads/2019/06/12125457/MPAsFisheries-brief.pdf?_ga=2.30884280.606827583.1626038560-742824820.1626038560.

345 *E.g.*, Mauricio Romero-Torres et al., *The Eastern Tropical Pacific Coral Population Connectivity and the Role of the Eastern Pacific Barrier*, 8 SCI. REPORTS 9354 (2018), https://doi.org/10.1038/s41598-018-27644-2.

346 Ruckelshaus et al., *supra* note 336, at 53; Steven A. Levin & Jane Lubchenco, *Resilience, Robustness, and Marine Ecosystem-Based Management*, 58 BIOSCI. 27, 28 (2008).

347 Ruckelshaus et al., *supra* note 336, at 53.

348 *Id.*

In 1992, Yale law professor Donald Elliott wrote that "[e]nvironmental law represents the state-of-the-art in using legal institutions and techniques to manage complex systems to achieve social goals."[349] Nevertheless, the fragmented nature of U.S. ocean law presented in Part II means that U.S. law does not readily embrace a systems approach to marine management or value the ocean as the complex system of complex adaptive systems that it is. Nevertheless, and especially given climate change and ocean acidification, the acknowledgement that the ocean is a complex system needs to become the foundation of how the United States implements its ocean and coastal law. Indeed, the IPCC itself recognized that climate change's impacts on the ocean are already challenging marine governance institutions, noting that "[s]hifts in species distributions and abundance has challenged international and national ocean and fisheries governance, including in the Arctic, North Atlantic and Pacific, in terms of regulating fishing to secure ecosystem integrity and sharing of resources between fishing entities."[350]

This Part examines the ocean as a complex adaptive system and suggests potential pathways for incorporating this vision of the ocean into existing U.S. ocean law and policy. It begins, however, by defining "complex adaptive system."

A. *Complex Adaptive Systems, Resilience, and Panarchy's Productive Paradox*

Exploiting the potential power of marine management paradoxes—that is, the unexpected benefits of management that appear in distant locations and across time—requires understanding two related models of how systems like the ocean function: complexity theory and panarchy. This section explores each in turn.

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[349] E. Donald Elliott, *Environmental Law at a Crossroad*, 20 N. KY. L. REV. 1, 2 (1992). For other discussions examining the relationship between complexity theory and environmental law, see generally Andrew Long, *Complexity in Global Energy-Environment Governance*, 155 MINN. J. L. SCI. & TECH. 1055 (2014); Robin Kundis Craig, *Learning to Think About Complex Environmental Systems in Environmental and Natural Resource Law and Legal Scholarship: A Twenty-Year Retrospective*, 24 FORDHAM ENV'T L. REV. 87 (2012-2013); Jeffrey Rudd, *J.B. Ruhl's "Law-and-Society System": Burying Norms and Democracy Under Complexity Theory's Foundation*, 29 WM. & MARY ENV'T L. & POL'Y REV. 551 (2005); J.B. Ruhl, *Thinking of Environmental Law as a Complex Adaptive System: How to Clean Up the Environment by Making a Mess of Environmental Law*, 34 HOUS. L. REV. 933 (1997); Gerald Andrews Emison, *The Potential for Unconventional Progress: Complex Adaptive Systems and Environmental Quality Policy*, 7 DUKE ENV'T L. & POL'Y F. 167 (1996).

[350] *2019 IPCC Ocean & Cryosphere Report*, *supra* note 11, at 16.

1. *Complexity theory and complex adaptive systems.*

Complex systems have several distinguishing properties. First, they exhibit complex collective behavior—that is, individual components, following readily discernible rules of behavior, act collectively in vast numbers to "give rise to the complex, hard-to-predict, and changing patterns of behavior that fascinate us."[351] This property is often referred to as the *self-organizing* nature of complex systems, and the difficult-to-predict results are deemed *emergent* behaviors or properties.[352] Explaining how this "emergent self-organized behavior comes about" is the central enterprise of complexity science.[353]

Second, complex systems exhibit signaling and information processing—that is, they "produce and use information and signals from both their internal and external environments."[354] As such, the behavior of objects in a complex system "is affected by memory or 'feedback,'" meaning "that something from the past affects something in the present, or that something going on at one location affects what is happening at another."[355] Thus, complex systems are linked systems, both temporally and spatially. Moreover, "the nature of this feedback can change with time."[356] In other words, how components of the system respond to each other and to outside stimuli is subject to evolution and change.

Finally, complex systems "adapt—that is, change their behavior to improve their chances of survival or success—through learning or evolutionary processes."[357] As a result, complex systems—alternatively referred to as "complex adaptive systems"[358]—are dynamic systems that

351 MELANIE MITCHELL, COMPLEXITY: A GUIDED TOUR 12 (2009); *see also* NEIL JOHNSON, TWO'S COMPANY, THREE IS COMPLEXITY 13, 15 (2007) (noting that a complex system "contains a collection of many interacting objects or 'agents,'" that it "exhibits emergent phenomena which are generally surprising, and may be extreme," and that "the emergent phenomena typically arise in the absence of any sort of 'invisible hand' or central controller").

352 *See* MITCHELL, *supra* note 351, at 13; *see also* JOHNSON, *supra* note 351, at 5-9 (discussing emergent behavior and giving examples from a number of areas).

353 MITCHELL, *supra* note 351, at 13; *see also* JOHNSON, *supra* note 351, at 3-5 ("Complexity Science can be seen as the *study of the phenomena which emerge from a collection of interacting objects* . . . . The Holy Grail of Complexity Science is to understand, predict and control such emergent phenomena—in particular, potentially catastrophic crowd-like effects such as market crashes, traffic jams, epidemics, illnesses such as cancer, human conflicts, and environmental change.").

354 MITCHELL, *supra* note 351, at 13.

355 JOHNSON, *supra* note 351, at 14.

356 *Id.*

357 MITCHELL, *supra* note 351, at 13; *see also* JOHNSON, *supra* note 351, at 14 ("The objects can adapt their strategies according to their history.").

358 *See* MITCHELL, *supra* note 351, at 13.

"change over time in some way."[359] Nevertheless, "[w]hile complex systems can be fragile, they can also exhibit an unusual degree of robustness to less radical changes in their component parts."[360] Specifically, the emergence that such systems display typically "is the result of a very powerful organizing force that can overcome a variety of changes to the lower-level components."[361] This combination of system dynamism and organizing forces gives ecosystems and social-ecological systems—both of which are complex adaptive systems—the properties of *ecological resilience* described in resilience thinking.[362]

What complexity science teaches environmental and natural resources law is that uncertainty and unpredictability are inherent limitations on the legal system's ability to perfectly control and regulate its subjects, whether those subjects are social systems, ecological systems, or socio-ecological systems. As John Miller and Scott Page have emphasized, "At the most basic level, the field of complex systems challenges the notion that by perfectly understanding the behavior of each component part of a system we will then understand the system as a whole."[363] Or, as Neil Johnson has more colorfully summarized, complexity theory "represents a slap in the face for traditional reductionist approaches to understanding the world."[364]

2. *Ecological resilience and panarchy.*

As the dominant model for translating complexity theory into ecology, ecological resilience is also important for the systems approach to ocean law. Ecological resilience and resilience thinking acknowledge that ecosystems and social-ecological systems are dynamic—not, as prior theories had assumed, inherently stable systems tending toward an equilibrium.[365] "Resilience," as a concept, recognizes that, in fact, there are at least three ways in which ecosystems experience and respond to changes.[366] The first and most common understanding of resilience refers to an ecosystem's ability to resist change or bounce back from system

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[359] *See id.* at 15.

[360] JOHN H. MILLER & SCOTT E. PAGE, COMPLEX ADAPTIVE SYSTEMS: AN INTRODUCTION TO COMPUTATIONAL MODELS OF SOCIAL LIFE 9 (2007).

[361] *Id.*

[362] *See* BRIAN WALKER & DAVID SALT, RESILIENCE THINKING: SUSTAINING ECOSYSTEMS AND PEOPLE IN A CHANGING WORLD 1-10 (2006).

[363] MILLER & PAGE, *supra* note 360, at 3.

[364] JOHNSON, *supra* note 351, at 17.

[365] Lance H. Gunderson & Craig R. Allen, *Why Resilience? Why Now?*, *in* FOUNDATIONS OF ECOLOGICAL RESILIENCE xiii, xiv-xv (Lanch H. Gunderson, Craig R. Allen & C.S. Holling eds., 2010).

[366] *Id.* at xv (citation omitted).

shocks.[367] Sometimes referred to as "engineering resilience," this sense of resilience refers to "the rate or speed of recovery of a system following a shock."[368] In contrast, the second aspect of resilience, ecological resilience, acknowledges that ecosystems can exist in multiple states rather than stabilizing around a single equilibrium state; as a result, changes and disturbance can "push" ecosystems over thresholds from one ecosystem state to another.[369] This second sense of resilience "assumes multiple states (or 'regimes') and is defined as the magnitude of a disturbance that triggers a shift between alternative states."[370] Finally, resilience thinking also acknowledges "the surprising and discontinuous nature of change, such as the collapse of fish stocks or the sudden outbreak of spruce budworms in forests."[371] The long-time persistence of an ecosystem (or collection of multiple ecosystems) like the Gulf of Mexico in an apparently stable, productive ecosystem state is no guarantee that humans can continue to disturb (abuse) the system and expect only a gradual or linear response. Indeed, sudden regime shifts have been documented for a number of marine ecosystems, including Jamaican coral reefs (caused by the combined impacts of overfishing, hurricanes, and disease)[372] and Alaskan kelp forests (caused by sea otter predation).[373] Thus, resilience thinking warns managers to expect discontinuous events within ecosystems managed primarily to satisfy human priorities, such as maximum fishing.

Resilience thinking also incorporates the panarchy model, wherein multiple ever-changing ecosystems and social-ecological systems operating at multiple geographical and temporal scales are dynamically interlinked and able to influence each other.[374] Climate change, for example, stresses a large-scale and long-term atmospheric carbon cycle as a result of fossil fuel burning accelerating the pace at which carbon leaves long-term storage. Because both the carbon cycle and the climate system operate at global geographic scales and time scales of decades to centuries,

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[367] *Id.*

[368] *Id.*

[369] *Id.*

[370] *Id.* at xv-xvi.

[371] *Id.* at xv.

[372] Terence P. Hughes, *Catastrophes, Phase Shifts, and Large-Scale Degradation of a Caribbean Coral Reef*, *in* FOUNDATIONS OF ECOLOGICAL RESILIENCE, *supra* note 365, at 205.

[373] James A Estes & David O. Duggins, *Sea Otters and Kelp Forests in Alaska*, *in* FOUNDATIONS OF ECOLOGICAL RESILIENCE, *supra* note 365, at 249, 251.

[374] *See*, *e.g.*, Ahjond S. Garmestani et al., *Panarchy, Adaptive Management and Governance: Policy Options for Building Resilience*, 87 NEB. L. REV. 1036 (2009); C.S. Holling, Lance H. Gunderson & Garry D. Peterson, *Sustainability and Panarchies*, *in* PANARCHY: UNDERSTANDING TRANSFORMATIONS IN HUMAN AND NATURAL SYSTEMS 63-102 (Lance H. Gunderson & C.S. Holling eds., 2002) (describing the importance of panarchy theory's nested hierarchies of resilience loops).

perturbances in their functions change the function of ecosystems and social-ecological systems at all scales below them.[375]

However, the panarchy model also illustrates how changes in system dynamics at smaller scales—say, by adding or removing a stressor to a local marine ecosystem—can affect the ecological resilience of all linked systems, regardless of whether the linked system is much larger or operates much more slowly.[376] This is the positive paradox of adopting a complex systems/resilience thinking approach to natural resource management in the Anthropocene: reducing some stressors at local and regional scales can increase multiple systems' resilience to other stressors, perhaps allowing those linked systems to avoid regime shifts into particularly unproductive or difficult-to-reverse altered states.[377]

B. *The Ocean as a Complex Adaptive System: Implications for Governance*

There is little debate that the ocean is a complex adaptive system containing multiple linked complex adaptive ecosystems.[378] This status has immediate implications for U.S. ocean law and policy. As Bigagli observed in 2017:

> Traditional practices approached the management of marine environmental and human systems from a sector-based perspective, developing blueprint strategies for the management of specific sectors and related environmental and socio-economic problems. However, scientific literature pointed to how these sector-based, centralised, "command and control" approaches do not have the capacity to solve complex, ill-structured, persistent problems of unsustainability, also called "wicked" problems. The dramatic decline of coastal and oceanic fish stocks caused by overfishing; biodiversity losses and transformed food webs, such as phase shifts on coral reefs and in kelp forests; and increasing marine pollution and decline in the provision of ecosystem

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[375] BENSON & CRAIG, *supra* note 8, at 63-64.

[376] *See, e.g.*, WALKER & SALT, *supra* note 362, at 90-93 (discussing the ability of local nutrient pollution or invasive species to lead to large-scale ecosystem collapse)

[377] WALKER & SALT, *supra* note 362, at 91-92, 144; *see also* BENSON & CRAIG, *supra* note 8, at 73.

[378] *See, e.g.*, Emanuele Bigagli, Marine Complex Adaptive Systems: Theory, Legislation, and Management Practices 11 (Mar. 22, 2017) (Ph.D. dissertation, Wageningen University) (ProQuest); Ruckelshaus et al., *supra* note 336, at 53; Levin & Lubchenco, *supra* note 346, at 27; Larry Crowder & Elliott Norse, *Essential Ecological Insights for Marine Ecosystem-Based Management and Marine Spatial Planning*, 32 MARINE POL'Y 772, 775-76 (2008).

> services have been largely attributed to a failure of ocean governance.[379]

In the Anthropocene, moreover, even the goals of ocean governance are changing. Increasing numbers of marine scientists are concluding, for example, that because it is no longer possible to completely control or prevent change in ocean systems, "the goal of management should be to maintain ecosystems in a healthy, productive, and resilient condition so that they can sustain human uses and provide the goods and services humans want and need."[380]

Among these scientists, the adoption of a complex systems view of the ocean, including ecological resilience and the potential for regime shifts, has led to calls for a new approach to management: resilience-based management (RBM).[381] RBM is defined as "using knowledge of current and future drivers influencing ecosystem function," such as population change or changes in land use, to "prioritize, implement, and adapt management actions that sustain ecosystems and human well-being."[382]

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379 Bigagli, *supra* note 378, at 11 (citations omitted); *see also* Crowder & Norse, *supra* note 378, at 776-77.

380 Bigagli, *supra* note 378, at 15 (citing Karen K. McLeod et al., *Scientific Consensus Statement on Marine Ecosystem-Based Management* 1 (2005), http://www.onlyoneplanet.com/marineEBM_ConsensusStatement.pdf).

381 Elizabeth McLeod et al., *The Future of Resilience-Based Management in Coral Reef Ecosystems*, 23 J. ENV'T MGMT. 291, 292 (2019). RBM has been discussed in the context of a variety of ecosystems since about 2012, although coral reefs remain a prominent focus in this research. *See generally*, *e.g.*, Vivian Y.Y. Lam, Christopher Doropoulos & Peter J. Mumby, *The Influence of Resilience-Based Management on Coral Reef Monitoring: A Systemic Review*, 12 PLOS ONE e0172064 (2017), https://doi.org/10.1371/journal.pone.0172064; Andrew K. Carlson et al., *Projected Impacts of Climate Change on Stream Salmonids with Implications for Resilience-Based Management*, 26 ECOLOGY FRESHWATER FISH 190 (2017), https://doi.org/10.1111/eff.12267; David J. Yu et al., *Learning for Resilience-based Management: Generating Hypotheses from a Behavioral Study*, 37 GLOB. ENV'T CHANGE 69 (2016); KENNETH R.N. ANTHONY ET AL., GREAT BARRIER REEF MARINE PARK AUTHORITY, A FRAMEWORK FOR UNDERSTANDING CUMULATIVE IMPACTS, SUPPORTING ENVIRONMENTAL DECISIONS, AND INFORMING RESILIENCE-BASED MANAGEMENT OF THE GREAT BARRIER REEF WORLD HERITAGE AREA (2013); Brandon T. Bestelmeye & David D. Briske, *Grand Challenges for Resilience-Based Management of Rangelands*, 65 RANGELAND ECOLOGY & MGMT. 654 (2012), https://doi.org/10.2111/REM-D-12-00072.1.

382 E. McLeod et al., *supra* note 381, at 292; *see also* Lam et al., *supra* note 381, at 2 (noting that "RBM steers management actions towards the preservation of fundamental ecosystem functions, structure, identity and feedbacks. RBM departs from the classic view of steady-state resource management and instead attempts to focus on the processes that govern system dynamics. Contrary to the emphasis on the maintenance of a static perceived optimal state in traditional management approaches, RBM is closely tied to the prevention of regime shifts, whereby a conspicuous change to the structure and function of a system occurs once a threshold is surpassed. Regime shifts involve complex feedback mechanisms that affect system dynamics, hence, a critical aspect of managing for resilience is a thorough understanding of ecological processes of the relevant ecosystems.").

These prioritized actions include threat mitigation ("controlling pollution, sedimentation, overfishing"), actions that support ecosystem processes (for example, improving water quality), and strengthening the abilities of communities dependent on particular marine ecosystems to adapt to the changes occurring in those ecosystems, including by changing how people earn their livelihoods.[383] RBM provides a path forward for governing the ocean in the Anthropocene, seeking not so much to "solve" climate change and its impacts but rather to cope with them, "acknowledg[ing] that humans are capable of driving change, adaptation, and transformation."[384]

C. *Planetary Boundaries, the Ocean, and Priority Stressors*

As noted, one of the key emphases of RBM is to reduce stressors on marine ecosystems.[385] Legally prioritizing which stressors to focus on, however, can depend on both local social-ecological realities (dynamite fishing remains a problem in some coral reef communities, for example, but not in the United States) and larger resilience goals. In the United States, these realities and goals will often overlap, as the Planetary Boundaries Project reveals.

Will Stefan, Johan Rockström, and their colleagues at the Stockholm Resilience Center first identified nine planetary boundaries in 2009.[386] Planetary boundaries "are human-determined values of the control variable" to keep the planet from crossing thresholds and entering into transformations that represent existential threats to current social-ecological systems.[387] The nine boundaries represent systems operating at a global scale, either directly or cumulatively, and include climate change, ocean acidification, stratospheric ozone depletion, atmospheric aerosol loading, biogeochemical flows (phosphorus and nitrogen nutrient pollution), global freshwater use, land system change, biodiversity loss, and chemical pollution.[388] In their 2009 article, these researchers concluded that humans had pushed the planet well outside our safe operating space with respect to biodiversity loss, nitrogen pollution, and climate change.[389] Their 2015 update article moderated those conclusions

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[383] E. McLeod et al., *supra* note 381, at 292.
[384] *Id.*
[385] *Id.* at 296.
[386] Johan Rockström et al., *Planetary Boundaries: Exploring the Safe Operating Space for Humanity*, 14 ECOLOGY & SOC'Y art.32, at 1 (2009), http://www.ecologyandsociety.org/vol14/iss2/art32/.
[387] *Id.* at 3.
[388] *Id.* at 8-9 tbl.1.
[389] *Id.* at 22 fig.6.

by working with risk zones instead of hard boundaries.[390] Nevertheless, the researchers concluded that genetic biodiversity loss and both nitrogen and phosphorus pollution had crossed into red zones, while climate change and land system change had reached the yellow risk zones. "Novel entities" (toxic pollutants), atmospheric aerosol loading, and functional diversity within biosphere integrity had not yet been quantified.[391]

The implications of the Planetary Boundaries Project for U.S. ocean law are three-fold. First, the ocean is a direct or indirect participant in at least six of the boundaries identified: climate change, ocean acidification, toxic pollution ("novel entities"), freshwater use (through mediation of weather patterns and climate), biodiversity ("biosphere integrity"), and biogeochemical flows (nutrient pollution).[392] Researchers have also pointed out that the 2009 and 2015 analyses of land-system change "do not account for the influence of marine biomes on climate, including that of ice, seagrass and mangroves . . . , nor do they account for how ocean–atmosphere coupling may counteract the effect of forest loss on climate."[393] Marine habitats can be as important as forests to planetary feedback loops, because "several coastal marine habitats have the highest carbon sequestration rates of any habitat on the plan[e]t."[394] Re-conceiving the land use change boundary in these terms thus makes the ocean directly relevant to *seven* of the nine planetary boundaries.

Second, the processes that affect the planetary boundaries are interconnected.[395] The same carbon dioxide emissions from fossil fuel burning that contribute to climate change also cause ocean acidification;

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[390] Will Steffan et al., *Planetary Boundaries: Guiding Human Development on a Changing Planet*, 347 SCIENCE 736, 736 (2015).

[391] *Id.*

[392] However, although the Planetary Boundaries Project incorporate marine system change from phosphorus and nitrogen:

> [T]he N and P boundaries purely focus on marine system change on the global scale . . . . Background marine biogeochemical regimes are highly heterogeneous (horizontally and with depth), driving differences in biogeochemical cycling, primary productivity and trophic pathways. These differences cause spatial variability in the vulnerability of marine systems to anthropogenic nutrient flows, and suggest the need for a more nuanced treatment of this boundary to account for regional marine effects that are consistent with the existing regional treatment of the P boundary in relation to freshwater systems. Importantly, a vast literature exists exploring the biogeochemistry of coastal and oceanic waters that could underpin such an extension to the boundary.

Kirsty L. Nash et al., *Planetary Boundaries for a Blue Planet*, 1 NATURE ECOLOGY & EVOLUTION 1625, 1627 (2017) (citations omitted).

[393] *Id.* at 1625-26.

[394] *Id.* at 1626.

[395] *Id.* at 1630.

ocean acidification and climate change both negatively impact biodiversity, as do nutrient and toxic pollution; and changes in the cryosphere resulting from climate change are transferring freshwater in the form of melting ice from land to the ocean, affecting terrestrial freshwater use, sea level rise, ocean currents, and marine ecosystems.[396] Overfishing affects nutrient flows and biodiversity.[397] While understanding these complex interactions is difficult and their existence makes predicting how well management interventions will work nearly impossible at any level of granularity,[398] they also, paradoxically, reinforce the admonition of RBM researchers: reduce the stressors on ocean systems that can be reduced.

Third, the planetary boundaries underscore the national-global tension that pervades ocean law. The ocean is a global resource, no part of which is completely immune from the influence of management decisions (or, in many cases, non-management) occurring elsewhere, even though international law divides the ocean into "sovereign and common-pool resources."[399] Incorporating planetary boundaries into ecosystem management is challenging for all ecosystems, but "increased integration of marine biomes into the planetary boundary concept may present larger and more immediate challenges to Earth systems governance than currently realized."[400]

That does not mean, however, that the United States should just throw up its hands. In global climate change mitigation efforts, a molecule of carbon dioxide emitted anywhere in the world contributes to climate change for all, raising significant concerns about free riding for the nations that choose to reduce their emissions at some economic or social cost.[401] In contrast, the ocean is not uniform, and relatively nearshore ocean environments are often the most important to a coastal nation like the United States. Thus, while the health of our marine environments is not completely under U.S. control, neither are management efforts within the United States completely meaningless in the face of other nations' activities. As one example, largely because of the United States' ESA and MMPA, the "Pacific Coast Feeding Group" of gray whales, which migrates along the Pacific Coast of North America from California to

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[396] *2019 IPCC Ocean & Cryosphere Report*, *supra* note 10, at 83-84, 205-08, 493.

[397] Nash et al., *supra* note 392, at 1627, 1629.

[398] *Id.* at 1630-31.

[399] *Id.* at 1631.

[400] *Id.*

[401] *Why Climate Progress Is Deadlocked*, CLIMATE LEADERSHIP COUNCIL, https://clcouncil.org/why-climate-progress-is-deadlocked/ (last visited July 12, 2021); Scott Tong, *The Ultimate Climate Change Challenge: Free Riders*, MARKETPLACE (Oct. 2, 2015), https://www.marketplace.org/2015/10/02/ultimate-climate-change-challenge-free-riders/.

Alaska, recovered by 2016 to a population of 27,000 after being hunted to near extinction,[402] allowing it to be removed from the endangered species list in 1994.[403] In contrast, the "western North Pacific population of gray whales, which summers off the Russian coast in the Okhotsk Sea, remains endangered with only around 200 individuals."[404] From the opposite perspective, the large "dead zone" (hypoxic zone) in the Gulf of Mexico, often the size of Massachusetts or New Jersey, "is primarily caused by excess nutrient pollution from human activities, such as urbanization and agriculture, occurring throughout the Mississippi River watershed,"[405] *not* from foreign pollution.

Purely domestic ocean law and policy decisions within the United States therefore still matter to the health of many marine ecosystems that are important to Americans even as those ecosystems respond to global warming and ocean acidification. Moreover, while the international community continues to debate the goals of, and processes for, reducing atmospheric carbon dioxide emissions sufficiently and quickly enough to begin to slow climate change itself, the Planetary Boundaries Project suggests that the United States could significantly improve the health of the marine waters under its control—and, given the panarchy paradox, maybe elsewhere as well—by concentrating its focus initially on two more accomplishable system-focused legal interventions. The first of these, tapping into the biodiversity planetary boundary, is to take a more precautionary approach to securing its marine food supply. The second—acknowledging that the planet is already pushing the limits of the nitrogen and phosphorus boundaries—is to increase regulation of marine nutrient pollution. As a bonus, there are additional environmental and adaptation benefits from pursuing these two management strategies in tandem.

D. *Exploiting the Governance Paradox of Valuing the Ocean as a System*

One notable aspect of the Planetary Boundaries Project is that—at least for the moment—climate change is *not* the planetary boundary that we are

402 Sw. Fisheries Sci. Ctr., *Gray Whales in the Eastern North Pacific*, NOAA FISHERIES, https://www.fisheries.noaa.gov/west-coast/science-data/gray-whales-eastern-north-pacific (last updated Feb. 1, 2021).

403 Final Rule to Remove the Eastern North Pacific Population of the Gray Whale From the List of Endangered Wildlife, 59 Fed. Reg. 31,094 (June 16, 1994) (to be codified at 50 C.F.R. pts. 17, 222).

404 Sw. Fisheries Sci. Ctr., *supra* note 402.

405 Press Release, NOAA, NOAA Forecasts Very Large 'Dead Zone' for Gulf of Mexico (June 10, 2019), https://www.noaa.gov/media-release/noaa-forecasts-very-large-dead-zone-for-gulf-of-mexico.

at most risk of having already crossed. Instead, there are two other boundaries currently far more worrisome than climate change itself—biosphere integrity, or the global loss of biodiversity, and biogeochemical flows, or nutrient pollution. U.S. ocean law can both feasibly and profitably focus on these two issues—couched in terms of food security and public health, respectively—to reduce existing stressors to its marine ecosystems while simultaneously improving the well-being of its residents.

1. *Seize the moment regarding marine food security.*

Marine fish, shellfish, and algae are a significant component of global food security. According to the United Nations Food & Agriculture Organization (FAO), "Global food fish consumption increased at an average annual rate of 3.1 percent from 1961 to 2017, a rate almost twice that of annual world population growth (1.6 percent) for the same period, and higher than that of all other animal protein foods (meat, dairy, milk, etc.), which increased by 2.1 percent per year."[406] However, wild-caught marine fisheries leveled off in the 1990s,[407] and less than two-thirds of fish stocks are being fished sustainably.[408] In contrast, marine aquaculture plays an increasing role in the world's food security, producing in 2018 30.8 million metric tons of fish and shellfish and over 32 million metric tons of aquatic algae, primarily kelp.[409]

Marine food security and marine biodiversity are interlinked. Overfishing and the related phenomenon of fishing down the food web threaten both ecosystem resilience and marine biodiversity.[410] Indeed, there is considerable evidence that industrialized commercial global overfishing produced some of the first pervasive stresses to marine ecosystems, creating legacy problems that still stymie effective marine management.[411] At the same time, marine biodiversity loss is a food security issue. As the discussion in Part II suggests, the changes occurring in the ocean and their impacts on marine food webs and ecosystems have direct consequences for human food security. From a global perspective,

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[406] U.N. FOOD & AGRIC. ORG., THE STATE OF WORLD FISHERIES AND AQUACULTURE: SUSTAINABILITY IN ACTION 3 (2020), http://www.fao.org/3/ca9229en/ca9229en.pdf [hereinafter 2020 FAO FISHERIES & AQUACULTURE REPORT].

[407] *Id.* at 4 fig.1.

[408] *Id.* at 47.

[409] *Id.* at 26, 31.

[410] *See* U. Rashid Sumaila & Travis C. Tai, *End Overfishing and Increase the Resilience of the Ocean to Climate Change*, 7 FRONTIERS MARINE SCI. 523 (2020), https://doi.org/10.3389/fmars.2020.00523.

[411] Jeremy B.C. Jackson et al., *Historical Overfishing and the Recent Collapse of Coastal Ecosystems*, 293 SCI. 619, 629-35 (2001).

the IPCC concluded in 2019 that, already, "[c]hanges in the ocean have impacted marine ecosystems and ecosystem services with regionally diverse outcomes, challenging their governance (*high confidence*)."[412] While, at the moment, these changes are both enhancing and undermining food security, depending on the exact community involved, the impacts on ecosystem services already "have negative consequences for health and well-being (*medium confidence*), and for Indigenous peoples and local communities dependent on fisheries (*high confidence*)."[413]

Future changes to the ocean, including species migration and food web simplification, pose greater threats to global food security, fisheries governance, and even national security—including for the United States.[414] Moreover, the decreasing supplies of wild seafood are also likely to be less safe because of elevated concentrations of mercury and other toxics in marine plants and animals and increasing contamination, especially of shellfish, by both *Vibrio* pathogens (the family of bacteria that include cholera and the flesh-eating *Vibrio vulnificus*) and harmful algal blooms like red tides.[415] "These risks are projected to be particularly large for human communities with high consumption of seafood, including coastal Indigenous communities (*medium confidence*), and for economic sectors such as fisheries, aquaculture, and tourism (*high confidence*)."[416]

Overfishing has long been considered the primary threat to marine biodiversity and ecosystem function,[417] and, as discussed in Part II, even the United States continues to struggle with managing fish stocks sustainably. However, range shifts primarily induced by climate change are challenging that belief, and they are already complicating fisheries regulation. A 2018 study of 686 marine species indicated that species along the Pacific Coast of North America could shift ranges as much as 1500 kilometers (more than 930 miles), while those on the Atlantic Coast could shift more than 600 kilometers (more than 370 miles).[418] As the researchers noted, "In the United States, fisheries are managed regionally, including species that are managed by individual states and federally

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[412] *2019 IPCC Ocean & Cryosphere Report*, *supra* note 10, at 16.

[413] *Id.*

[414] *Id.* at 26; THE WHITE HOUSE, FINDINGS FROM SELECT FEDERAL REPORTS: THE NATIONAL SECURITY IMPLICATIONS OF A CHANGING CLIMATE 4-6 (2015), https://obamawhitehouse.archives.gov/sites/default/files/docs/National_Security_Implications_of_Changing_Climate_Final_051915.pdf

[415] *2019 IPCC Ocean & Cryosphere Report*, *supra* note 10, at 26.

[416] *Id.*

[417] BENSON & CRAIG, *supra* note 8, at 115-17 (collecting citations).

[418] James W. Morley et al., *Projecting Shifts in Thermal Habitat for 686 Species on the North American Continental Shelf*, 13 PLOS ONE e0196127, at 12 (2018), https://doi.org/10.1371/journal.pone.0196127.

managed fisheries that are governed by regional councils with representatives from neighboring states,"[419] and their projected range shifts are more than sufficient to move commercially important fish stocks across regulatory jurisdictions within the United States, from the United States to Canada, from Mexico to the United States, and, on the Pacific Coast, from Canada to the United States (Alaska).[420] Other management challenges include "shifts in fishing locations, conflict over regional allocation of fisheries quota, displaced fishermen, and changes in stock boundaries."[421]

Given the future increasing risks both to and from U.S. fisheries, a renewed focus on marine food security from a systems perspective, with the goal of greatly reducing the stresses that marine food production imposes on marine ecosystems, is an appropriate starting point for incorporating a systems valuation of the ocean in U.S. ocean law. Indeed, this timing and new focus are even more appropriate given the likely shifts in how the United States will secure its marine food supply in the near future. Even before climate change complicates the subject, marine fisheries are at their limits globally,[422] and, as noted, marine aquaculture is quickly making up the marine food security gap.[423] While the United States is currently a relatively minor marine aquaculture producer on the global scale,[424] the aquaculture industry is poised to expand rapidly over the next few decades, especially in federal waters.[425]

Like overfishing, many types of marine aquaculture can stress marine ecosystems.[426] However, neither all aquaculture operations nor all

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[419] *Id.* at 23.

[420] *Id.* at 17 fig.7, 18 fig.8.

[421] *Id.* at 23.

[422] Robin Kundis Craig, *Re-Tooling Marine Food Supply Resilience in a Climate Change Era: Some Needed Reforms*, 38 SEATTLE U. L. REV. 1189, 1191-96, 1198-1202 (2015).

[423] *Id.* at 1196-98.

[424] *Celebrating Aquaculture Week 2020*, NOAA FISHERIES (Sept. 22, 2020), https://www.fisheries.noaa.gov/feature-story/celebrating-aquaculture-week-2020.

[425] In his May 7, 2020, Seafood Executive Order, then-President Trump put NOAA in charge of facilitating aquaculture project permitting and ordered the U.S. Army Corps of Engineers (Army Corps) to establish nationwide permits for finfish, seaweed, and multispecies aquaculture in federal ocean waters. Exec. Order No. 13,921, 85 Fed. Reg. 28,471, § 6 (May 7, 2020) The executive order also ordered "[t]he Secretary of Commerce, in consultation with the Secretary of Defense, the Secretary of the Interior, the Secretary of Agriculture, the Secretary of Homeland Security, the Administrator of the Environmental Protection Agency, other appropriate Federal officials, and appropriate Regional Fishery Management Councils, and in coordination with appropriate State and tribal governments," to identify at least two Aquaculture Opportunity Areas in federal waters and to complete a programmatic Environmental Impact Statement for them pursuant to the National Environmental Policy Act (NEPA). *Id.* § 7. While President Biden is reviewing the Seafood Executive Order, he has not, as of November 2021, rescinded it.

[426] *Marine Aquaculture and the Environment*, NOAA FISHERIES, https://www.fisheries.noaa.gov/insight/marine-aquaculture-and-environment (last visited July 14, 2021).

aquacultured species have the same impacts to ecosystems, and some forms of marine aquaculture can actually improve marine ecosystem function and reduce other stressors. For instance, marine aquaculture can enhance the stocks of imperiled or previously imperiled species.[427] More expansively, shellfish and kelp aquaculture are often two of the least polluting forms of human food production, marine or terrestrial.[428] As the FAO has emphasized, mollusks like clams and oysters are filter feeders, meaning that aquacultured mollusks do not need to be fed.[429] Similarly, seaweeds grow through photosynthesis.[430] As a result, "[m]arine bivalves, filter-feeding organisms that extract organic matter from water for growth, and seaweeds, which grow by photosynthesis by absorbing dissolved nutrients, are sometimes described as extractive species."[431] Thus, not only does aquaculture of these species impose little pollution burden on the marine environment, but these species can actually reduce nutrient pollution in marine environments while providing tasty human food, regardless of whether the pollution comes from fed finfish aquaculture[432] or other sources, such as fertilizer runoff from upstream agriculture.[433] In addition, shellfish aquaculture and kelp aquaculture can improve water quality,[434] and kelp aquaculture is being promoted for its carbon sequestration amenities.[435]

There are also benefits to growing kelp and shellfish together. Seaweed aquaculture can help buffer areas of the ocean from the effects of ocean

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[427] *Id.*

[428] Jessica S. Turner et al., *Minimal Effects of Oyster Aquaculture on Local Water Quality: Examples from Southern Chesapeake Bay*, 14 PLOS ONE e0224768, at 1 (2019), https://doi.org/10.1371/journal.pone.0224768 (citation omitted). *See also* Matt Parker & Suzanne Bricker, *Sustainable Oyster Aquaculture, Water Quality Improvement, and Ecosystem Service Value Potential in Maryland Chesapeake Bay,* 39 J. SHELLFISH RESEARCH 269, 276 (2020), https://doi.org/10.2983/035.039.0208 (noting that oyster aquaculture in Maryland did not affect dissolved oxygen or ammonia levels in the water, indicating that the aquaculture was not negatively affecting the environment).

[429] 2020 FAO FISHERIES & AQUACULTURE REPORT, *supra* note 406, at 26.

[430] *Id.* at 27.

[431] *Id.*

[432] *Id.* at 27, 29.

[433] Parker & Bricker, *supra* note 428, at 277-78.

[434] *E.g.*, Zhibing Jiang et al., *Kelp Cultivation Effectively Improves Water Quality and Regulates Phytoplankton Community in a Turbid, Highly Eutrophic Bay*, 707 SCI. TOTAL ENV'T 135561 (2020), https://doi.org/10.1016/j.scitotenv.2019.135561; Julie M. Rose, Suzanne B. Bricker, Mark A. Tedesco & Gary H. Wikfors, *A Role for Shellfish Aquaculture in Coastal Nitrogen Management*, 48 ENV'T SCI. & TECH. 2519, 2519-23 (2014).

[435] *E.g.*, Calvyn F.A. Sondak et al., *Carbon Dioxide Mitigation Potential of Seaweed Aquaculture Beds (SABs)*, 29 J. APPLIED PHYCOLOGY 2363, 2363-71 (2017), https://doi.org/10.1007/s10811-016-1022-1.

acidification.[436] This buffering phenomenon has already been observed in connection with natural seagrass beds and kelp forests,[437] but recent studies in Japan, Korea, and China indicate that kelp farms produce the same effects—namely, a higher pH level (less acidic water) for the waters within the seaweed farm compared to adjacent waters away from the farm.[438] "These findings demonstrate that the net primary production of seaweed farms acts as an important sink of CO_2," and "co-culture of bivalves and seaweed aquaculture in multitrophic aquaculture systems can protect the bivalves from ocean acidification, while also mitigating the impacts associated to nutrient release from the bivalves."[439]

We are at a moment in the United States when fisheries managers know that they will need to adapt to climate change impacts. Various state and federal agencies know that they need to decide more comprehensively how to regulate marine aquaculture. Federal agencies are already testing the limits of their jurisdiction to regulate this expanding industry through their fragmented regulatory authorities,[440] and Congress has considered a new federal statute to govern it,[441] potentially creating another siloed compartment of federal ocean regulation. No approach offered thus far from within the United States' fragmented governance has considered marine aquaculture as simultaneously a food security, fisheries job transition, public health, marine biodiversity, climate adaptation, and climate resilience enterprise. The state and federal governments' inabilities to adopt a systems view of the ocean is hampering the very urgent regulatory need to distinguish among the various types of marine

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[436] Ik Kyo Chung et al., *The Future of Seaweed Aquaculture in a Rapidly Changing World*, 52 EUR. J. PHYCOLOGY 495, 501 (2017); Xi Xiao et al., *Seaweed Farms Provide Refugia from Ocean Acidification*, 776 SCI. TOTAL ENV'T 145192, at 1 (2021), https://doi.org/10.1016/j.scitotenv.2021.145192.

[437] Xiao, *supra* note 436, at 2 (citing seven other studies showing similar results).

[438] *Id.* at 4. The results were particularly strong at aquaculture facilities growing *Saccharina japonica* (Areschoug), a brown kelp widely aquacultured throughout Asia. *Id.*

[439] *Id.* (citations omitted).

[440] Most notably, in 2016 the Gulf of Mexico Fishery Management Council finalized rules pursuant to its authority to regulate fisheries under the Magnuson-Stevens Fishery Conservation and Management Act to regulate marine aquaculture in the federal waters of the Gulf of Mexico. Both the U.S. District Court for the Eastern District of Louisiana and the U.S. Court of Appeals for the Fifth Circuit declared the regulations invalid because aquaculture is not fishing. Gulf Fishermens Ass'n v. Nat'l Marine Fisheries Serv., 968 F.3d 454, 456 (5th Cir. 2020). In January 2021, the U.S. Army Corps of Engineers finalized three nationwide permits for marine aquaculture ("mariculture") using its authorities under the Rivers and Harbors Act of 1899 and Section 404 of the Clean Water Act. Reissuance and Modification of Nationwide Permits, 86 Fed. Reg. 2744 (Jan. 13, 2021) (to be codified at 33 C.F.R.).

[441] *E.g.*, Advancing the Quality and Understanding of American Aquaculture (AQUAA) Act, H.R. 6191, 116th Cong. (2020) (seeking to create aquaculture enterprise zones in federal waters to promote this emerging industry).

biodiversity and to promote the enterprises and species that accomplish multiple marine management goals[442]—including, possibly, helping to ensure that the plant does not cross its biodiversity, nutrient pollution, or ocean acidification boundaries. A complex systems approach to ocean law in this area should emphasize increased security of the country's marine food supply, in terms of both quantity[443] and food safety,[444] while minimizing existing and potential new stressors to the marine environment, such as by reducing wild fishing limits and quotas and favoring aquaculture operations that grow native species of kelp, shellfish, and finfish that do not require feeding or antibiotic regimes.

2. *Dealing with nutrient pollution.*

Nutrient pollution is a known problem in U.S. environmental law and policy—including, explicitly, a marine problem. Water flowing over and from farms, in the forms of both irrigation return flows and runoff from rain or snowmelt, carries excess fertilizer to the ocean.[445] Nutrients also reach the water through atmospheric deposition, such as from the burning of fossil fuels.[446] Once there, nutrients induce large blooms of marine plants—phytoplankton and algae. Algae are marine plants, many of which are beneficial to marine food webs.[447] Marine algae include both the large marine seaweeds and kelp and the nearly microscopic algal forms of marine phytoplankton.[448] The small phytoplankton forms of algae can create an "algal bloom," which "is a rapid increase in the population of algae in an aquatic system. . . . Typically only one or a few phytoplankton species are involved and some blooms may be recognized by discoloration

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442 *See generally* Robin Kundis Craig, *Promoting "Climate Change Plus" Industries Through the Administrative State: The Case of Marine Aquaculture*, YALE J. REGUL. (forthcoming 2022).

443 NOAA emphasizes that "[t]he United States imports 70 to 85 percent of its seafood, and nearly 50 percent of this imported seafood is produced via aquaculture. Driven by imports, the U.S. seafood trade deficit has grown to $16.9 billion in 2019." *U.S. Aquaculture*, NOAA FISHERIES, https://www.fisheries.noaa.gov/national/aquaculture/us-aquaculture (last updated July 8, 2021).

444 *E.g.*, David C. Love et al., *Risks Shift Along Seafood Supply Chains*, 28 GLOB. FOOD SEC. 100476, at 2 (2021) (tracing risks from seafood imports to the United States, both wild caught and aquacultured, and noting that "[s]eafood consumption is consistently one of the most common causes of foodborne disease outbreaks with known etiologies.). Love et al. note that, "seafood is the most common type of imported food linked to outbreaks, and the rate of imported seafood outbreaks is increasing." *Id.*

445 Robert J. Diaz & Rutger Rosenberg, *Spreading Dead Zones and Consequences for Marine Ecosystems*, 321 SCI. 926, 927 (2008).

446 *Id.*

447 *What is a Harmful Algal Bloom?*, NOAA, https://www.noaa.gov/what-is-harmful-algal-bloom (last updated April 27, 2016).

448 *Id.*

of the water resulting from the high density of pigmented cells."[449] This discoloration can give algal blooms common names, such as "red tides."[450] Increasing nutrient concentrations are the usual cause of algal blooms[451] because, like terrestrial plants, marine phytoplankton respond to nitrogen and phosphorus compounds as fertilizers.

Algal blooms impact both marine ecosystems and human health. At the ecosystem level, as the blooms die off, their decomposition consumes all the oxygen in the water column, leading to hypoxic conditions that make large areas of the ocean uninhabitable by marine animals.[452] In the United States, the largest of these so-called "dead zones" occurs seasonally in the northern Gulf of Mexico at the mouth of the Mississippi River and can reach the size of Massachusetts or New Jersey—over 7000 square miles.[453]

Dead zones are now common throughout the world's coastal regions.[454] The number of dead zones in the world's seas—including around the United States—has doubled every decade since 1960 as a result of increasing marine pollution, and a 2008 study identified more than 400 dead zones throughout the world.[455] Perhaps most disturbingly, dead zones are missing biomass compared to what would be expected, suggesting that the oxygen deprivation that algal blooms cause can have long-term effects on a region's biodiversity and productivity.[456]

Nutrient pollution is also a recognized public health issue, with both human and financial costs. In the ocean, the most direct health cost of the failure to adequately control nutrient pollution is harmful algal blooms, or HABs. A HAB is a bloom of a species of phytoplankton that produces toxic or harmful effects.[457] With respect to human health, the most important HABs are those that "produce toxins that can kill fish, mammals and birds, and may cause human illness or even death in extreme cases."[458]

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[449] *Reference Terms: Algal Bloom*, SCIENCEDAILY, https://www.sciencedaily.com/terms/algal_bloom.htm (last visited July 17, 2021).

[450] Danielle Hall, *What Exactly Is a Red Tide?,* SMITHSONIAN OCEAN (Aug. 2018), https://ocean.si.edu/ocean-life/plants-algae/what-exactly-red-tide.

[451] *Id.*

[452] *Id.*

[453] *See* Jennifer Vargas, *Gulf Wildlife 'Dead Zone' Keeps Growing*, NBC NEWS (May 7, 2010), https://www.nbcnews.com/id/wbna37028908.

[454] *See* Diaz & Rosenberg, supra note 445, at 926 ("[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.").

[455] *Id.* at 926, 926-28.

[456] *Id.* at 927-28.

[457] *What Is a Harmful Algal Bloom?*, NOAA, https://www.noaa.gov/what-is-harmful-algal-bloom (last updated Apr. 27, 2016).

[458] *Id.*

For example, sea lions in California have died when blooms of certain marine algae produce domoic acid.[459] Public health officials have identified several HAB-related human illnesses,[460] caused when humans eat contaminated seafood (generally shellfish) and are poisoned by the accumulated toxins.[461] Climate change is acting in concert with excess nutrient pollution to make harmful algal blooms worse.[462]

The Planetary Boundaries Project recognized nutrient pollution as a global problem that is pushing the Earth dangerously close to a transformative threshold. However, it is also a U.S. problem. As the U.S. EPA states, "Harmful algal blooms are a major environmental problem in all 50 states. Red tides, blue-green algae, and cyanobacteria are examples of harmful algal blooms that can have severe impacts on human health, aquatic ecosystems, and the economy."[463] Harmful algal blooms are neither new nor completely unnatural—hundreds of years ago, early west coast settlers were occasional poisoned by toxins in the seafood they consumed—but their economic significance to the United States has increased.[464] Moreover, while there are important variations among the different types of HABs that recur in the United States, overall "HABs are affecting more regions with more toxins and impacts than was the case decades ago."[465] Some of this increase results from better monitoring, but nutrient pollution remains an important factor in the increasing number and expanding locations of HAB events,[466] particularly "in certain estuaries, embayments, and sounds . . . [where t]he emerging cyanobacterial problem in the freshwater-to-marine continuum is one example of nutrient

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[459] SeaWeb, *The Rising Tide of Ocean Plagues: How Humans are Changing the Dynamics of Disease,* EUREKALERT! (Feb. 17, 2006), http://www.eurekalert.org/pub_releases/2006-02/s-trt021206.php.

[460] *See* Lynn M. Grattan et al., *Harmful Algal Blooms and Public Health*, 57 HARMFUL ALGAE 2, 3 (2016), http://dx.doi.org/10.1016/j.hal.2016.05.003 (describing five of the most common HAB-related illnesses).

[461] Donald M. Anderson et al., *Marine Harmful AlgalBblooms (HABs) in the United States: History, Current Status and Future Trends*, 102 HARMFUL ALGAE 101975, at 3 (2021), https://doi.org/10.1016/j.hal.2021.101975 ("The resulting human poisoning syndromes linked to consumption of shellfish have been given the names paralytic, diarrhetic, neurotoxic, amnesic, and azaspiracid shellfish poisoning (PSP, DSP, NSP, ASP, AZP) to describe primary symptoms or the toxins involved. Except for ASP, all are caused by biotoxins synthesized by dinoflagellates; the ASP toxin, domoic acid, is produced predominantly by diatoms within the genus *Pseudo-nitzschia.*").

[462] *2019 IPCC Ocean & Cryosphere Report*, *supra* note 11, at 16.

[463] *Harmful Algal Blooms*, U.S. ENV'T PROT. AGENCY, https://www.epa.gov/nutrientpollution/harmful-algal-blooms (last updated Nov. 30, 2020).

[464] Anderson et al., *supra* note 461, at 1, 2.

[465] *Id.* at 27.

[466] *Id.* at 27-28.

pollution-driven enhancement of HAB incidence."[467] Notably, 7% of the United States' continental coastal waters have experienced overgrowth of algae as a result of nutrient pollution.[468]

As the EPA has noted, aquatic nutrient pollution in the United States comes from a number of sources, including "fertilizer, animal manure, sewage treatment plant discharge, detergents, stormwater runoff, cars and power plants, failing septic tanks and pet waste."[469] The Federal Water Pollution Control Act, better known from its 1977 amendments as the Clean Water Act,[470] extends its water quality protections to the ocean,[471] and nutrients are pollutants that the act regulates.[472] Some of the sources of nutrient pollution that the EPA lists are already subject to Clean Water Act regulation, especially sewage treatment plants[473] and concentrated animal feeding operations.[474] Many, however, are not. The Clean Air Act is the primary authority for regulating car and power plant emissions. The EPA, however, has long worked to reduce nitrogen emissions from both sources for air quality reasons, and the migration (however slow) away from fossil fuels toward renewable energy sources will further reduce these sources' contributions to nutrient pollution of the ocean.[475] Instead, a systems approach to the ocean should inspire a redoubling of efforts under the Clean Water Act to bring agricultural point and nonpoint source nutrient pollution under control.

Agriculture's exceptionalism is a longstanding feature of Clean Water Act regulation, reflecting a mythologized icon of the small family farm.[476]

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[467] *Id.* at 28.

[468] U.S. ENV'T PROT. AGENCY, THE FACTS ABOUT NUTRIENT POLLUTION (2015), https://www.epa.gov/sites/production/files/2015-03/documents/facts_about_nutrient_pollution_what_is_hypoxia.pdf.

[469] *Id.*

[470] 33 U.S.C. §§ 1251-1388.

[471] *See id.* § 1343 (establishing the ocean discharge criteria); *id.* § 1362(12) (defining "discharge of a pollutant" to include discharges into the navigable waters, contiguous zone, and the ocean); *id.* § 1362(7) (defining "navigable waters" to explicitly include the territorial sea).

[472] *Id.* § 1362(6) (defining pollutant to include both sewage and "agricultural waste"); *State Progress Toward Developing Numeric Nutrient Water Quality Criteria for Nitrogen and Phosphorus*, U.S. ENV'T PROT. AGENCY, https://www.epa.gov/nutrient-policy-data/state-progress-toward-developing-numeric-nutrient-water-quality-criteria (last updated July 20, 2021).

[473] 33 U.S.C. § 1311(b)(1)(B) (designating that effluent limitations for publicly owned treatment works—sewage treatment plants—will be based on secondary treatment).

[474] *Id.* § 1311(a) (prohibiting the discharge of pollutants); *id.* § 1362(12) (defining "discharge of a pollutant" to require a point source); *id.* § 1362(14) (defining "point source" to explicitly include concentrated animal feeding operations).

[475] *Nutrient Pollution — The Sources and Solutions: Fossil Fuels*, U.S. ENV'T PROT. AGENCY, https://www.epa.gov/nutrientpollution/sources-and-solutions-fossil-fuels (last updated Dec. 11, 2020).

[476] J.B. Ruhl, *Farms, Their Environmental Harms, and Environmental Law*, 27 ECOLOGY L.Q. 263, 265-69, 293-305 (2000); *see also* Robert W. Adler, *Agriculture and Water Quality: A*

The Act accordingly exempts "agricultural stormwater discharges and return flows from irrigated aquaculture" from being considered point sources.[477] Routine farming activities and the construction of farm stock ponds, irrigation ditches, and farm roads are likewise exempt from the Section 404 "dredge and fill" permit program,[478] and water features converted to dry farmland before December 23, 1985, are often exempt from regulation as "prior converted cropland."[479]

Nevertheless, several new realities suggest that the Clean Water Act can and should play a larger role in how farms are run, especially to reduce the nutrient pollution that reaches the ocean. First, the reality of farming in the United States has changed. As the U.S. Department of Agriculture recognizes, "[a]gricultural production in the 21st century . . . is concentrated on a smaller number of large, specialized farms in rural areas where less than a fourth of the U.S. population lives."[480] Industrialized agriculture does not warrant the same kinds of exemptions from water quality regulation that small family farms do. Second, both the EPA and state governments have increasingly recognized the importance of agricultural nutrient pollution, and many states have already enacted laws and regulatory programs to address this problem.[481] Third, the EPA has used the Clean Water Act's Total Maximum Daily Load (TMDL) authorities[482] to create new tools to connect agricultural water pollution—including nutrient pollution—to larger water quality goals. The first of these, directly related to ocean water quality, is the Chesapeake Bay regional TMDL that the EPA established in late December 2010.[483] This

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Climate-Integrated Perspective, 37 VT. L. REV. 847, 850-52 (2013) (discussing the water quality impacts of agriculture).

[477] Ruhl, *supra* note 476, at 296; 33 U.S.C. § 1362(14).

[478] 33 U.S.C. § 1344(f)(1).

[479] LAURA GATZ & MEGAN STUBBS, CONG. RSCH. SERV., IF11136, PRIOR CONVERTED CROPLAND UNDER THE CLEAN WATER ACT 1-2 (2019), https://fas.org/sgp/crs/misc/IF11136.pdf; U.S. Army Corps of Engineers, Regulatory Guidance Letter 90-07 on Clarification of the Phrase "Normal Circumstances" as it Pertains to Cropped Wetlands (Sept. 26, 1990), https://www.nap.usace.army.mil/Portals/39/docs/regulatory/rgls/rgl90-07.pdf. For a good short history of this exemption, see Roger A. McEowen, *The Prior Converted Cropland Exemption from Clean Water Act Jurisdiction*, AGRIC. L. & TAX'N BLOG (Sept. 25, 2017), https://lawprofessors.typepad.com/agriculturallaw/2017/09/the-prior-converted-cropland-exception-from-clean-water-act-jurisdiction.html.

[480] *Farming and Farm Income*, ECON. RSCH. SERV., U.S. DEP'T OF AGRIC., https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/farming-and-farm-income/ (last updated Sept. 2, 2021).

[481] ROBIN KUNDIS CRAIG & TERRY SCHLEY NOTO, ENV'T DEF. FUND, STATE NONPOINT SOURCE POLLUTION CONTROL PROGRAMS FOR AGRICULTURAL CERTAINTY: A LOOK AT AGRICULTURAL CERTAINTY 128-29 (2012) (on file with author).

[482] 33 U.S.C. § 1313(d).

[483] Clean Water Act Section 303(d): Notice for the Establishment of the Total Maximum Daily Load (TMDL) for the Chesapeake Bay, 76 Fed. Reg. 549 (Jan. 5, 2011).

TMDL established regional limits on nitrogen, phosphorus, and sediment pollution, allocated among 92 segments of the tidally influenced portion of the Chesapeake Bay watershed and affected water quality programs in Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia, and the District of Columbia.[484] The second is the EPA's renewed interest in water quality trading. The EPA first released its water quality trading policy in 2003, emphasizing its use for nutrient and sediment pollution.[485] However, in 2019 and 2020, it released a number of new documents to encourage water quality trading[486]—including new partnerships with the U.S. Department of Agriculture specifically aimed at nutrient pollution.[487] In addition, a map published by the EPA reveals increased use of water quality trading in the United States, especially in Minnesota and the Chesapeake Bay states.[488]

Thus, despite agriculture's exceptionalism under the Clean Water Act, it is possible to use the Act's existing tools to reduce nutrient pollution in the United States, to the benefit of both our own coastal environments and global Planetary Boundaries. Indeed, the National Academy of Sciences has already recommended a TMDL or TMDL-like mechanism to address the Gulf of Mexico dead zone.[489] Framing the nutrient pollution issue in terms of enhancing public health,[490] quality of life,[491] and marine food

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[484] *Id.* at 549-50.

[485] U.S. ENV'T PROT. AGENCY, WATER QUALITY TRADING APPENDIX B: US EPA OFFICE OF WATER, WATER QUALITY TRADING POLICY B-4 (2005), https://www.epa.gov/sites/default/files/2016-04/documents/wqtradingtoolkit_app_b_trading_policy.pdf.

[486] *E.g.*, Memorandum from David P. Ross, Assistant Adm'r, U.S. Env't Prot. Agency, to Regional Administrators, Region 1-10, on Updating the Environmental Protection Agency's (EPA) Water Quality Trading Policy to Promote Market-Based Mechanisms for Improving Water Quality (Feb. 6, 2019), https://www.epa.gov/sites/default/files/2019-02/documents/trading-policy-memo-2019.pdf.

[487] Memorandum from the Off. of Water, U.S. Env't Prot. Agency, on Next Steps in EPA's Nutrient Engagement (Feb. 2019), https://www.epa.gov/sites/default/files/2019-02/documents/next-steps-epa-nutrient-engagement-2019.pdf.

[488] *Water Quality Trading*, U.S. ENV'T PROT. AGENCY, https://www.epa.gov/npdes/water-quality-trading (last updated Nov. 16, 2021).

[489] COMM. ON THE MISS. RIVER & THE CLEAN WATER ACT, NAT'L ACAD. OF SCIENCES, MISSISSIPPI RIVER WATER QUALITY AND THE CLEAN WATER ACT: PROGRESS, CHALLENGES, AND OPPORTUNITIES 8, 12 (2008).

[490] For examples of a public health framing, see *Health Alert Issued for Blue Green Algal Bloom*, FLA. DEP'T OF HEALTH IN MARION CNTY. (May 17, 2021), http://marion.floridahealth.gov/newsroom/2021/05/05_17.html; Michael Wines, *Behind Toledo's Water Crisis, A Long-Troubled Lake Erie*, N.Y. TIMES (Aug. 4, 2014), https://www.nytimes.com/2014/08/05/us/lifting-ban-toledo-says-its-water-is-safe-to-drink-again.html.

[491] For examples of a quality of life framing, see *Harmful Algal Blooms Cause Closure of Two Cayoga County Beaches*, WSYR (July 13, 2021, 5:56 PM EDT), https://www.localsyr.com/news/local-news/harmful-algal-blooms-cause-closure-of-two-cayuga-

security[492] should aid the political palatability of increased nutrient protection measures. Overall, reducing the nutrient stressors to the ocean will give this complex system more resilience to cope with other stressors, such as climate change and ocean acidification, preserving the many values it provides human beings.

VI. CONCLUSION

Americans must adapt to a changing ocean. While this task would be much easier if there were an effective global regime to stabilize or reduce the anthropogenic greenhouse gas concentrations in the atmosphere, no such regime is yet in place. Nevertheless, the United States, and other coastal governments, should resist the temptation to view climate change mitigation as the only regulatory pathway worth pursuing in terms of influencing, and reducing the magnitude of, the changes occurring in the complex system of systems that is the world ocean.

There is no doubt that a systems view of the ocean should humble human attempts at comprehensive governance and management. The emergent properties of complex systems, the potential for ecosystems to cross critical thresholds and transform, and the panarchy model of multiscalar influence thoroughly undermine any human aspiration to even grossly maintain marine ecosystems in the states we prefer while simultaneously harvesting all the ecosystem goods that we desire. In short, we are not fully in charge. As the IPCC emphasizes, climate change's impacts to the ocean challenges the capacity of all governance systems to respond, both regarding human health and well-being and in terms of communities' abilities to adapt effectively.[493] Moreover, it laments, "[g]overnance arrangements (e.g., marine protected areas, spatial plans and water management systems) are, in many contexts, too fragmented across administrative boundaries and sectors to provide integrated responses to the increasing and cascading risks from climate-related changes in the ocean."[494]

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county-beaches/; Michelle Liu, *All 21 of Mississippi's Beaches Are Closed Because of Toxic Algae*, CNN (July 9, 2019, 4:06 PM EDT), https://www.cnn.com/2019/07/07/us/mississippi-beaches-algae-closure-trnd/index.html.

[492] For examples of a food security framing, see *Certain Dungeness Crabs Recalled Because of Poisoning Risk*, FOOD SAFETY NEWS (Dec. 31, 2020), foodsafetynews.com/2020/12/certain-dungeness-crabs-recalled-because-of-poisoning-risk/; *Central Washington Coast Closed To Recreational Crab Fishing Due To Domoic Acid*, KXRP NEWS RADIO (Nov. 25, 2020, 6:16 AM), https://www.kxro.com/central-washington-coast-closed-to-recreational-crab-fishing-due-to-domoic-acid/.

[493] *2019 IPCC Ocean & Cryosphere Report*, *supra* note 10, at 29.

[494] *Id.*

However, it is equally clear that human actions and activities matter. That fact is the very point of the Anthropocene. Reconciling those realities reveals the panarchy governance paradox that a complex systems view of the ocean underscores: law can accomplish more to aid ecosystems and social-ecological systems in adapting to a changing ocean by categorizing humans as stressors rather than managers and by prioritizing the reduction of the stressing activities.

It is easy to criticize the starting points proposed in this Article as incomplete—they are. Nevertheless, they represent a realistic beginning response to the profound governance challenges that a changing ocean poses. Valuing the ocean as a complex system will not, in itself, fix the United States' ocean governance fragmentation problem. However, a systems perspective does provide insight into how the United States' fragmented ocean laws can still rationally and meaningfully prioritize the increased resilience of the ocean's many social-ecological systems, possibly helping the entire world avoid crossing a transformative threshold at the same time. From this perspective, nutrient pollution and marine food security emerge as the first two logical priorities. States and the EPA can address nutrient pollution far more aggressively than they currently do pursuant to their existing Clean Water Act authorities. Given changing industry realities, the expanding marine aquaculture industry and commercial fishing industry in the United States both require additional attention. A systems approach underscores how both these industries are linked to Americans' overall food security, allowing for a more comprehensive marine food policy (a "Blue Food" policy[495]) that simultaneously minimizes the impact of food security on changing marine ecosystems.

Our future depends on how the ocean responds as a system to the multiple stresses humans are inflicting upon it. To emphasize two components of the trillions of dollars of ecosystem services at stake, the ocean's continuing ability to dampen the impacts of anthropogenic greenhouse gas emissions has been keeping the planet habitable, while its smallest communities of phytoplankton continue to provide half the oxygen we breathe. Complex systems theory and resilience thinking teach that reducing anthropogenic stressors on the ocean can lower the chances that either local ecosystems or the entire planet irreversibly cross thresholds into far less productive and hospitable states of being. The

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[495] BLUE FOOD ASSESSMENT, BUILDING BLUE FOOD FUTURES FOR PEOPLE AND THE PLANET 6 (2021), https://re54e8libu2wprcq1nsbw051-wpengine.netdna-ssl.com/wp-content/uploads/BuildingBlueFoodFuturesforPeopleandThePlanet_The-Report-of-the-Blue-Food-Assessment-Digital_Sept2021_Digital.pdf

Planetary Boundaries Project, in turn, identifies key stressors to focus on—and they are not all climate change.

Revaluing the ocean as a complex adaptive system thus paradoxically illuminates paths to effective marine governance action in the face of nearly overwhelming and unpredictable future change. Reducing marine nutrient pollution and rethinking the ocean's role in food security in the U.S. will not eliminate all the Anthropocene's challenges. But they might—just might—help buy humanity some additional time to figure out more comprehensive solutions while simultaneously enhancing the adaptive capacities of our own ocean places and the Americans who depend upon them.