



Blue Carbon

Integrating Ocean Ecosystems in Global Climate Action

Cispata Bay mangroves from the Vida Manglar project in Colombia. © Daniel Uribe

- The ocean plays a critical role in the global carbon cycle, absorbing approximately 25% of anthropogenically-generated atmospheric carbon which is then distributed throughout the ocean.
- Multiple ocean and coastal ecosystems sequester and store globally significant amounts of “blue carbon” which can be released if these ecosystems are disturbed by anthropogenic activities. In particular, coastal blue carbon ecosystems—mangroves, seagrasses and tidal marshes—are the most efficient natural carbon sinks on Earth on a per area basis. These blue carbon ecosystems cover an area equivalent to only 1.5% of terrestrial forest, but their ongoing degradation causes carbon emissions equivalent to 8.4% of the emissions from terrestrial deforestation¹.
- Factors that determine if an ocean ecosystem can be integrated into current climate mitigation policy—and as such is actionable as a climate mitigation solution—include: the presence of high carbon stocks, evidence for long-term carbon storage, and the capacity for people to manage and effectively measure greenhouse gas emissions (GHG) and removals resulting from changes in these ecosystems. In contrast, while some ocean and coastal ecosystems and organisms are essential components of the ocean carbon cycle, their carbon mitigation capacity is not directly responsive to management actions and/or do not permanently sequester or store carbon.
- **Mangroves, seagrasses and tidal marshes meet the criteria as actionable in climate mitigation policy and are already recognized for their climate mitigation value by the Intergovernmental Panel on Climate Change (IPCC).** These blue carbon ecosystems are already included in some countries’ Nationally Determined Contributions (NDCs), national GHG Inventories, and other climate mitigation mechanisms. Conservation and restoration of blue carbon ecosystems offers an efficient pathway to avoid GHG emissions, particularly for nations with large areas of coastal vegetation and high rates of loss. These ecosystems also provide valuable ecosystem services, including coastal protection and fisheries that are applicable to climate adaptation and resilience policies, such as in National Adaptation Plans (NAPs).

¹ Griscom et. al. (2017)

- **Ocean ecosystems such as macroalgae (including kelp and seaweed farms) and benthic ocean sediment ecosystems are known to sequester and store carbon, but the magnitude of this carbon value cannot yet be assessed.**

There are significant scientific uncertainties around the pathways and quantities of carbon sequestered and stored in these ecosystems and emissions resulting from their disturbance. These carbon accounting uncertainties mean that it is not currently feasible to incorporate these ecosystems into mitigation policy that requires carbon accountability. Climate policy actions not requiring carbon accounting—such as inclusion in NDCs—may be possible for some geographies.



Monterey Bay, California, United States. © Keith A. Ellenbogen

- **The current evidence is that calcifying organisms, such as coral and oyster reefs do not remove net carbon from the ocean or atmosphere and hence cannot be considered to contribute to climate mitigation.** These ecosystems are important for adaptation and resilience for coastal communities and biodiversity in many geographies and so can be included in adaptation policy mechanisms. The climate mitigation value of pelagic ecosystems, including those with mobile marine fauna and phytoplankton, is currently being investigated, but is not yet established scientifically and is unlikely to be actionable.
- **Many ocean ecosystems are important for climate adaptation and resilience** and can be included in adaptation policies and actions.
- **Further scientific research and capacity building is needed to expand the inclusion of blue carbon ecosystems in climate mitigation, adaptation and resilience commitments and activities.** This includes expanding the capacity of policymakers and governments to assess, monitor and account for the climate mitigation and adaptation value of these ecosystems.
- **Blue carbon ecosystems can and should be included in climate mitigation and adaptation policies and actions wherever possible.**
 - Countries should work to include blue carbon activities in NDCs, in national GHG inventories, and raise ambition for the inclusion and/or increase of blue carbon ecosystems in NAPs and other national climate policies.
 - Countries should act to address the drivers of blue carbon ecosystem loss and expand conservation and restoration of these ecosystems.
 - Blue carbon interventions, if properly designed and executed, have the potential to contribute to climate mitigation, adaptation and biodiversity goals generating a wide array of benefits that meet numerous objectives of the Sustainable Development Goals, Convention on Biological Diversity, and other global targets.
 - Local communities are essential to effective and successful conservation and restoration of blue carbon ecosystems and as such policies and actions must be inclusive and equitable.
- **Innovative financing models are essential for scaling mitigation actions through the management of blue carbon ecosystems.** Market-based approaches are already under development. Carbon credits for mangrove projects have been piloted and are now be purchased through the voluntary carbon market. Alternative and innovative financing approaches are now needed to provide long-term, sustainable resources for conservation of blue carbon ecosystems under a broad range of differing physical, ecological, social and political conditions.

Criteria for Actionable Blue Carbon Ecosystems for Mitigation

Ocean ecosystems are considered **actionable mitigation blue carbon ecosystems** and important to climate mitigation policy if the management of these ecosystems—such as conservation or restoration actions—results in a measurable reduction in GHG emissions to, or increased GHG removals from, the ocean or atmosphere. Actionable mitigation blue carbon ecosystems are currently recognized by the IPCC and can be included in national GHG inventories.

EVALUATING OCEAN ECOSYSTEMS AS ACTIONABLE BLUE CARBON FOR MITIGATION

		Scale of GHG removals or emissions are significant	Long-term storage of fixed CO ₂	Anthropogenic impacts on the ecosystem are leading to C emissions	Management is practical/possible to maintain/enhance C stocks and reduce GHG emissions	Included in IPCC GHG accounting guidelines ²	Climate Adaptation Value
Actionable Blue Carbon Ecosystems for Mitigation	Mangrove	YES	YES	YES	YES	YES	YES
	Tidal marsh	YES	YES	YES	YES	YES	YES
	Seagrass	YES	YES	YES	YES	YES	YES
Emerging Blue Carbon Ecosystems	Macroalgae	YES	YES	YES	YES	NO	YES
	Benthic sediments	?	YES	YES	?	NO	?
	Mud flats	?	?	YES	?	NO	YES
Other Ocean Ecosystems (Not Actionable)	Coral reef	NO	NO	NO	NO	NO	YES
	Oyster reefs	NO	?	NO	NO	NO	YES
	Phytoplankton	YES	?	?	NO	NO	NO
	Marine fauna (fish)	NO	NO	YES	NO	NO	YES

Source: Adapted from Lovelock & Duarte, 2019

² 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands.

Actionable Blue Carbon Ecosystems for Mitigation



Carbon Storage

These blue carbon ecosystems sequester carbon through photosynthesis, which is stored in plant biomass and the soil below. Between 50–90% of the carbon is stored in the soils where it can remain for millennia.³ These ecosystems have the highest rates of nature-based carbon sequestration per area: sequestration in tidal marshes is on average $242 \text{ gC m}^{-2} \text{ yr}^{-1}$, mangroves is $168 \text{ gC m}^{-2} \text{ yr}^{-1}$ and seagrasses is $83 \text{ gC m}^{-2} \text{ yr}^{-1}$.⁴

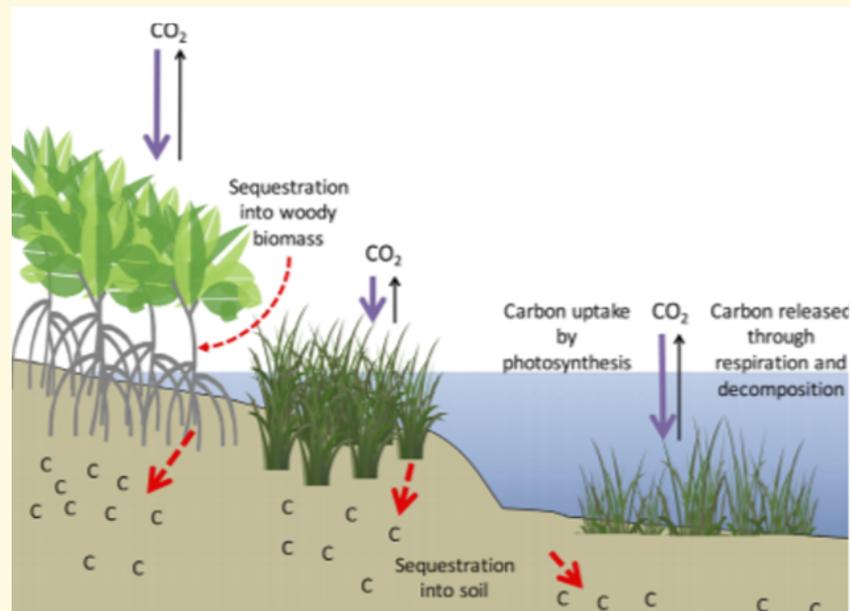


Figure 1: Image from Howard et. al, 2017

³ Howard et. al. (2017)

⁴ Taillardat et. al. (2018)

PHOTOS, LEFT TO RIGHT: Mangroves in Mozambique. © bartolomeo/Flickr Creative Commons; Salt marshes in Duxbury, Massachusetts, USA. © Conservation International/photo by Sarah Hoyt; Com, National Park, Timor Leste. © Paul Hilton for Conservation International

	MANGROVES	TIDAL MARSHES	SEAGRASSES
Drivers of Loss	Aquaculture, Agriculture, Coastal Development, Sea-level Rise	Agriculture, Coastal Development, Sea-level Rise	Coastal Pollution, Coastal Development
Annual Emissions from anthropogenic impacts ⁵	144–681 million Mg CO ₂	21–760 million Mg CO ₂	62–813 million Mg CO ₂
Ecosystem management for carbon	Numerous approaches to carbon management including ecosystem conservation (such as MPAs), restoration, hydrological restoration.	Numerous approaches to carbon management including ecosystem conservation (such as MPAs), restoration, hydrological restoration, coastal rewetting.	Numerous approaches to carbon management including ecosystem conservation (such as MPAs), restoration, improving water quality through management of sediment and nutrient runoff.
Adaptation value	Coastal protection, ensuring food security (fisheries), erosion control, biodiversity protection		
Uncertainties	Carbon storage, sequestration, and emissions are scientifically established. Scientific research is still needed to understand non-CO ₂ GHG emissions, local and regional scale variations in carbon stocks, and in carbon sequestration rates with restoration.	Carbon storage, sequestration, and emissions are scientifically established. Scientific research is still needed to understand geographic distribution of ecosystem, non-CO ₂ GHG emissions, local and regional scale variations in carbon stocks, and in carbon sequestration rates with restoration.	Carbon storage, sequestration, and emissions are scientifically established although with less certainty than mangroves and tidal marshes. Scientific research is still needed to understand geographic distribution of ecosystem, non-CO ₂ GHG emissions, local and regional scale variations in carbon stocks, and in carbon sequestration rates with restoration. Governance and legal tenure of submerged lands is uncertain in many regions and can provide challenges to carbon accounting and crediting.
Mitigation Policy/ Finance Implementation	<ul style="list-style-type: none"> • Some countries already including management of mangroves in NDCs • Mangroves are integrated into REDD+ in some countries • Some countries include mangroves within national GHG inventories • Carbon credits for conservation and restoration of mangroves available on voluntary markets 	<ul style="list-style-type: none"> • Some countries are already including management of tidal marshes in NDCs • Some countries including tidal marshes into national GHG inventories • Methodologies for obtaining carbon credits exist for tidal marshes although to date no carbon credits have been generated 	<ul style="list-style-type: none"> • Some countries already including management of seagrasses in NDCs • IPCC guidelines allow integration of seagrasses in national GHG inventories, although no countries are currently doing so • Methodologies for obtaining carbon credits exist for seagrasses although to date no carbon credits have been generated

⁵ Howard et. al. (2017)

Emerging Blue Carbon Ecosystems

	MACROALGAE (SEAWEED & KELP)	MARINE SEDIMENTS	COASTAL MUD FLATS
Carbon Storage	 <p>Macroalgae (seaweed and kelp) are highly effective at sequestering carbon from the surrounding ocean via photosynthesis. This results in large areas of standing biomass with an estimated 87–127 million Mg C⁶ globally. In contrast to other coastal habitats, macroalgae release the majority (>75%) of their accumulated carbon into the ocean. Most of this released carbon is reabsorbed into the ocean, and hence not sequestered. But up to 10% of macroalgae carbon is transported by the ocean and buried in sediments on the continental shelf or deep-sea where it is effectively removed from the carbon cycle. Local oceanic conditions are the main factor determining how much macroalgae carbon is effectively sequestered. The largest rates of macroalgae carbon sequestration occur along kelp-dominated rocky coastlines close to canyons, fjords or with narrow continental shelves.</p>	 <p>Marine sediments across the ocean floor are one of the largest pools of organic carbon on Earth, storing 2322 Pg C in the top 1 m of depth⁷. This is the accumulation of millennia of carbon deposited in the oceans. If left undisturbed, marine sediment carbon will remain in place. If disturbed, these carbon deposits can be released into the ocean and, subject to appropriate oceanic conditions, may be transported to the surface and released into the atmosphere.</p>	 <p>Unvegetated mud flats are vast in extent, estimated to cover occupy at least 127,921 km² globally.⁸ Mud flats store sediments and carbon that originates from both marine and terrestrial sources and accumulates over time. Research is emerging as to the magnitude of carbon in mudflats. However, uncertainties remain as to the permanence of carbon held in mud flat sediments.</p>
Drivers of Loss	Ocean warming, coastal pollution, coastal development	Deep-sea trawling (fisheries), deep sea mining	Reclamation and land-conversion for coastal development, changes in hydrology and sediment input, colonization by invasive species, coastal erosion, and sea-level rise.

6 Howard et. al. (2017)
 7 Atwood et. al. (2020)
 8 Murray et. al (2019)

PHOTOS, LEFT TO RIGHT: Monterey, California, United States. © Keith A. Ellenbogen; A Queen Conch on white sand sea floor. Exuma Cays Land and Sea Park, Bahamas. © Jeff Yonover; The Wadden Sea in Schobüll in Germany. © manfredxy

	MACROALGAE (SEAWEED & KELP)	MARINE SEDIMENTS	COASTAL MUD FLATS
Annual Emissions from anthropogenic impacts	Unknown	Initial estimates of 1.47 Pg CO ₂ annually released into the ocean resulting from bottom trawling. ⁹ The fraction of this carbon reaching the upper ocean and atmosphere is currently unknown.	Unknown
Ecosystem management for carbon	<p>Conservation and restoration of macroalgae is possible if the drivers of loss can be addressed including water quality management and other approaches. If increasing water temperatures are the dominant driver of loss, restoration may not be possible.</p> <p>Conservation of the long-term carbon stores generated by macroalgae requires managing the integrity of the continental shelf and deep-sea locations where macroalgae carbon accumulates, which may be far from production sites.</p>	Marine sediment carbon can be maintained by reducing bottom trawling in areas of high marine sediment carbon through managing fishing fleets or implementing MPAs.	Ecosystem conservation (such as MPAs). Restoration of hydrology and sediment flows. Restoration might also be possible where mud flats have been converted to aquaculture or colonized by invasive species (<i>Spartina</i>).
Adaptation value	Coastal erosion control, food security (fisheries)	None	Coastal protection (wave attenuation)
Uncertainties	<p>There are significant scientific uncertainties as to the quantity, location and permanence of carbon stored by macroalgae ecosystems and the factors driving variability.</p> <p>The potential to scale macroalgae farming as a globally relevant (and manageable) carbon sink currently has many significant environmental, political, and engineering uncertainties.</p> <p>Efforts to sink seaweed in the deep sea as a means of ocean carbon removal should be paused until both the potential climate mitigation value and ecological impacts have been established.</p>	Significant uncertainties as to quantitative atmospheric impact of deep-sea trawling (i.e., how much of the disturbed ocean sediment carbon reaches the ocean surface) and the geographical and temporal variation in these emissions. Physical and biological factors driving variation in potential atmospheric emissions have not been well defined.	Impacts of reclamation and land conversion on emissions is unknown. Uncertainties in the permanence of carbon held in mud flat sediments and rates of sequestration.
Mitigation Policy/ Finance Implementation	<p>A number of countries have indicated an interest in including wild macroalgae conservation and/or macroalgae farming for mitigation in their NDCs.</p> <p>Methodologies for carbon credits are not available. Significant science is needed before such methodologies are viable.</p>	Currently not included in mitigation policy or financing mechanisms.	Currently not included in mitigation policy or financing mechanisms.

9 Sala et. al. (2020)

Other Ocean Ecosystems

	PHYTOPLANKTON	CALCIFYING ORGANISMS (CORAL REEFS, OYSTER REEFS)	MARINE FAUNA (FISH)
			
Carbon Storage	The estimated amount of phytoplankton carbon in the oceans is 0.5–2.4 billion Mg C. The size of the global phytoplankton carbon pool is relatively stable. Most phytoplankton are short lived and thus, carbon remains stored in their biomass only for hours to weeks. However, a small fraction of carbon in phytoplankton (0.1% or 0.5–2.4 million Mg C yr ⁻¹) will sink and become sequestered long-term in seafloor sediments.	Habitats dominated by calcifying organisms do not contribute to GHG mitigation, as the process of calcification releases CO ₂ and thus these ecosystems are likely to be net CO ₂ sources rather than sinks. Coral reefs and oyster reefs protect coastal wetlands during extreme events and thus may indirectly contribute to carbon sequestration by coastal wetland systems.	Rather than removing atmospheric carbon directly, fish, whales and other marine fauna accumulate carbon in their biomass. This carbon is later released back into the ocean through respiration and defecation. Most fish feces are rapidly consumed by bacteria, ultimately greatly limiting the carbon reaching the deep ocean. While increases in fish and macro fauna populations, and hence fish biomass, will result in increases in the fish biomass carbon pool, it is not clear if this change will result in any additional total ocean carbon sequestration as the carbon in the system is ultimately limited by phytoplankton primary productivity.
Drivers of Loss	Changing ocean temperatures, ocean circulation patterns	Ocean warming, ocean acidification, coastal development, coastal pollution, overfishing	Overfishing, coastal development, ocean warming, human disturbance
Annual Emissions from anthropogenic impacts	None	None	Negligible

PHOTOS, LEFT TO RIGHT: © Ilya Sviridenko; Atauro Island, Timor Leste. © Paul Hilton for Conservation International; A school of Yellowstripe Scads in tight formation Shot in Raja Ampat Islands, Airborek Jetty, Dampier Strait, West Papua Province, Indonesia. © Jeff Yonover

	PHYTOPLANKTON	CALCIFYING ORGANISMS (CORAL REEFS, OYSTER REEFS)	MARINE FAUNA (FISH)
Ecosystem management for carbon	<p>Despite representing a globally relevant carbon pool, phytoplankton are not well suited to climate mitigation policies because the ecosystem sequestration capacity cannot be manipulated without geoengineering.</p> <p>Fertilizing the ocean with iron to stimulate the production of phytoplankton biomass which then sinks into the deep ocean has been controversial mainly because there is no verifiable evidence that a significant carbon reaches the deep sea and because a range of adverse, unintended consequences have been identified.</p>	None	None
Adaptation value	None	Coastal protection from storms, sediment and erosion control, food security	Food security
Uncertainties	The effectiveness and ecological impacts of stimulating phytoplankton production via iron fertilization or other approaches is currently unknown.		The significance of fish and other marine fauna in increasing the amount of carbon transferred to the deep sea is not well established.
Mitigation Policy/Finance Implementation	Not eligible for existing policy and finance applications.	A number of countries have included reef management and conservation as <i>adaptation</i> actions within NDCs.	A number of countries have included fisheries management as <i>adaptation</i> actions within NDCs.

Resources for Blue Carbon

Incorporating Blue Carbon Ecosystems in National Greenhouse Gas Inventories:

2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. Methodological Guidance on Lands with Wet and Drained Soils, and Constructed Wetlands for Wastewater Treatment

This supplement extends the content of the 2006 IPCC Guidelines by providing updated science based on recent advances, and also added inland organic soils and wetlands on mineral soils, coastal wetlands including mangrove forests, tidal marshes and seagrass meadows and constructed wetlands for wastewater treatment.

Advice on Reporting Emissions and Removals from Management of Blue Carbon Ecosystems:

This resource has been developed to provide practical advice on incorporating coastal wetland ecosystems into National Greenhouse Gas Inventories by linking UNFCCC decisions related to coastal wetlands with existing IPCC guidance. It also illustrates how countries can apply principles outlined in the document by using examples of national experience.

Guidance for including Blue Carbon in Countries' NDCs:

The Blue Carbon and Nationally Determined Contributions: Guidelines on Enhanced Action

This resource includes technical guidance and lessons learned on how to incorporate blue carbon in NDCs, enabling countries to harness the national mitigation and adaptation benefits of coastal ecosystems.

Assessment of Blue Carbon in NDCs:

Coastal Blue Carbon Ecosystems: Opportunities for Nationally Determined Contributions

An assessment of blue carbon inclusion in the first Nationally Determined Contributions (NDCs) – 151 countries referred to at least one blue carbon ecosystem and 71 countries referred to all three in their initial NDC.

Coastal and marine ecosystems as Nature-based Solutions in new or updated Nationally Determined Contributions

A preliminary analysis of the first NDC revision cycle. As of June 2021, 33 out of 63 countries that have already submitted their new or updated NDC have included coastal and marine nature-based solutions (NbS). A final analysis of the first NDC revision cycle will be completed once all updated NDCs are submitted.

Advancing Oceans and Blue Carbon in the UN Climate Negotiations:

Unpacking the UNFCCC Global Stocktake for Ocean-Climate Action

This report provides an overview of the Global Stocktake and maps how the ocean and coastal ecosystems can be reflected.

Implementing Blue Carbon Credit Projects in Coastal Ecosystems:

Voluntary carbon market methodology for conservation and restoration activities in tidal wetland ecosystems – VM0007 REDD+ Methodology Framework (REDD+MF), v1.6

Verra recently produced this methodology for carbon crediting projects, including tidal wetland ecosystems defined as mangroves, tidal marshes, and seagrasses.

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