SOLUTION SERIES

FOUNDATION FOR CLIMATE RESTORATION

# COASTAL BLUE CARBON PRACTICES

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## OVERVIEW

The Foundation for Climate Restoration is committed to restoring a climate that supports the long-term survival of humanity and our natural world. To this end, the Foundation's explicit goal is to reduce atmospheric carbon dioxide ($CO_2$) to preindustrial levels of 300 parts per million (ppm) by 2050.

This is the fourth installment of the Foundation's Solution Series, which examines a diverse portfolio of natural and technological approaches that can remove $CO_2$ from our atmosphere and return us to safe, preindustrial levels of carbon.

In this paper, we explore Coastal Blue Carbon Practices through a climate restoration lens. We discuss these methods' ability to achieve durable, scalable, financeable, and equitable outcomes and then provide ways for readers to advocate for their safe and thoughtful implementation.


## INTRODUCTION

On certain coastlines around the world, you'll find unique ecosystems like mangroves, seagrass meadows, and tidal salt marshes. These ecosystems take up a tiny share of the Earth's surface—about 1%[1]—but they store an incredible amount of carbon. On land, oxygen facilitates the microbe activity that breaks down biomass and re-releases its carbon into the air as $CO_2$. As a result of being underwater, these coastal soils are anaerobic,[2] so they can store disproportionately large amounts of carbon for very long timescales.[3,4]

But these coastal ecosystems are under threat. Many of these areas are being destroyed by industrial and coastal developments, pollution, exploitation, and deforestation for aquaculture.[5] When coastal ecosystems are developed, they are drained, and their soils release the carbon that they have stored for centuries or millennia. As our climate changes, it is becoming increasingly

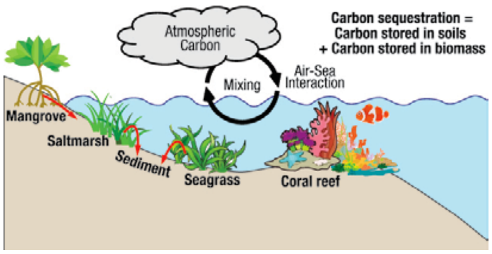



*Image citation: Research Gate*

important to safeguard existing stocks of carbon. It is much more efficient and cost-effective to prevent the release of $CO_2$—by protecting existing carbon stocks like these coastal blue carbon ecosystems, for example—than to remove $CO_2$ from the atmosphere after it has been released.

**COASTAL BLUE CARBON** refers to the flux[6] and storage of carbon in coastal ecosystems,[7] including mangroves,[8] tidal salt marshes,[9] and seagrass meadows.[10]

Seagrasses, mangroves, and salt marshes currently store up to five times more carbon per hectare than terrestrial forests,[11] but this stored carbon is released into the atmosphere as $CO_2$ if the ecosystems are destroyed.[12] A staggering 25-50% of vegetated coastal habitats have already been lost, equating to a release of 1 billion tons of $CO_2$ annually.[13] Coastal blue carbon practices, which improve the health of coastal ecosystems, can support climate restoration efforts by sequestering 2.4 to 4.5 Gt $CO_2$ per year by 2030 while avoiding billions of tons of $CO_2$ emissions from ecosystem degradation.[14]

Parties of the Paris Agreement have recognized the importance of these coastal ecosystems in meeting their Nationally Determined Contributions. As of December 2020, 59 of the 161 parties included conservation and restoration of blue carbon ecosystems as the only specific negative emissions technology mentioned.[15] Unfortunately, the effectiveness of ecosystem-based carbon dioxide removal (CDR) is reduced as warming increases, underscoring the need for additional options for mitigation and climate restoration. With these ecosystems declining at an alarming rate, now is the time to prioritize their preservation and restoration in order to contribute to our global climate targets.

**BLUE CARBON** is a broad term that refers to carbon captured by the world's ocean and coastal ecosystems. Coastal blue carbon refers to a subset of blue carbon that only includes the carbon captured and stored by coastal ecosystems.

## HOW COASTAL BLUE CARBON PRACTICES WORK

Coastal blue carbon can be stored in a number of places: in soil, in living biomass above ground (e.g., leaves, branches, stems), in living biomass below ground (e.g., roots), and in non-living biomass (e.g., plant litter and dead wood) found in mangroves, salt tidal marshes, and seagrass meadows.[16] This carbon is absorbed for short timescales by aquatic life, and some of that carbon gets stored in sediment, where it can remain for millennia.[17]

Coastal blue carbon is different from soil carbon in two critical ways. First, given that coastal blue carbon is primarily stored in underwater coastal soils, it does not require land that would otherwise be needed for agriculture. It can, however, compete with aquaculture. Second, coastal blue carbon has the capacity to store carbon for longer than terrestrial soil carbon because there is less oxygen available under water. Oxygen is required for decomposition and subsequent $CO_2$ release. Because the soils of coastal blue carbon ecosystems are underwater, they contain far less oxygen and have much slower rates of decomposition.[18]

Coastal blue carbon practices include **conservation** and **restoration**. Conservation refers to methods, like improved management and protection practices, that reduce the loss and degradation—and resulting $CO_2$ emissions—of existing ecosystems. Restoration practices, like re-establishment (i.e., rebuilding a former wetland) and rehabilitation (i.e., repairing the functions of a degraded wetland), facilitates increased $CO_2$ drawdown and long-term storage.[19,20] Community groups can implement conservation programs that incentivize landowners to change harmful cultivation and grazing practices that damage these areas, and they can facilitate restoration by removing invasive species and planting native vegetation.

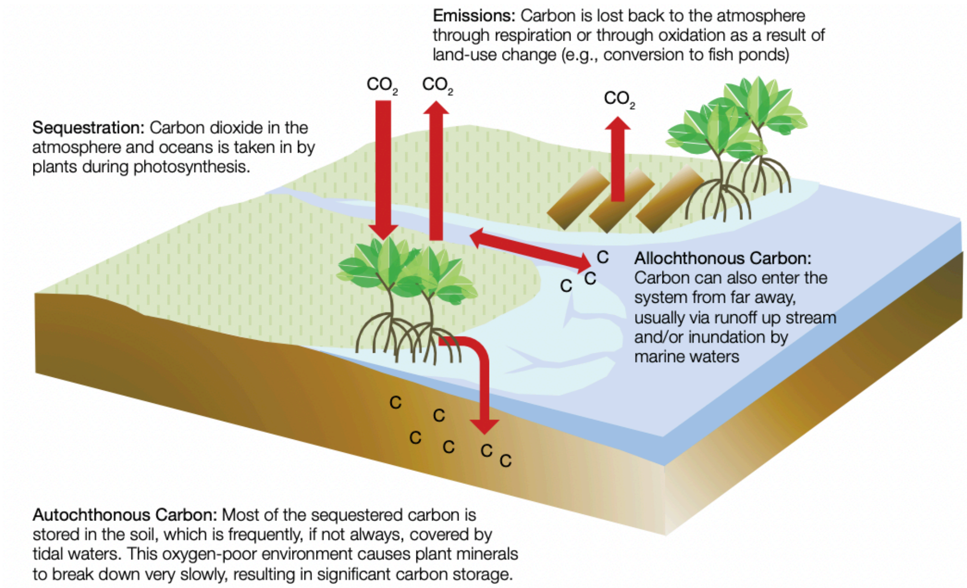



**Figure 1.3** Mechanisms by which carbon moves into and out of tidal wetlands

*Image citation: COASTAL BLUE CARBON*

## BENEFITS AND BARRIERS TO ADOPTION

### ECONOMIC BENEFITS

Like many types of ecosystem restoration, coastal blue carbon practices can provide economic benefits to local communities in the form of employment opportunities and ecotourism. These thriving ecosystems can also support local livelihoods and improve food security by increasing fish and other seafood populations.[21] Building "green" infrastructure (i.e., replanting vegetation through coastal blue carbon practices), rather than "gray" infrastructure (i.e., building levees or dredging rivers), can be more cost-effective in preventing flood damage, in addition to providing environmental and social benefits.[22]

### ECOLOGICAL BENEFITS

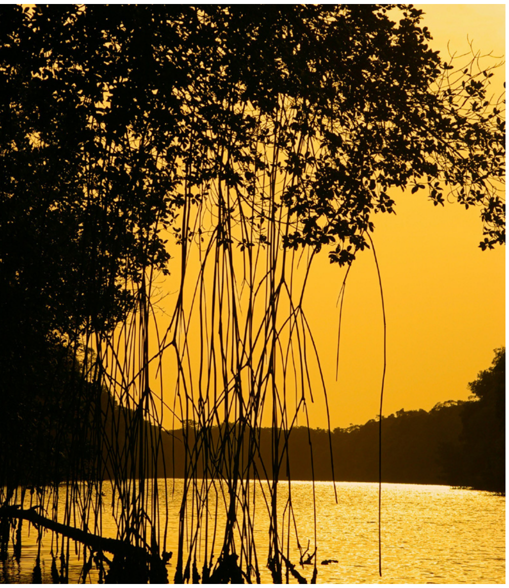
In addition to optimizing carbon sequestration and storage, coastal blue carbon practices improve ecosystem biodiversity and health, which, in turn, increase the area's resilience to climate change.[23] Coastal blue carbon management can also enhance water quality because wetlands act as natural water purifiers, filtering pollutants and contaminants from coastal waters and land runoff and helping maintain coastal marine water quality.[24]

### SOCIAL BENEFITS

Strong and healthy networks of wetlands can provide ecosystem services that support the livelihoods, culture, food security, water quality, recreation, and tourism of local communities and users.[25] Coastal regions are often the hardest hit by extreme weather events, but healthy coastal blue carbon ecosystems can reduce coastal erosion, prevent storm surges, and mitigate the impacts of sea level rise and extreme weather events in these areas. Wetlands can also provide attractive settings for outdoor activities.[26] Additionally, these ecosystems support the health of fisheries, which provide valuable nutrition for millions of people, particularly in developing countries where fish is a primary source of protein.[27]

## RISKS AND BARRIERS TO ADOPTION

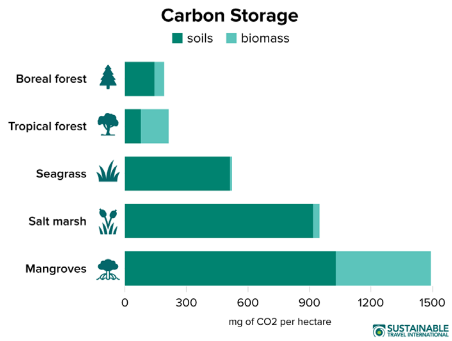
If not implemented properly, coastal blue carbon practices can reduce biodiversity and compromise the local ecosystem.[28] Alternatively, the conditions that favor organic carbon storage may also facilitate the production of methane ($CH_4$) and nitrous oxide ($N_2O$), two greenhouse gasses with substantially more warming potential than $CO_2$, making them of immediate climatic concern.[29]



In terms of barriers to adoption, coastal blue carbon projects are subject to local land-use and zoning policies and must compete with the land used for aquaculture and human development.[30] With changing coastal management and sea-level rise, some coastlines can become highly sensitive to damage from climate change impacts.[31] If coastal ecosystems are degraded again—for example, by storm surges damaging mangroves—wetland management practices would need to be indefinitely maintained to ensure that these fragile ecosystems remain intact.[32] Saturation is also a concern given that wetlands can only hold a finite amount of carbon until they are no longer able to sequester additional carbon.[33]

In addition, monitoring and verifying the carbon removal of coastal blue carbon ecosystems is costly and poorly understood, making quantification and management difficult.[34] Until recently, the practical tools and guidance for adequate measurement of blue carbon have been lacking, particularly in developing countries. Many calculations have overestimated the amount of $CO_2$ sequestered,[35] and the need for continual monitoring and quantification can be unreasonably expensive.[36] Still, there is a need for internationally accepted measuring and monitoring procedures for carbon accounting.[37] Given these implications, a growing number of remote sensing tools can provide unique and valuable information on coastal vegetation structure and area coverage that could not easily be obtained otherwise.[38,39] To fill in this gap, the NOAA Blue Carbon Inventory Project was launched in 2021. It seeks to enhance the capacity to integrate coastal wetland data into national greenhouse gas inventories, which will allow for comprehensive reporting in order to track progress towards meeting the goals of the Paris Agreement.[40]

## COASTAL BLUE CARBON PRACTICES AS A CLIMATE RESTORATION SOLUTION




*Data source above: Pendleton et al. 2012 and Pan et al. 2011*

*Image citation: COASTAL BLUE CARBON*

To be durable, a solution must keep the captured $CO_2$ out of circulation for at least a century.

### DURABILITY

Like carbon stored in terrestrial ecosystems, coastal blue carbon is sequestered in living plant biomass for relatively short periods of time: years to decades. But unlike terrestrial ecosystems, carbon can be sequestered in coastal soils for significantly longer: centuries to millennia.[41] The latter results in very large carbon stocks because the soil is saturated with water, maintaining an anaerobic state (i.e., low to no oxygen). The soil builds up quickly, leading to continuous accumulation of carbon over time.[42] Therefore, coastal blue carbon practices are a more durable solution compared to land-based forest carbon practices.

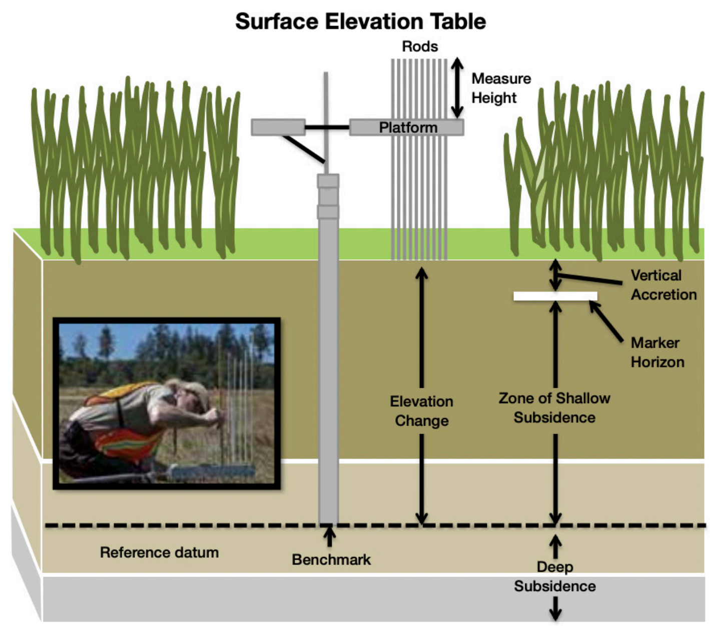



**Figure 5.3** Diagram of a Surface Elevation Table (SET) marker horizon (MH) method used to detect changes in soil surface elevation. Inset image: USFWS biologist Bill Bridgeland taking measurements on a SET (© Roy Lowe, U.S. Fish and Wildlife Service).

The durability of many coastal wetland restoration projects have been compromised by natural risks (e.g., extreme weather), external risks (e.g., resource access or land tenure concerns), or internal risks (e.g., establishing long-term management plans).[43] If drivers of coastal degradation, like industrial and coastal development, pollution, and deforestation,[44] are not addressed, they can continue to degrade coastal ecosystems despite restoration efforts.[45]

Temperature, salinity, and sediment type also affect the durability of coastal blue carbon storage.[46] Like terrestrial soil carbon, these coastal carbon stocks can be released back into the atmosphere due to climate change or human intervention like drainage or excavation. Currently, 485-539 tons of $CO_2$ are released per hectare each year globally due to disturbances of coastal ecosystems.[47]

In light of this, coastal blue carbon practices are a durable climate restoration solution only if suitable locations are selected, particularly those that have previously supported the species being restored. They must be protected from human-driven forms of coastal degradation and must have long-term management plans in place.

To be scalable, a solution must be able to be scaled within a decade to remove and store at least 10 Gt of $CO_2$ per year.

## SCALABILITY

The scalability of coastal blue carbon practices depends largely on which types of ecosystems are conserved or restored.

| ECOSYSTEM TYPE | % OF EARTH'S SURFACE | $CO_2$ SEQUESTRATION | OTHER NOTABLE FACTS |
|---|---|---|---|
| **Mangroves**[48,49] | 0.1% | 0.024 Gt $CO_2$/yr | Store up to 10 times more carbon per hectare than terrestrial forests |
| **Seagrass Meadows**[50] | 0.2% | 0.027 Gt $CO_2$/yr | Capture carbon up to 35 times faster than tropical rainforests and absorb 10% of the ocean's carbon each year |
| **Tidal Salt Marshes**[51] | 0.01% | 0.07 Gt $CO_2$/yr | Have a greater capacity for carbon sequestration than other coastal wetland and forested terrestrial ecosystems, but there is limited and declining global area available |

These sequestration rates are low compared to our 10 Gt/yr benchmark for climate restoration solutions.[52] However, climate restoration requires both dramatically reducing emissions as well as substantially scaling up carbon dioxide removal. Coastal blue carbon systems serve as major carbon stocks, and thus, protecting and restoring them can avoid significant $CO_2$ emissions.

Globally, the combination of avoided emissions plus carbon sequestration could reach a scale of 2.4-4.5 Gt/yr by 2030.[53] Therefore, it seems unlikely that coastal blue carbon practices can be scaled to meet climate restoration's goal of removing and storing at least 10 Gt of $CO_2$ per year within a decade. However, because these practices present many co-benefits with few risks and barriers to adoption, they should certainly be included in a portfolio of restorative solutions.[54]

To be financeable, the solution must have funding that is already available or easily mobilized.

## FINANCEABILITY

Coastal blue carbon practices do not currently meet our benchmark for financeability[55] because projects can involve high upfront costs and relatively expensive measurement and verification methods.[56] The costs of coastal blue carbon projects range widely (from \$240 to \$30,000 USD per ton of $CO_2$),[57] but could potentially be reduced to less than \$100/t of $CO_2$ if projects are designed with a multi-functional approach, rather than exclusively for carbon removal and storage.[58] For example, mangroves are among the least expensive solutions to finance,[59] and private sector financing has already played a significant role in implementing such projects.[60] If a mangrove restoration project is designed with goals including ecosystem restoration, eco-tourism, and adaptation benefits, the multitude of goals can broaden the funds available.

To be equitable, a solution must address historical injustices while providing a just distribution of benefits and burdens to all, regardless of income, race, and other characteristics.

## EQUITY

The impacts of human-induced climate change present a unique set of environmental, social, and health challenges for those who live and work in close proximity to the ocean.[61] Coastal or ocean stakeholders include individuals or groups that have something of value (physical, symbolic, etc.) that could be affected by coastal projects,[62] including those living or working in the coastal community, Indigenous communities, NGOs, government entities, corporations, and other businesses that would be affected by a project. Those who use the ocean for activities such as fishing and water sports are also considered stakeholders.

Historically, coastal blue carbon projects have put profit before people and the planet.[63] Project funders tend to prioritize the lowest-cost CDR, but this approach risks underpaying local communities for ecosystem services, disproportionately burdening them and preventing them from utilizing their resources more profitably in the future.[64] When funded through carbon offsets, civil society organizations have critiqued blue carbon projects and initiatives for turning these ecosystems into a commodity that legitimizes continued emissions elsewhere.[65] Blue carbon initiatives have also grappled with integrating local knowledge, traditional customs, livelihoods, and rights, all of which can lead to subtle forms of cultural erasure and community displacement.

**PROCEDURAL JUSTICE BEST PRACTICES:** In support of procedural justice, community stakeholders must be engaged throughout project planning and implementation, with special attention paid to food security[66] and carbon impacts elsewhere.[67] Additionally, project leaders should: consider the biophysical and socio-political contexts of projects;[68] honor existing cultural protocols; compensate stakeholders for their participation;[69] include engagement initiatives in the project budget; and host workshops to build relationships and foster open communication with community members.[70]

## PROCEDURAL JUSTICE

Targeting and engaging with coastal users requires dedicated thought and consideration to ensure all individuals and groups who should have their voices heard have a seat at the table. This can be achieved through targeted flyers in public locations, advertisements in local newspapers, and community event calendars and postings, among other approaches. Conversations with community members can help identify target stakeholders in their area that might otherwise not be included in these processes.[71]

Coastal states have jurisdiction over 12 nautical miles of their coastline,[72] but ocean stakeholders are not confined to coastal communities and can sometimes include those that use the ocean for recreation, food sources, or income. Additionally, land and tenure rights for land-based projects are generally straightforward but can be more complex for ocean-based projects. With this in mind, project developers should specifically engage the Indigenous peoples and small-scale food producing communities who have place-based knowledge of the ocean and risk being overlooked during the engagement process.[73]

In order to be more equitable, coastal blue carbon projects must distribute more benefits to historically disadvantaged groups, by funding projects that provide local benefits, job opportunities, mentorship, and education. But it is important to note that each set of benefits and burdens for projects can differ across communities, and it is ultimately up to them to decide what is beneficial or burdensome to them. These benefits can differ within communities as well, underscoring the importance of robust engagement to understand local power dynamics and differences.

Blue growth[80] has created injustices for those who live or lived near pollution and waste, small-scale fishers and users of marine resources who lost access to ecosystem services, and other marginalized groups who have experienced inequitable social, cultural, and economic impacts while being excluded from decision-making processes.

[82]"The term "ocean grabbing" has been used to describe actions, policies or initiatives that deprive small-scale fishers of resources, dispossess vulnerable populations of coastal lands, and/or undermine historical access to areas of the sea."

## DISTRIBUTIVE JUSTICE

Access to ocean resources has historically been inequitably distributed.[74] In order to more fairly allocate the benefits of blue carbon practices, protocols for the redistribution of co-benefits, like Climate, Community, and Biodiversity Standards and Social Carbon, have been established.[75] Additionally, leaders of coastal blue carbon projects should: ensure land rights are reserved for local stakeholders;[76] mitigate the risk of climate gentrification as developers move into neighborhoods settled on higher ground[77]; and create Community Benefit Agreements[78] that address the disproportionate impact of rising seas, severe hurricanes, storm surges, increased poverty, and poor housing options on coastal communities.

## REPARATIVE JUSTICE[79]

Different reparation approaches can remediate harms suffered by coastal stakeholders in a way that fits their cultural contexts. For example, policymakers can follow the example of California's Senate Bill 796[81] in order to return land to those dispossessed or displaced by ocean grabbing.[82] Additionally, funding for clean-up and other direct services should be allocated to communities that have experienced pollution, waste, environmental degradation, and restricted access to ecosystem services. Importantly, these reparative measures should be funded by the Global North, which is most responsible for historic greenhouse gas emissions.[83] Policies should also support community-led coastal blue carbon work in Small Island Developing States, in developing countries in the Global South, and in historically marginalized communities in the United States.[84]

Because the range of stakeholders in this space varies widely, plan design will have to elicit and incorporate the feedback and insight of all those affected by coastal blue carbon policy. As a result, effective reparative policies will need to be site-, culture-, and context-dependent. Therefore, these ideas, developed by a few people with limited context to all cultures and situations,[85] are limited in their explanation. This approach to ensuring justice is processual, as it recognizes the rights of everyone to pursue political programs that suit their situation, culture, and values.

## TRANSFORMATIVE JUSTICE

Before we can achieve transformative outcomes, we must move away from a system fixated on growth and financial gain, and instead prioritize human welfare and environmental sustainability.[[86]] Coastal blue carbon projects can better achieve transformative justice by prioritizing human welfare and environmental sustainability through approaches like regenerative ocean development, community-based blue economies, and community-supported fisheries.[[87]] Moreover, since marginalized communities have historically lacked access to and benefit from coastal areas, transformative measures should encourage funding programs that meaningfully connect these communities with the ocean and other coastal activities and projects.[88]"

## HOW TO SCALE COASTAL BLUE CARBON PRACTICES

### RESEARCH AND DEVELOPMENT OPPORTUNITIES

Despite the growth of climate funding overall, ocean climate research funding is currently inadequate.[89] With sufficient funding, we could further explore quantifying blue carbon stocks, managing blue carbon, and mitigating the risks of climate damage, like coastal erosion, on sequestration capacity.[90]

### POLICY OPPORTUNITIES

Internationally, environmental concerns have resulted in increased attention to global ocean governance.[91] In response, there have been numerous policies, management strategies, and tools implemented to conserve and restore coastal blue carbon ecosystems.[92] Still, more policies and incentives are needed to encourage the restoration and protection of wetlands in blue carbon ecosystems, including new finance mechanisms that can mobilize additional funds by combining best practices in coastal management with climate change mitigation goals and needs.[93,94]

Government policy can support the protection and restoration of coastal blue carbon ecosystems by restricting the commercial, human, and industrial development of these ecosystems, preserving protected coastal ecosystems, and providing funding to restore degraded coastal ecosystems. Additional supportive policies include ensuring coastal managers have clear and secure land rights to these areas and the resources within them, incentivizing sustainable management, and creating a multi-stakeholder coastal management initiative to oversee activities within these areas.[95] While some such policies exist in the United States already,[96–100] there are still many critical coastal areas that would benefit from protection or restoration through similar policies. Advocates can work with local elected officials to adopt policies that protect or expand the carbon sequestration of their local coastal regions.

## CONCLUSION

While coastal blue carbon practices cannot reach a scale of at least 10 Gt of $CO_2$ sequestration per year, protecting and restoring these ecosystems can bring substantial climate, social, and economic benefits. Like many nature-based solutions, coastal blue carbon ecosystems currently store huge quantities of carbon, and their ongoing destruction and degradation contribute significantly to global emissions. These ecosystems are limited in their scalability because they are suited to only a small share of the Earth's surface, but supporting their long-term health will nonetheless avoid emissions and remove some atmospheric $CO_2$.

Additionally, coastal blue carbon ecosystems can provide social and economic benefits to the populations most threatened by climate change impacts. With equitable implementation, practices that support these threatened ecosystems[101] can make an important contribution to a portfolio of climate restoration solutions.

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96. This bill would create high-quality jobs and equitable training and employment opportunities across climate resilience sectors, including agriculture, forestry, and coastal ecosystem restoration. A new Office of Climate Resilience within the White House would create a national climate resilience plan focused on worker protection and equity, and several new grant programs would support communities with climate resilience planning. The bill also outlines how to remove barriers to employment based on immigration status and prior history with the criminal justice system. https://carbon180.org/policy-tracker

97. This bill would establish an NOAA-led Interagency Working Group on Coastal Blue Carbon to develop a national map of coastal blue carbon ecosystems. The working group would conduct research to establish national restoration goals and priorities for coastal blue carbon ecosystems; assess the biophysical, social, and economic barriers to restoration of coastal blue carbon ecosystems; study the effects of environmental and human stressors on sequestration rates; and preserve continuity of coastal blue carbon data. The bill directs the working group to collaborate with the National Academy of Sciences to assess long-term effects of geologic carbon stores in deep sea environments, including their effects on marine species and ecosystems. https://carbon180.org/policy-tracker

98. This bill would re-establish a Civilian Conservation Corps (CCC) to create federal conservation jobs across public and private US lands. This revitalized CCC would partner with host organizations to ensure that projects reflect local landscape and community needs and prioritize job creation and conservation benefits for underserved populations. Conservation projects eligible under the new CCC would span agriculture, forestry, and coastal ecosystem restoration. Projects would include educational trainings for new career pathways in conservation. https://carbon180.org/policy-tracker

99 This bill would establish a Blue Carbon Program within NOAA to further conservation objectives, focusing on the research and evaluation of blue carbon storage as well as protection and restoration of blue carbon ecosystems. For the latter, the bill would establish a grant program and require NOAA to designate “blue carbon areas of significance” with guidelines for their protection. The bill also directs FWS, NPS, and NOAA to conduct coastal and marine activities to sequester carbon and halt carbon and methane emissions. https://carbon180.org/policy-tracker

100 This bill would establish a Blue Carbon Program within NOAA to further conservation objectives, focusing on the research and evaluation of blue carbon storage as well as protection and restoration of blue carbon ecosystems. For the latter, the bill would establish a grant program and require NOAA to designate “blue carbon areas of significance” with guidelines for their protection. The bill also directs FWS, NPS, and NOAA to conduct coastal and marine activities to sequester carbon and halt carbon and methane emissions. https://carbon180.org/policy-tracker

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