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Ocean and Climate Discussion Series

"Climate-Smart" Marine Protected Areas for Mitigation and Adaptation Policy

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This brief reviews the potential climate benefits of marine protected areas (MPAs), discusses how policymakers and practitioners can help ensure that MPAs are "climate smart," and underscores that, because a suite of mitigation and adaptation policies is necessary to address the climate challenge, climate-smart MPAs merit a place in the climate policy toolbox. It is part of Ocean Conservancy's "Ocean and Climate Discussion Series," which provides science-based analysis to inform the global dialogue on integrating ocean issues into climate policy.

Introduction

Until recently, the global fight against climate change has largely overlooked the ocean-climate nexus. There is now a growing movement to correct this. Ocean and climate champions—including nations, non-federal governments, and nongovernmental organizations—are creating ocean-climate leadership coalitions, working to elevate ocean issues in international climate negotiations, and incorporating ocean issues into their own climate goals. Broadly, these efforts are focused on dramatically reducing economy-wide greenhouse gas pollution, given the profound damage it is causing the ocean through effects such as ocean warming and acidification. They are also focused on ensuring that governments do not overlook the full suite of sustainable ocean-based measures that can reduce greenhouse gas pollution and build resilience to its impacts.

Among these ocean-based measures, policy experts have increasingly promoted marine protected areas (MPAs) in general and "climate-smart" MPAs in particular (1). Yet there is not widespread understanding in the mainstream climate community—which historically has focused more on energy sectors than on natural climate solutions—of how MPAs can contribute to climate mitigation and adaptation and what it means for an MPA to be climate-smart (i.e., to have enhanced climate benefits). How can MPAs contribute to carbon sequestration? How can MPAs help communities adapt to climate-driven changes to the ocean and ocean ecosystem services? How can MPAs help build ecosystem resilience and preserve biodiversity in ways that account for future climate impacts? To create MPAs with enhanced climate benefits, what factors should be considered in their design?

To address these questions, this brief reviews the climate benefits that MPAs can have and discusses emerging principles to guide how policymakers and practitioners can make MPAs climate-smart. It is important to acknowledge, of course, that a wide range of ambitious climate strategies across sectors, from electricity and transportation to agriculture and buildings, is necessary to address the climate crisis. Yet, as this brief underscores, climate-smart MPAs merit a place in the climate policy toolbox.

MPAs, Other Area-Based Measures, and Integrated Ocean Management

An MPA is defined as "a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (2). The term includes a broad variety of management measures, some excluding all uses, and many providing for multiple uses. They are ideally used in conjunction with other effective area-based conservation measures (OECMs)—which are areas that are effectively conserved but not part of an official protected area system—as part of integrated ocean and coastal management to create integrated spatial development strategies for larger areas (3, 4).

Background: Climate mitigation and adaptation potential of MPAs

Our understanding of the potential conservation benefits of MPAs and other area-based management approaches has evolved over time, as has our understanding of what makes MPAs successful in realizing these benefits. Although ocean protections have long been used as a tool for habitat and species conservation, research from the past decade has shown that ocean protections also offer a range of climate mitigation and adaptation opportunities (5). The magnitude and timeline

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of the climate benefits of MPAs, however, vary greatly depending on factors such as geography, ecosystem type (e.g., deep sea corals, seagrasses), connectivity, level of protection, and effectiveness of management measures.

Mitigation potential of MPAs

Blue carbon ecosystems

The mitigation potential of MPAs that are designed to prevent the loss—or allow for the restoration, migration, and expansion—of blue carbon ecosystems is well established. From a scientific perspective, the long-term carbon sequestration potential of mangroves, seagrasses, and salt marshes is fairly well understood and there are generally accepted quantitative approaches to measuring carbon storage value. Using MPAs to protect these ecosystems can enhance climate mitigation by ensuring that blue carbon ecosystems will continue to sequester carbon well into the future (6, 7). This is not to say that relying on blue carbon protections for long-term carbon storage is without risk. Regardless of the strength and long-term durability of protections applied within an MPA, these ecosystems can still be vulnerable to inundation from rapid sea level rise and degradation from human activity. Future development or agriculture, aquaculture, and nutrient runoff from nearby human activities can degrade them, making them net emitters of carbon (7). Accurately accounting for outside risk in estimating their long-term mitigation potential is therefore both important and scientifically complex. To maintain the carbon storage capacity of these ecosystems within MPAs, human activities outside of MPAs might need curtailing.

What are "blue carbon" ecosystems?

Coastal ecosystems such as mangroves, salt marshes, and seagrass meadows play an important role in sequestering carbon. Per unit area, these "blue carbon" ecosystems sequester up to five times more carbon than terrestrial forests, although they cover less than 3% of the area of terrestrial forests (8–11). These ecosystems contain some of the largest stocks of irrecoverable soil organic carbon,[1] and mangroves also likely represent the largest stock of biomass carbon of any forest type by unit area in the world (12). Protecting blue carbon ecosystems from damage or loss, or increasing their coverage through restoration, are important strategies for carbon uptake and storage. However, they must be part of a larger suite of mitigation solutions across sectors of the economy, as blue carbon mitigation contributions on a global scale are relatively modest.

Other types of ocean ecosystems or resources

The carbon mitigation value of MPAs that protect types of ocean ecosystems or resources beyond blue carbon has not been widely studied and is much less certain, although they may offer significant climate adaptation benefits (see more below), as well as other important ecological and social values.

The role of ocean life in carbon storage

The ocean is the world's largest carbon sink and plays a variety of roles in the global carbon cycle. Physical and chemical processes governed by temperature, wind speed, ocean circulation, and atmospheric carbon dioxide levels control much of the ocean's carbon uptake. However, aquatic life controls another large portion of ocean carbon uptake and sequestration (13). In the coastal zone, mangrove forests, seagrass meadows, and salt marshes capture large amounts of carbon in their tissues through photosynthesis. Everywhere in the ocean, phytoplankton also turn carbon dioxide into living structures. A small portion of the carbon captured by marine plants is sequestered for decades to centuries by burial in sediments near shore and by the collective action of microbes, herbivores, and higher predators, which consume this carbon captured in the surface or coastal ocean and transport it to the deep ocean and seafloor primarily via sinking fecal pellets. Vertically migrating species, including certain fishes, marine mammals and invertebrate zooplankton, are thought to help return some nutrients to surface waters, possibly altering patterns of phytoplankton production and biological carbon capture. In addition, when whales and other large marine species die, their bodies sink to the ocean floor, where they—and the carbon they contain—may be incorporated into the seabed (14). In coastal systems, predators help protect the carbon sequestration potential of vegetated marine ecosystems by ensuring that herbivore populations do not overgraze plants (15).

Different types of ocean and coastal ecosystems can have widely varying carbon storage potential. For example, in comparison to blue carbon ecosystems, kelps have relatively less mitigation value because they do not form roots and shed vegetation seasonally thus decreasing their long-term carbon sequestration potential. Meanwhile, stony corals are net sources of carbon dioxide (16). There are also many ocean ecosystems and resources for which scientists do not have agreed-upon measurements of carbon storage potential. For example, there have been proposals to capture carbon by increasing fish or whale populations, or by protecting seabed sediment carbon stocks. The carbon sequestration potential of these types of approaches, however, remains uncertain and is the subject of ongoing research and debate (16). In addition, there are significant governance and accountability challenges associated with carbon accounting for area- and use-based restrictions that would cover resources outside of jurisdictional boundaries.

This high level of uncertainty around carbon storage accounting for these ecosystems and resources does not, however, mean that protections for these ecosystems and resources are irrelevant to the broader carbon sequestration picture. Kelp forests, coral reefs, phytoplankton, and other carbon sequestration mechanisms play crucial roles in the overall ocean carbon cycle, even if they are not sufficiently quantifiable for consideration in climate mitigation policies at this time (16). By preserving biodiversity and ecosystem function, MPAs can help ensure ocean ecosystems continue to function in their roles in this overall carbon cycle (17).

Adaptation potential of MPAs

Human community adaptation

Sea level rise and fisheries risks (discussed below) are two of the most universal and significant ocean-based climate impacts for which MPAs can provide human community adaptation benefits. MPAs designed in consultation with local communities can help maximize these benefits, as well as account for other potential adaptation needs such as preservation of local or tribal culture and traditions.

Protection from storms and sea level rise: Coastal ecosystems such as intact wetlands, mudflats, and reefs can protect coastal communities, infrastructure, and property from storms and the increased flooding and soil erosion that accompany sea level rise. Plant roots help keep soils in place (6, 8, 18); wetlands and mudflats provide broad areas where elevation rises slowly, attenuating wave energy and slowing the rise in flooding before it reaches built structures (19, 20); and coastal soils filter and purify pollutants from flood waters. Moreover, these ecosystems can be more effective than manmade alternatives given that they can sometimes accommodate sea level rise as they accrete more soil over time and rise in elevation (6). Coastal ecosystems can be more cost-effective than traditional infrastructure as well (21). MPAs designed to protect these coastal ecosystems by restricting harmful activities, such as overfishing, dredging and other seafloor disturbance, conversion to aquaculture, and clearing for development, can buffer local impacts of storms and sea level rise and increase the resilience of local communities.

Fisheries recovery and food security: Fisheries sustain billions of people globally, but increased pressures from fishing, coastal development, growing populations, and climate change threaten their continued ability to provide food and livelihoods. A variety of MPAs have long been used to increase fish populations by relieving fishing pressure in a given area or during a particular season when fish are more easily caught in large numbers (e.g., breeding aggregations) (6). In recent years, there has been progress with respect to MPAs also being designed with the economic and social resilience of fisheries-dependent communities, tribal communities, and other traditional users in mind (22). Well-designed MPAs can effectively aid the recovery of depleted fish stocks; protect essential fish habitat (e.g., wetlands, seagrasses); increase reproduction; promote genetic diversity and rebuild the age structures of fish populations, which increase the resilience of ecosystems and fish populations; and improve the health of surrounding populations and habitats, as juvenile and adult animals, eggs, and larvae find their way out of reserves (6). MPAs can therefore be an important part of supporting climate adaptation of fisheries and the human communities that depend on them for food or income.

Ecosystem adaptation

Holistic ecosystem-based protections: Marine environments such as blue carbon ecosystems, coral reefs, kelp forests, deep ocean canyons, seamounts, and hydrothermal vents provide habitat for a broad diversity of species, which have long been at risk from human disturbances. Historically, area-based protections accounted for disturbances such as overfishing, development, tourism, and shipping, but climate change adds a new type of long-term, systemic disturbance.

MPAs that effectively build ecosystem resilience and support species adaptation in the face of climate change are designed to maintain species diversity, genetic diversity within species, habitat complexity, and opportunities for species to migrate or adapt to new conditions. For example, MPAs, when they are designed as a connected network (or are very large), can serve as migration corridors for ocean wildlife whose former home ranges have become inhospitable owing to changing ocean conditions; "landing zones" for migrating species to move into; and areas with reduced disturbance for those species that cannot move. MPAs can be designed to promote genetic diversity by supporting larger populations of individual species, enhancing the gene pool and, consequently, increasing both the adaptability and resilience of populations to changes in ocean conditions. They can also be designed to safeguard reproductive output and thus increase the spatial extent of the targeted populations (6).

Targeted protections for specific outcomes: MPAs and other area-based protections can be used to support specific adaptation-relevant features of an ecosystem. For example, marine vegetation, such as kelps and seagrasses, can decrease ocean acidification locally and provide refuge for vulnerable calcifying (shell-forming) organisms (6).

Emerging principles of "climate-smart" MPAs

Viewed broadly, most MPAs have at least some climate benefit. One of the co-benefits of the longstanding MPA emphasis on maintaining valuable ecosystem services—as well as preserving and restoring threatened ecosystems and wildlife—is that it also reduces the strain on species and communities that climate change has also displaced or otherwise stressed (6).

"Climate-smart" MPAs, however, are meant to augment traditional marine protection outcomes. So the question is, if policymakers are considering adopting MPAs explicitly for their potential climate mitigation or adaptation benefits, how can MPAs be designed and adaptively managed to enhance those benefits? Climate-smart marine protection should be designed in a way that a) protects or restores the mitigation potential of ocean ecosystems and/or b) maximizes the "climate resilience" of ocean ecosystems or coastal communities—i.e., their ability to tolerate or adapt to ocean changes due to climate—including their resilience over time, specifically taking into account changing ocean conditions.

Several principles are emerging that should guide how policymakers and practitioners can achieve climate-smart marine protection.

Mitigation

- MPAs that protect blue carbon ecosystems are broadly accepted as climate-smart. Protection of blue carbon ecosystems is an established nature-based mitigation strategy with clearly quantifiable carbon sequestration benefits that integrates well into existing policy frameworks. Potential future changes in conditions of blue carbon habitats should be considered in the context of designing and managing MPAs in ways that maximize the durability of their climate mitigation contributions. Consideration also should be given to the marine food webs to maximize sequestration benefits.

- MPAs that aim to protect or enhance carbon mitigation in non-blue carbon habitats (e.g., seafloor sediments) need to be supported by analyses that estimate how much carbon the MPAs will sequester and for how long. In addition, advances in policy mechanisms governing protections across jurisdictional boundaries are needed that would formally recognize and standardize these as accepted mitigation strategies. Regardless of current unknowns, these MPAs may have significant climate adaptation and resilience benefits that should not be overlooked.

Adaptation

Climate-smart MPAs intended to significantly contribute to ecosystem and/or human community resilience should be developed as part of a larger integrated ocean management strategy (that incorporates both MPAs and OECMs) and should include the following elements:

- Establish clear design and management objectives that specifically respond to present or projected climate impacts, paired with ongoing, well-resourced monitoring, assessment, and enforcement. Use restrictions within MPAs should be strategically designed to match the climate outcomes being sought.

- Prioritize ecological spatial connectivity to enable ocean ecosystems to adapt to the widest possible range of climate trajectories. This includes creating connected networks of MPAs, and ensuring that standalone MPAs span areas sufficiently large to protect the full range of marine habitats and ecological processes present. McLeod et al. suggest that "MPAs should be a minimum of 10-20 km in diameter" especially "to accommodate self-seeding by short distance dispersers." This ensures that organisms, populations, species, nutrients, genes, and energy can exchange freely among distinct habitats, populations, communities, and ecosystems (23–25).

- Aim to protect the full range of biodiversity present in the protected area, to protect several resources and benefits, rather than species only of commercial or cultural significance (24). This will retain a broader array of future options than will a sole focus on one present benefit.

- Support local economic and community resilience to climate change by explicitly taking into account multiple climate-dependent paths of commercially, recreationally, and culturally important resources. Design the MPA to support multiple benefits to ensure continued relevance in the face of a broad range of potential future scenarios.

- For MPAs that protect coastal ecosystems, identify nearby communities and infrastructure that are particularly vulnerable to existing and predicted future sea level rise, storm surge, or more frequent or severe flooding and incorporate design and management approaches that would maximize nature-based protections from those impacts across a range of potential future scenarios.

- Design MPAs with Indigenous Peoples as full partners to ensure protected areas are established in a way that is consistent with Indigenous rights and respects Tribal self-determination, and support and encourage

Indigenous protected areas. In addition, design MPAs with local input to ensure key community needs for climate adaptation are fully considered. Ensure protections do not exacerbate existing inequalities among human communities, and consider how design and management might help address the needs of vulnerable community members.

Note that there is also an emerging discussion around how MPA design and management should evolve spatially or temporally in response to climate-driven changes. Management strategies could include accommodating adaptive behaviors such as poleward movements of fish populations (26), using dynamic design features that will enable managers to adjust the time, place, and type of protections as species shift their distributions and human uses continue (26, 27). These concepts are still emerging from both the scientific and governance standpoints, and therefore are not discussed in this brief, but they may merit consideration as the discussion evolves further.

Conclusion

Designed appropriately, climate-smart MPAs can be important tools supporting climate mitigation and adaptation goals. Policymakers, however, must also remain aware of the limits of MPAs. MPAs to support climate mitigation are currently best suited for blue carbon ecosystems, yet these ecosystems—impressive as their carbon sequestration capacity is—can contribute only a small fraction of the total emissions reductions necessary to meet the goals of the Paris Agreement and limit warming to 1.5 degrees Celsius over preindustrial levels. Governments and advocates must therefore be clear that they are pursuing climate-smart MPAs as a mitigation tool to supplement rather than displace ambitious reductions in greenhouse gas pollution from sectors such as transportation and electricity. Likewise, climate-smart MPAs can be a powerful tool to support adaptation, ecosystems, wildlife, and human communities in the face of increasing climate impacts. Yet alone, they are insufficient to fully prepare coastal ecosystems and human communities for climate change. Even MPAs that are designed specifically for climate adaptation will have their intended benefits continually affected by climate change absent aggressive mitigation (28). Nonetheless, climate-smart MPAs have a necessary role to play as part of a broader suite of complementary climate mitigation and adaptation solutions.

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Notes

[1] Irrecoverable carbon stocks are those that, if released, could not be re-captured through ecosystem restoration efforts in time to prevent the world's average temperature from exceeding 1.5 degrees Celsius above pre-industrial levels.

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