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Article

Marine Biodiversity, Climate Change, and Governance of the Oceans

Robin Kundis Craig

S.J. Quinney College of Law, University of Utah, 332 South 1400 East, Salt Lake City, UT 84112-0730, USA; E-Mail: robin.craig@law.utah.edu; Tel.: +1-801-581-5165; Fax: +1-801-581-6897

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Abstract: Governance of marine biodiversity has long suffered from lack of adequate information about the ocean's many species and ecosystems. Nevertheless, even as we are learning much more about the ocean's biodiversity and the impacts to it from stressors such as overfishing, habitat destruction, and marine pollution, climate change is imposing new threats and exacerbating existing threats to marine species and ecosystems. Coastal nations could vastly improve their fragmented approaches to ocean governance in order to increase the protections for marine biodiversity in the climate change era. Specifically, three key governance improvements would include: (1) incorporation of marine spatial planning as a key organizing principle of marine governance; (2) working to increase the resilience of marine ecosystems be reducing or eliminating existing stressors on those ecosystems; and (3) anticipation of climate change's future impacts on marine biodiversity through the use of anticipatory zoning and more precautionary regulation.

Keywords: marine; ocean; biodiversity; marine spatial planning; MSP; climate change; adaptation

1. Introduction

In 2010, more than 2,700 scientists from over 80 nations completed the first worldwide Census of Marine Life, delineating a comprehensive baseline of Planet Earth's marine biodiversity for the first time ever [1]. The Census represented a significant improvement in our understanding of marine biodiversity, because "at the outset of the Census, oceanographers estimated that only 5 percent of the ocean had been systematically explored for life" [1] (p. 6). It filled many existing gaps in our knowledge regarding the species that inhabit the oceans, as Census scientists surveyed the entirety of the world's ocean. They reported "an unanticipated riot of species," raising the estimate for the number of known marine species from 230,000 to nearly 250,000—and "the Census still could not reliably estimate the total number of species, the kinds of life, known and unknown, in the ocean" [1] (p. 3). Marine biodiversity is extensive, including perhaps over one million species, and varied in the extreme [1]. The Census "found living creatures everywhere it looked, even where heat would melt lead, seawater froze to ice, and light and oxygen were absent. It expanded known habitats and ranges in which life is known to exist. It found that in marine habitats, extreme is normal" [1] (p. 3).

Despite this biological richness, however, the Census also found signs of decline in both species and the sizes of individuals—declines that had occurred fairly quickly, sometimes within a human generation [1]. Perhaps most importantly, it found that phytoplankton, the basis of marine food webs and the source of approximately 50% of the world's atmosphere oxygen, have declined since 1899 [1] (p. 6 and p. 31).

There are many human-caused threats to marine bioversity, and, as will be explained in more depth in Part 2, they are significant individually, cumulatively, and synergistically with each other and with climate change. As individual threats, overfishing and habitat destruction have traditionally ranked as most important [1]. Declines in species abundance from overfishing can be very fast, while the few recoveries have been fairly slow [1] (pp. 28–29). Indeed, according to the Census, "evidence shows that most species entering human commerce decline, often sharply," and biodiversity at both the top and the bottom of ocean food webs appears to have decreased significantly [1] (p. 31). Cumulatively, human uses of the ocean have increased to include a wide variety of exploitative and often polluting activities, from tourism and recreation to offshore aquaculture to energy production [1]. These uses can conflict with each other as well as impact marine biodiversity, both directly and indirectly [1]. As one example, Mediterranean Sea biodiversity has declined significantly because of the cumulative and synergistic effects of overexploitation and overfishing, habitat destruction, pollution, introduced species, and now climate change [2].

As studies of the Mediterranean Sea indicate [2], climate change poses the newest and in many ways most pervasive threat to marine biodiversity. Greenhouse gases in the atmosphere set in motion geophysical and geochemical processes that are both warming the sea and acidifying it [1], with consequent direct and indirect impacts on marine life. According to the Census of Marine Life, "changes in ocean temperatures, currents, and chemistry would redistribute much marine life. Census researchers predict a decline in diversity in a tropical ocean that becomes warmer, and an increase of diversity at latitudes of about 50 to 70 degrees in both hemispheres" [1] (p. 25). Changes in ocean temperature, in fact, have joined overfishing and habitat destruction as one of the three most powerful causes of decreases in marine species' abundance [1] (p. 31).

As the world copes with the climate change era, improved marine governance will be of ever-increasing importance if we are to maintain anything approaching broad and resilient marine biodiversity in the face of pervasive ecological, chemical, and physical changes to the ocean's environments. Notably, there is already evidence of the ocean's resilience, because "in enough cases to encourage conservation, the Census of Marine Life documented the recovery of some species" [1] (p. 4). Without improved governance, however, such recoveries are increasingly unlikely, particularly if climate change impacts continue to intensify. This Article first examines the existing and climate change threats to marine biodiversity, then recommends three improvements to ocean governance in areas of national jurisdiction—under international law, the 200-mile Exclusive Economic Zone (EEZ) that individual nations can unilaterally regulate, as opposed to the high seas, where international treaties are required—that could help preserve marine biodiversity through the climate change era.

2. Existing and Climate Change Impacts on Marine Biodiversity

2.1. Existing Stressors to Marine Biodiversity

Ocean biodiversity is threatened by a number of stressors. Severe reductions of biodiversity in many parts of the world, and the resulting "jellyfish seas," are profound evidence of this accumulated stress [3]. This section summarizes the most important of these existing stressors.

2.1.1. Coastal Degradation

In 2005, the Millennium Ecosystem Assessment (MEA) described in detail the cumulative existing degradation of coastal ecosystems, emphasizing that these systems "are now undergoing more rapid change than at any time in their history" through a complex synergy of physical, chemical, and biological/ecological changes [4] (p. 516). It concluded that "these impacts, together with chronic degradation resulting from land-based and marine pollution, have caused significant ecological changes and an overall decline in many ecosystem services" [4] (p. 516). Nor is such coastal degradation likely to cease any time in the near future. The United Nations Environment Programme (UNEP) expects coastal populations worldwide to increase from a density of approximately 77 people per square kilometer to 115 people per square kilometer by 2025, and density is correlated to coastal degradation [5].

2.1.2. Overfishing

While coastal degradation can devastate near-shore marine biodiversity, overfishing is considered the primary traditional threat to marine biodiversity more generally [4]. This is especially true when fishing methods also destroy habitat, such as through blast fishing and ocean trawling [4] (p. 479). Overfishing leads to declines in marine biodiversity in three ways. First, overfishing impacts the targeted species, often to the point of fisheries collapse [4] (p. 479) and [6], which is generally defined as a 90 percent reduction in the speciess abundance [7]. Such impacts pervade the marine world, and total global catch in marine and coastal fisheries is declining despite increased investment in fishing effort [4] (pp. 481–482). Indeed, in its 2010 review of the world's fisheries, the United Nations Food and Agriculture Organization (FAO) concluded that "the increasing trend in the percentage of overexploited, depleted and recovering stocks and the decreasing trend in underexploited and moderately exploited stocks give cause for concern" [7] (p. 8).

Second, through "by-catch," overfishing reduces the populations of non target species incidentally caught in nets or on lines, most of which are thrown back in the water dead or dying [4] (p. 479). Such by catch can be destructive both of the non-target species and the ecosystem more generally. For example, in the Bering Sea, pollock fisheries catch between 200 and 1,400 metric tons of salmon sharks and Pacific sleeper sharks every year; 1,000 metric tons is the equivalent of about 7,400 sharks [8]. Salmon sharks in particular occupy a high trophic level, and as Wright (2010) has pointed out, "reductions in salmon sharks and Pacific sleeper sharks in the numbers reported could disrupt the Bering Sea ecosystem in unexpected ways, notably by removing predation pressure from a more effective pollock predator. Any of several pollock predators may be kept in check by salmon sharks and Pacific sleeper sharks—including squid (Decapodiformes), which could prey on all pollock age classes" [8] (p. 642).

Finally, overfishing has resulted in a phenomenon known as "fishing down the food web": as larger, more desirable, and higher trophic species are fished out, fishers shift to smaller and once-less-desirable species [4] (p. 479), [9] (p. 1045) and [10] (p. 15). As a result, overfishing of the original target species eventually leads to overfishing of far more species at lower trophic levels, far more pervasively disrupting marine food webs. Such disruptions can alter a marine ecosystem's overall ecological state, and restoration may become impossible [4] (p. 488) and [9]. Indeed, as proof of how pervasive and destructive marine overfishing actually is, a team of scientists reported in *Science* that, if current trends in overfishing continue unabated, global fish stocks will, as a whole, be entirely collapsed commercially by the middle of the 21st century [11].

2.1.3. Invasive Species

A third existing stressor is invasive species, which can opportunistically exploit coastal ecosystems that are already degraded and destroyed as well as causing new and independent stresses. As has been demonstrated repeatedly, from jellyfish in the Black Sea to zebra mussels in the Great Lakes, non-native species can quite successfully travel to new coasts in ships' ballast water [12]. According to estimates, as many as 7,000 marine species may be transported in ballast water every day, including marine-facilitated human diseases such as cholera [12]. Invasive species also escape from aquariums or are intentionally introduced into new marine ecosystems [12].

Once introduced into new environments, invasive species can alter marine ecosystem function and ecosystem services and can reduce native biodiversity [2,12]. In some circumstances, the invader simply takes over the new ecosystem. As one extreme example, in the 1980s the comb jelly *Mnemiopsis* was introduced into the Black Sea through ballast water, where it bloomed prodigiously and devoured the base of the Black Sea food chain, devastating the anchovy population and most of the rest of the food web [13].

2.1.4. Marine Pollution

A variety of sources of marine pollution affect marine biodiversity. In many parts of the world, for example, sewage discharges remain an important source of coastal pollution [14]. Nutrient pollution from on-land activities, such as runoff from farms that includes fertilizer or atmospheric deposition from power plants, can contribute to harmful algal blooms and marine hypoxic, or "dead," zones [15]. Harmful algal blooms directly impact marine biodiversity by toxifying marine organisms, especially shellfish [15], while dead zones drive oxygen-dependent life away [15]. The number of dead zones in the ocean has doubled every decade since 1960, and a 2008 study identified more than 400 dead zones throughout the world [16].

Toxic pollution is also a substantial impairment to marine biodiversity. As the MEA noted, "the estimated 313,000 containers of low-intermediate emission radioactive waste dumped in the Atlantic and Pacific Oceans since the 1970s pose a significant threat to deep-sea ecosystems should the containers leak, which seems likely over the long term" [4] (p. 483). Moreover, toxic chemicals continue to reach the oceans through a variety of industrial processes discharging wastes into upstream waterways and through various forms of dispersed water pollution, such as atmospheric deposition and runoff. Several of these chemicals bioaccumulate in ocean organisms. For example, methyl mercury, the organic form of mercury, becomes more concentrated the further up the food web a species resides [17]. High-level marine predators such as tuna, swordfish, shark, and mackerel can end up with mercury concentrations in their bodies that are 10,000 times or more the ambient concentration of mercury in the water [18]. Indeed, mercury contamination is already prevalent in food fish [19–22]. Other toxic pollutants such as polychlorinated biphenyls (PCBs) also bioaccumulate and are considered a cause of increased mortality to marine mammals such as the beluga whales in the St. Lawrence River [23,24] and orcas off the west coast of the United States [25].

Plastic pollution also affects marine biodiversity. Floating plastic waste accounts for 80 percent or more of marine debris [25]. Various marine animals can become physically entangled in larger forms of plastic debris, leading to injury, dismemberment, and death [26,27]. Many marine species also consume plastic trash; plastic bags, it turns out, look a lot like jellyfish, which is a food item for sea turtles and other species, and other marine animals intentionally or accidentally consume plastic trash [26,27]. Once swallowed, the plastic can both inhibit adequate nutrition by taking up space in the digestive system and directly cause death by choking or through internal damage [28]. A 2011 study reported that at least 9.2 percent of fish in and below the Great Pacific Garbage Patch—a concentrated gyre of plastic pollution in the northern Pacific Ocean—had plastic debris in their stomachs, and the researchers estimated that fish in the North Pacific are ingesting 12,000 to 24,000 tons of plastic every year [29].

2.2. Climate Change's Impacts on Marine Biodiversity

The consensus view of world climate scientists, as presented in the Intergovernmental Panel on Climate Change's (IPCC's) 2007 report, is that Earth's climate system is warming [30]; "evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes" [30] (p. 31) and [31]; and most of the observed change is very likely caused by humans' greenhouse gas emissions [30] (p. 39). Climate change is likely to significantly affect marine biodiversity in a number of ways. The most important of these impacts will be: changes in ocean temperature; changes in ocean current patterns; sea-level rise; and ocean acidification.

2.2.1. Changes to Ocean Temperatures

Ocean surface temperatures and ocean heat content are both increasing [30]. The IPCC indicated in 2007 that most regions of the ocean have already experienced SST increases of between 0.2 and 1.0 degree Celsius [30]. It predicted that, under its "business-as-usual" (A2) scenario, ocean temperatures would increase by another 0.5 to 1.0 degree Celsius by 2029 and by up to 4 degrees Celsius by 2099, with warming continuing for at least another century thereafter [30]. However, more recent research by an international team of scientists indicated "that ocean temperature and associated sea level increases between 1961 and 2003 were 50 percent larger than estimated in the 2007 Intergovernmental Panel on Climate Change report" [32]. Moreover, temperature increases have been detected more than 3,000 m below the ocean's surface [33].

As a result of this increasing temperature, marine ecosystems are also changing. The IPCC reported in 2007 that "in some marine and freshwater systems, shifts in ranges and changes in algal, plankton and fish abundance are with *high confidence* associated with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels and circulation" [30] (p. 2). It projected widespread ecosystem changes as a result of changes in major marine currents beginning at about the point when global average temperatures increase by about 2.5 to 3.0 degrees Celsius [30]. Even before that point, however, changes in ocean temperatures are already causing temperature-sensitive marine species to migrate poleward [34,35]. Some marine species may go at least locally extinct because of temperature-induced changes in their habitat or food supply, especially in the tropics [36]. More pervasively, by promoting widespread shifts in species' ranges and species invasions of new habitats, climate change will have direct impacts on marine biodiversity and on fishing and fish stocks [7], especially at the Earth's poles [36]. A study published in *Nature* concluded that ocean temperature is a major determinant of marine biodiversity and that changes in ocean temperature "may ultimately rearrange the global distribution of life in the ocean" [37] (p. 1098).

Such changes in marine biodiversity from ocean temperature may also increase the effects of climate change itself. For example, "scientists have found that as the oceans become warmer, they are less able to support the phytoplankton that have been an important influence on moderating climate change" [38].

2.2.2. Changes to Ocean Currents

As the IPCC has noted, seawater circulates in both surface currents and in three-dimensional, globe-spanning, interconnected currents below the surface—sometimes far below the surface [30]. Prevailing winds drive the surface currents, are driven by the prevailing winds, which account for 13 to 25 percent of all ocean water movement [30]. In contrast, the more three-dimensional ocean currents are driven by differences in temperature and salt concentration (salinity) and hence are known as the thermohaline circulation [30]. These powerful ocean currents redistribute heat, "stir up nutrients, transport food, mix salt- and freshwater, and even influence much of the weather and climate that we experience across continents" [30] (pp. 10–11). As climate changes alter atmospheric temperatures, wind patterns, and sea temperatures, it is also altering the ocean's patterns of currents.

Ocean currents are important to marine biodiversity for a number of reasons, but one of the most important of these is upwellings. Upwellings occur when "deep nutrient-rich water rises up to replace the water carried away from the coast" [39]. Because upwellings are nutrient-rich, they support plankton blooms and high concentrations of marine plants and animals, including commercially important species of fish [39]. Upwellings regularly occur off the coasts of California, Chile, and South Africa [39], and these highly productive areas of the ocean support "20% of global fishery yield" [40].

Changes in ocean currents can convert these regions of high productivity to hypoxic zones, more commonly known as "dead" zones. Changes in wind patterns off the northwest Pacific coast of the United States, for example, increased upwellings of nutrients to the point where the nutrients over-fertilized plankton growth, creating a "boom and bust" cycle in which decaying plankton blooms consumed most of the oxygen in the water [41]. Three other such climate change-related dead zones have been detected, one off the coast of Chile and Peru in South America and one each off the west and east coasts of Africa [39]. More severe changes to ocean circulation and ocean currents have been associated with mass extinctions—of both marine and terrestrial life—in the past, and climate change may drive such extinctions again in the future [42].

2.2.3. Sea-Level Rise

Climate change-driven sea level rise occurs for two main reasons: thermal expansion and melting land-based ice [30]. Currently, the contribution of each source to sea-level rise is about equal [43], although the contribution of melting ice may be increasing [44]. Sea-level rise causes multiple impacts on coastal ecosystems, especially with respect to highly productive—but also highly vulnerable—estuaries [45].

According to the Climate Institute, "During the 20th century, sea level rose about 15–20 cm (roughly 1.5 to 2.0 mm/year), with the rate at the end of the century greater than over the early part of the century" [46]. However, the unexpectedly increasing pace of polar and glacier ice melting around the world has made predicting future sea level rise difficult [43]. Complicating these predictions from the melting of the world's major ice sheets are studies that indicate that smaller mountain glaciers are also making a significant contribution to global sea level rise—as much as 12 cm by the end of the century—as they disappear worldwide [47].

While long-term sea-level rise predictions are difficult, initial sea-level rise will primarily affect marine biodiversity in low-lying coastal areas, especially because sea-level rise appears to be accelerating [48]. The IPCC indicated that, with about a 3 °C increase in global average temperature, 30% of the world's coastal wetlands will be lost [30] (p. 51), and barrier islands, mangrove forests, and near-shore coral reefs are similarly vulnerable [30]. These are coastal ecosystems of high biodiversity, and their destruction or decline will consequently decrease marine biodiversity overall.

2.2.4. Ocean Acidification

The oceans are naturally basic, with a pH of about 8.16, and that pH level has been remarkably stable over geological time [49]. Since the start of the Industrial Revolution the oceans have been absorbing billions of tons of CO_2. The oceans have absorbed so much CO_2, in fact, that their pH is changing [30] (p. 9). Ocean acidification begins when CO_2 in the atmosphere dissolves into seawater [50]. Once dissolved, CO_2 reacts with the seawater to form carbonic acid [51]. In the last century and a half or so, the average ocean surface water pH has dropped by 0.1 unit, with greater drops predicted for the near future [30]. This decrease in pH interferes with a number of species functions, especially shell-building [51]. The results over the long term for marine biodiversity could be devastating. A recent article in *Science*, for example, concluded that "the current rate of (mostly fossil fuel) CO_2 release stands out as capable of driving a combination and magnitude of ocean geochemical change potentially unparalleled in at least the last ~300 million years of Earth history, raising the possibility that we are entering an unknown territory of marine ecosystem change" [52] (p. 1062).

3. Adapting Marine Governance for the Benefit of Marine Biodiversity

Marine biodiversity is important to ocean governance because biodiversity is one important measure of an ecosystem's health [1] (p. 10). Thus, changes in marine biodiversity—positive or negative—can provide one outcome measurement of how well a governance regime is working. By this measure, moreover, ocean governance is an area of law and policy much in need of improvement, even before climate change adaptation is considered [53].

In most coastal nations, regulation of marine resources is highly fragmented, with different governmental entities overseeing multiple independent and largely uncoordinated regimes to address fishing, shipping, marine mammals, endangered species, invasive species, pollution of the marine environment, national security, and offshore energy production [53–55]. In the United States, for example, the U.S. Commission on Ocean Policy emphasized in 2004 that 11 of 15 cabinet-level departments and numerous federal agencies and sub-agencies had some role to play in ocean governance, with no overarching scheme for coordinating their efforts [56]. As a result, one of its primary recommendations was for improved coordination through a National Ocean Council [56].

These fragmented governance systems have traditionally done little to address marine biodiversity *in toto*. Instead, regulatory regimes tend to focus on particular species—either because those species are commercially important (fisheries management), protected under domestic or international law (whales, endangered species), or, less frequently, recognized to be a problem to economically important interests (invasive species) [55]. Species-focused approaches on land have occasionally resulted in much broader protections for surrounding ecosystems, such as through the "critical habitat" and recovery plan provisions of the United States' Endangered Species Act [57]. In the marine environment, however, such species-focused regimes have almost always missed the bigger picture, as it were, because they often never "see" the larger ecosystems involved or overall ocean ecological health.

Nations should improve three aspects of their marine governance regimes to both enhance protections for marine biodiversity and to help those nations adapt to climate change's impacts on marine biodiversity: (1) incorporate marine spatial planning as a key organizing principle of marine governance, including the use of biodiversity-relevant marine reserves; (2) work to increase the resilience of marine ecosystems be reducing or eliminating existing stressors on those ecosystems; and (3) begin to anticipate climate change's future impacts on marine biodiversity through the use of anticipatory zoning and more precautionary regulation.

3.1. Incorporate Marine Spatial Planning and Marine Reserves

Marine spatial planning (MSP) reduces regulatory fragmentation of the oceans by considering all actual and potential uses of the ocean and the needs of the marine ecosystem itself in one comprehensive plan for a particularly geographic area of the ocean [55]. Coastal nations have traditionally used MSP to separate conflicting uses of their seas, such as fishing and diving, as well as to establish marine protected areas (MPAs) and "no-take" marine reserves [55].

Properly conducted, the process of MSP forces a government or management entity to identify all of the potential uses that it wants to incorporate into a given marine area, both present and in the immediate future [55]. In addition, the government or management entity should also identify potential or actual conflicts between those uses, including conflicts with the ecosystem itself [55]. In the United States and Canada, for example, the placement of shipping lanes in the Bay of Fundy unnecessary promoted collisions between large commercial ships and the highly endangered North Atlantic right whale [56]. Scientists at the New England Aquarium worked with shipping companies, commercial fishers, whale watching companies, agencies in both Canada and the United States, and the international maritime law officials to move the shipping lanes four nautical miles to the east, reducing the potential for whale-ship collisions by 80% [58]. These protections for right whales are just one small example of how a more comprehensive view of how humans use the oceans can greatly improve the safeguards for marine biodiversity without significantly compromising other interests in the ocean.

Australia's re-zoning of the Great Barrier Reef Marine Park in 2004 provides a more comprehensive example of how nations can use MSP to promote biodiversity goals [55]. The 2004 re-zoning took a decade to complete, but its goal was a Representative Areas Program that would both identify and protect the various kinds of ecosystems found in the Great Barrier Reef [55]. The new zoning plan protects examples of all seventy bioregions within the Park [55]. However, because the Great Barrier Reef Marine Park is legally designated as a multiple use park, the new zoning plan also fulfills the more traditional purposes of MSP such as identifying and separating potentially conflicting uses of the park: zones include, for example, Shipping Areas, Fisheries Experimental Areas, and General Use Zones as well as several kinds of MPA and marine reserve designations [55].

As the Bay of Fundy's shipping lanes indicate, MSP can improve marine biodiversity even without the use of MPAs and marine reserves. However, as Australia's re-zoning of the Great Barrier Reef Marine Park suggests, incorporation of marine reserves into MSP can significantly enhance marine biodiversity goals. Studies indicate the incorporation of well-enforced marine reserves or "no take" areas into MSP can enhance marine biodiversity. In the Mediterranean Sea, for example, marine reserves tend to support healthy predator-dominated ecosystems "characterized by high fish biomass and benthic communities dominated by non-canopy algae" [2] (p. 5). In contrast, poorly enforced marine reserves, marine protected areas that allowed fishing, and open fishing parts of the Mediterranean had lower fish biomass, more extensive algae cover, and, in the worst areas, barrens [2].

The Census of Marine Life can help contribute to the future selection of marine sites to be protected for biodiversity purposes, and its baselines can inform governments and other implementing agencies of when changes to the relevant ecosystem are occurring [1] (p. 4) and [32]. In addition, and especially in coral reef-rich regions such as Australia, the Coral Triangle and Micronesia in the South Pacific, and the Caribbean, nations are actively incorporating MSP as a climate change adaptation measure, seeking to protect the socio-ecological systems that depend on these reefs and their biodiversity despite increasing impacts from climate change [55].

3.2. Increase the Resilience of Marine Ecosystems by Reducing Current Stressors

Because climate change interacts synergistically with existing stressors to reduce marine biodiversity [55], one important climate change adaptation strategy is to reduce existing stressors to marine ecosystems [59]. MSP and marine reserve designations can, themselves, help to drive such attention to non-climate change stressors. For example, the Northwestern Hawaiian Islands are one of the last nearly pristine coral reef ecosystems in the world, leading to their protection through U.S. law as the Papahānaumokuākea Marine National Monument [55]. The recognition of this system's biological and cultural importance to Native Hawaiians helped to inspire the phase-out of commercial fishing there and continuing efforts remove plastic litter arriving from the Great Pacific Garbage Patch, eliminate invasive species, and re-introduce native and endemic species to the various islands and atolls [55] (p. 127).

Perhaps perversely, climate change threats to marine ecosystems already recognized as biologically, socially, and/or economically important can inspire nations and management entities to do more to reduce existing non-climate-change stressors to those ecosystems. For example, the threat of an economically and socially devastating loss of coral reefs in the Coral Triangle to climate change and ocean acidification has inspired the nations there to increasingly protect their coral reef ecosystems from other kinds of threats, especially overfishing and destructive fishing practices, through MPAs [60,61]. Even efforts to address land-based pollution—traditionally one of the most difficult external stressors for ocean managers to address—can be inspired as a result of climate change. In Australia, for example, a 2007 study that detailed the climate change vulnerabilities of the Great Barrier Reef helped to spur a groundbreaking governance partnership between the Commonwealth of Australia and the State of Queensland to reduce sediment, fertilizer, and pesticide water pollution to the reef coming from farmers and ranchers in eastern catchments (watersheds) [55] (pp. 144–146) and [62]. The two governments' Reef Water Quality Protection Plan 2009 explicitly acknowledges past failures in addressing water quality and emphasizes that "the impending threat of climate change to the Reef has been recognized as far more serious since the commencement of the Reef Plan in 2003 and escalated the urgency of taking remedial action" [62] (p. 5).

3.3. Begin to Anticipate Climate Change Impacts on Marine Biodiversity

MSP can also help to improve ocean governance in a climate change era by allowing governance institutions to anticipate the increasing dynamism of marine ecosystems and marine biodiversity. Anticipating future changes allows governments and management entities to adjust marine management regimes, including MSP, before future use interests have reified. As a result, governments and managers acting before these changes actually occur can thus avoid many of the political and sometimes legal problems that arise once people have invested in the new uses that climate change may make available and hardened their positions regarding "proper" management. In addition, governments and managers can also try to anticipate future conflicts and prioritize uses of marine areas before anyone has made costly infrastructure investments that may be difficult to re-locate later. Such considerations may be particularly important for nations trying to balance biodiversity protections into the future with offshore energy development, such as in coastal nations who are actively pursuing development of offshore wind farms [55].

Anticipatory planning is already occurring for the protection of marine biodiversity. The poles, especially the Arctic, are already experiencing substantial migrations of species into their ecosystems [34–36]. In addition, Arctic sea ice is melting, and the nations that surround the Arctic are already preparing legally for future increased—perhaps unfettered—access to the resources of the Arctic Ocean [55] (pp. 158–159). These resources include new commercial fishing grounds [55] (p. 159).

However, new commercial fishing grounds have in the past proven disastrous for the marine biodiversity of the region [55] (pp. 158–159). In general, according to the MEA, "within 10–15 years of their arrival at a new fishing ground, new industrial fisheries usually reduce the biomass of the resources they exploit by an order of magnitude" [3] (p. 503). In anticipation of the opening of the Arctic to increased fishing, and out of a desire to protect these regions of the ocean from devastating exploitation, in 2009 the United States' North Pacific Fisheries Management Council, acting through its authority under the Magnuson-Stevens Fisheries Conservation and Management Act and with the approval of the Secretary of Commerce, established the Arctic Management Area, anticipatorily closing the federal waters off Alaska to fishing until the relevant species and ecosystems and the impacts of fishing could be better understood [55] (pp. 159–160). Such anticipatory governance measures will be an increasingly important governance tool in the climate change era for protecting marine biodiversity in the face of climate change impacts.

4. Conclusions

Climate change is already impacting marine biodiversity, both through its own effects on marine ecosystems and through synergistic interactions with existing stressors, such as habitat destruction, overfishing, and marine pollution. These climate change impacts should become an important driver of improvements in ocean governance for coastal nations as part of an overall national climate adaptation strategy, spurring coastal nations to better protect their marine resources and the ecosystem services they provide, to reduce existing stressors to marine biodiversity, and to anticipate the future alterations that climate change will bring.

In some cases, greater attention to ocean governance in a climate change era—which, as noted, is largely a climate change adaptation measure—could also inspire more governance attention to the root causes of climate change and hence to climate change mitigation. In Australia, for example, climate change impacts on the Great Barrier Reef have become one important inspiration for surrounding communities to reduce their climate footprint [55] (pp. 143–144).

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