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NOAA Blue Carbon White Paper

Prepared on Behalf of the NOAA Cross-Line Office Blue Carbon Team

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Key Messages

- 'Blue carbon'—the ability of multiple ocean and coastal ecosystems to sequester and store significant amounts of carbon—is increasingly highlighted as a nature-based climate solution with multiple co-benefits for mitigation, adaptation, and resilience. Blue carbon has the potential to help countries pursue the goals of the Paris Agreement by providing a trackable mechanism for carbon sequestration and storage. In addition, a strong network of healthy **coastal blue carbon ecosystems**[1]—seagrasses, mangroves, and salt marshes—can protect coastal communities from storms, waves, erosion, and flooding; protect biodiversity; and provide ecosystem services that support livelihoods, culture, food security, water quality, recreation, and tourism. When coastal blue carbon ecosystems are degraded or lost, these benefits for mitigation and adaptation are reduced, and substantial amounts of stored carbon are released into the atmosphere.
- Among all marine carbon mitigation measures, coastal blue carbon ecosystems (mangroves, salt marshes, and seagrasses) offer potential for supportive management actions because of the advanced state of science, including guidelines provided by the Intergovernmental Panel on Climate Change (IPCC) for inclusion in National Greenhouse Gas Inventories (NGGI) (*1*). While coastal blue carbon habitats are some of the most efficient natural carbon sinks, their global emissions mitigation benefits are limited by their relatively small geographic coverage. Moreover, coastal ecosystems are increasingly threatened by dense human populations and associated pressures along the world's coasts. Despite these challenges associated with coastal blue carbon, given what we know about its significant carbon sequestration and other services, it remains an important tool in developing a holistic approach to confronting the climate crisis.
- Marine and coastal protected areas—like National Estuarine Research Reserves and National Marine Sanctuaries—offer important opportunities to protect and restore blue carbon by providing long-term conservation, and serving as focal points for research, education, and community engagement. Via networked research and monitoring, these areas also serve to strengthen our understanding and future application of blue carbon in conservation and management activities.
- Numerous countries already include blue carbon ecosystems in their Nationally Determined Contributions (NDC) as mitigation and/or adaptation measures, offering the potential for a common language and a suite of approaches to international monitoring and evaluation of methods. For countries with large areas of blue carbon habitat, conservation and restoration can offer an efficient means to offset greenhouse gas (GHG) emissions, and provide a pathway for climate finance.
- The National Oceanic and Atmospheric Administration (NOAA) has primarily focused on *coastal* blue carbon ecosystems, given the state of the science and mapping capabilities in coastal regions. NOAA and its partners are pioneering methods for quantifying coastal blue carbon within the National Estuarine Research Reserves, as an example. NOAA also supports the integration of coastal wetlands data into the Environmental Protection Agency (EPA)-led U.S. National GHG Inventory. NOAA shares its expertise and tools with individual states, and with other countries, to include blue carbon ecosystems within their GHG Inventories and 'natural and working lands (NWL)' policies, and to sustainably manage these habitats for their multiple benefits.
- Other ocean ecosystems, such as those containing macroalgae (including kelp, sargassum, and other seaweeds) and seabed sediments, as well as macroalgal aquaculture, are also known to sequester or store carbon at climate-relevant magnitudes (*2*), but the science is not yet sufficiently resolved to include them in broader climate management contexts (e.g., NGGIs, NDCs). NOAA has stewardship responsibilities for these ecosystems under various authorities, along with a suite of capabilities and expertise that could be applied to understanding and assessing the potential for marine carbon dioxide removal (mCDR) by these ecosystems and aquaculture.

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[1] This white paper primarily focuses on coastal blue carbon ecosystems—seagrasses, mangroves, and salt marshes—because this carbon is absorbed and stored in habitats that can be managed through existing laws and policy and that have adaptation and resilience co-benefits.

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What is Blue Carbon?
The term 'blue carbon,' in its broadest sense, can refer to the absorption and storage of atmospheric carbon dioxide by the ocean, marine habitats, and wild marine organisms. As a subset of blue carbon, NOAA has primarily focused on coastal blue carbon ecosystems—seagrasses, mangroves, and salt marshes—because this carbon is absorbed and stored in habitats that can be managed through existing laws and policy and that have adaptation and resilience co-benefits. Coastal blue carbon is carbon that is sequestered via photosynthesis and stored in coastal blue carbon ecosystems including salt marshes, mangroves, and seagrass beds. Coastal blue carbon ecosystems form deep, carbon-rich soils, and store carbon at a much greater rate per unit area than terrestrial habitats (*3*).

While coastal blue carbon habitats have been shown to sequester up to ten times as much carbon per equivalent area as tropical forests (*4*), making them some of the most efficient natural carbon sinks in the world, they cover only a relatively small portion (<1%) of the Earth's surface. In the United States, it is estimated that coastal blue carbon habitats sequester a net quantity of 4.8 million metric tons (MMT) of carbon dioxide annually, which represents less than 0.1% of the total annual U.S. carbon dioxide emissions of 5,000 MMT/year (*5*). Globally, existing coastal blue carbon ecosystems sequester approximately 100 MMT of carbon dioxide annually (*6*), corresponding to 0.25% of worldwide total carbon dioxide emissions of about 40,000 MMT/year (*7*).

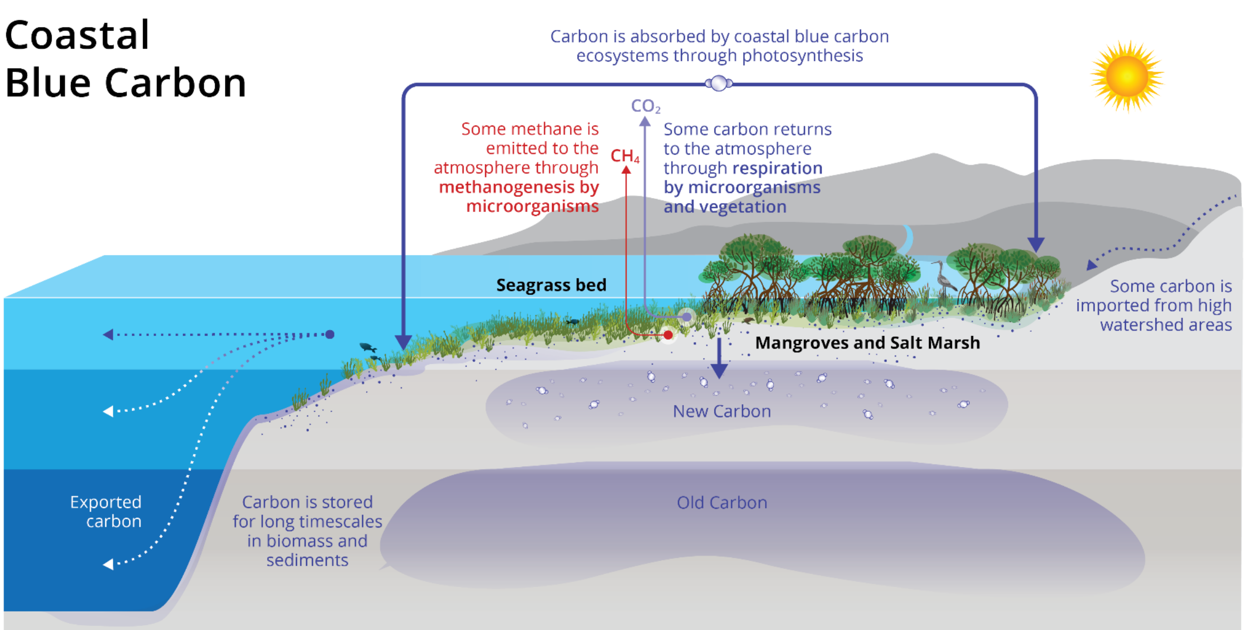

Figure: The fate of carbon in coastal blue carbon ecosystems (e.g., seagrasses, mangroves, and salt marshes).

Other coastal habitats are also being considered for their ability to facilitate carbon dioxide removal. For example, kelp forests are increasingly recognized as a blue carbon habitat, although they differ from coastal wetland blue carbon habitats in that carbon is not stored in sediments within the habitat. Instead, carbon is transported offshore and must sink to deep waters (deeper than 1,000 m), or be otherwise buried, in order to be sequestered for potentially centuries or millennia (*8, 9*). The inclusion of kelp and other macroalgae habitats into blue carbon accounting presents challenges, as the precise amount and location of carbon storage are difficult to determine.

Additional research is required to reliably include these habitats in GHG accounting and NDCs. Macroalgae farming (i.e., aquaculture) can also result in carbon sequestration in sediments below the farms and recent research has indicated that approximately 48 million km^2 (~6x the area of the contiguous United States) of open ocean are suitable for macroalgal aquaculture, however for the purposes of this paper, we are only considering wild primary producers as blue carbon.

Calcifying organisms such as corals and oysters are not considered blue carbon because the formation of calcium carbonate skeletons and shells releases carbon dioxide, and thus these organisms do not, on net, sequester carbon. However, as ecosystem engineers, these organisms play significant roles in coastal and estuarine systems (*10, 11*). These include improving water clarity and promoting seagrass expansion (*12*), preventing salt marsh erosion (*13*), removing nutrients (*9*), and trapping sediments that may allow for the storage of allochthonous carbon.

Habitats that store carbon, but do not actively sequester carbon dioxide from the atmosphere, also play a critical role in blue carbon processes. Ocean sediments are among the largest carbon reservoirs on Earth, storing an estimated 2,322,000 MMT carbon in the top meter alone, nearly twice that of terrestrial soils (*14*). If these sediments remain undisturbed, this carbon can be stored indefinitely. However, human activities such as dredging, trawling, and oil and mineral extraction are increasingly disturbing these sediments. Disturbance of shallow and coastal sediments could release the carbon stored in the sediments back into the atmosphere (*2*), although this is unlikely to happen with deep (>1000 m) sediment disturbance.

Blue Carbon for Mitigation, Adaptation, and Resilience

Coastal habitats around the world are being lost at a rapid rate, largely due to coastal development. Rising temperatures and sea level rise pose additional risks, as rapidly increasing inundation can drown these ecosystems. When coastal blue carbon habitats are damaged or destroyed, their carbon sequestration capacity is diminished or lost and previously stored carbon can be released (*15*). Global estimates suggest that 150 to 1,020 MMT (*16*) of carbon dioxide are being released annually due to blue carbon habitat loss, which represents 0.4–2.5% of the global anthropogenic carbon dioxide emissions of about 40,000 MMT (*7*).

Marine and coastal protected areas can be effective tools for protecting and restoring blue carbon ecosystems and their GHG mitigation functions. Restoring salt water flow into degraded coastal wetlands that have been tidally restricted due to human activity can reduce methane (a 25x more potent greenhouse gas than carbon dioxide) emissions. Measures to protect coastal wetlands from loss can be more cost effective than restoration of degraded blue carbon ecosystems (*17*).

From an adaptation and resilience perspective, because coastal blue carbon habitats protect shorelines from wave erosion and can reduce storm surge impacts to coastal communities, they are increasingly incorporated into natural and nature-based infrastructure approaches to coastal resilience. During 2012's Hurricane Sandy, coastal wetlands prevented $625 million in direct flood damages (*18*). Blue carbon habitats, including seagrasses, salt marshes, mangroves, kelp forests, and macroalgae farms, provide a diverse range of ecosystem services (*19*), including habitat for recreationally- and commercially-important fish species (*20*), nutrient removal and eutrophication mitigation, raw materials and food, sediment stabilization, and employment (*3*).

Within the U.S., several states are actively working to include blue carbon ecosystems within their GHG Inventories and 'natural and working lands (NWL)' policies. This opens the door for further coordination between state and federal agencies to improve science and management, including how kelp management and seaweed farming fits with NWL policies, recognizing their economic and employment opportunities.

Blue Carbon and Nationally Determined Contributions

The emissions mitigation and climate adaptation potential of the coastal blue carbon ecosystems seagrasses, mangroves, and salt marshes is recognized by the IPCC (*1*), paving the way for countries to include these ecosystems in national greenhouse gas inventories (NGGIs) and Nationally Determined Contributions (NDCs). Including coastal blue carbon in NGGIs is an important step in enabling their use in NDCs, which track plans and actions to combat climate change. To date, only a handful of countries have incorporated coastal blue carbon ecosystems in their NGGIs. The U.S. is among these countries and is working to extend this capability to developing countries in order to amplify the use of blue carbon as a nature-based climate solution on a global scale.

Numerous countries are identifying blue carbon as adaptation and/or mitigation measures in their NDCs. The flexibility of the NDC structure allows countries to use them to reflect the country's climate change commitments, including those related to adaptation, and to link to other policy frameworks such as National Adaptation Plans, Adaptation Communications, and domestic constructs such as Coastal Zone Management Plans (*21*). Incorporation of blue carbon in NDCs can range from a foundational recognition of the value of blue carbon to more specific targets/measures, and the approach varies from country to country depending on their needs and capabilities. For those with large areas of blue carbon habitat, conservation and restoration can offer an efficient means of reducing and offsetting greenhouse gas emissions and can therefore act as meaningful contributions to NDCs. However, as highlighted in the recent study by the National Academies of Sciences, Engineering, and Medicine, including blue carbon in NDCs is not a substitute for the reduction of emissions from other sectors of the economy, including agriculture, forestry, and other land uses (*22*).

The inclusion of blue carbon in NDCs can also be an important pathway for scoping and securing climate finance both domestically and internationally. For example, countries could design policies that create incentives for protecting and restoring blue carbon ecosystems, and signal to international funders a commitment to blue carbon as a nature-based climate solution. With targets and ambitions identified through NDCs, countries are looking for assistance in developing new funding and finance mechanisms. There is increasing interest from public and private sources seeking investment in blue carbon activities that can generate social, environmental, and financial benefits. However, a lack of projects at the scale to meet current demand is now a bottleneck to investment. The link between blue carbon, NDCs, and climate finance is an area of potential opportunity for enhancing nature-based climate solutions and requires more attention.

Current efforts are aiming to scale up blue carbon restoration. For example, Pakistan plans to reforest 1 billion mangroves within its Indus Delta, aided by voluntary carbon market mechanisms developed with funding and science contributions from U.S. federal agencies. Similar market mechanisms developed for sustainable seascapes, including seabed management and seaweed farming, coupled with guiding marine policies, could potentially result in a downdraw of 1 billion tons of carbon dioxide per year (*6*).

Future Directions for Blue Carbon

The U.S., working with international partners, is building on and connecting blue carbon science, engagement, policy, and management expertise to better support adaptation, mitigation, and resilience goals at the community, state, national, and international levels. With targeted investments and enhanced strategic partnerships, NOAA can: support a strong community of practice; advance a better understanding of carbon sequestration and the impact of habitat loss on GHG emissions; develop insights and guidance about where to prioritize future restoration investments; and generate more comprehensive and precise data on the presence and condition of coastal wetlands–particularly salt marsh communities and seagrass meadows. Investment in coastal blue carbon efforts now could improve U.S. coastal management, resulting in many co-benefits that support healthy coastal ecosystems, communities, and economies in the decades to come.

A large advancement in our ability to manage blue carbon and leverage its mitigation potential may come from increasing our understanding of “oceanic” blue carbon processes such as the magnitude and location of macroalgal and megafaunal carbon storage in deep ocean sediments. These processes could result in the significant accumulation of carbon in deep ocean (deeper than 100m) sediments and waters, where it can remain for thousands to millions of years. It is estimated that deep ocean sediments represent the largest non-fossil pool of organic carbon on the planet. However, the origin and rate of carbon export to these sediments is not well understood. While the carbon in deep sea sediments is not well quantified or monitored, the volume of carbon stored and long to indefinite storage horizon make this deep sea carbon important to climate mitigation strategies. A more complete understanding of the processes that lead to storage of carbon in the deep ocean will impact the feasibility of including it in carbon accounting exercises necessary for NDCs and carbon markets. Similarly, research is needed to better quantify the amount and fate of carbon exported from the coasts to the ocean, both to understand the amount of carbon being sequestered in shelf sediments and to identify the appropriate source area for management and carbon accounting. Greater quantification of the impacts of activities such as fishing, sediment disturbance, and environmental change, including sea level rise, on blue carbon is similarly necessary for a complete and accurate accounting of the national and global mitigation potential of blue carbon. Finally, focused interdisciplinary research (including social science), stakeholder engagement, and capacity building is needed to identify meaningful pathways to integrate blue carbon in community resilience strategies, including the consideration of tradeoffs, enhancing the link between NDCs and climate finance, and developing sustainable blue economies.

NOAA’s Role in Blue Carbon

NOAA plays a leadership role in advancing blue carbon as a nature-based climate solution through a broad suite of activities, including: scientific research, assessment, mapping, monitoring, and measurement; protection, restoration, and management of habitats important to fisheries and threatened/endangered species as well as coastal and marine protected areas; community stakeholder engagement and extension; climate adaptation and resilience research and capacity building at the community, state and international levels; integrating coastal blue carbon habitats into greenhouse gas inventories; and marine and coastal ecosystem management and policy. NOAA seeks to quantify carbon storage and sequestration in coastal blue carbon habitats, and examines how changes (e.g., sea level rise, increased nutrient availability, sediment deposition on salt marshes, and ecosystem restoration) alter the carbon sequestration and storage in these habitats.

Protected areas are linchpins for biodiversity conservation and climate resilience, and the U.S. is now engaged in a broad based initiative to conserve 30% of the nation’s lands and waters by 2030 (*23*). NOAA acts to preserve and restore blue carbon ecosystems through marine and coastal protected areas, such as the National Estuarine Research Reserves and National Marine Sanctuaries. These protected area systems provide a long-term legal and management framework for conservation and restoration of blue carbon habitats, as well as serve as focal points for research, education, and community engagement. The agency also supports restoration projects and grants through the NOAA National Marine Fisheries Service (NMFS), National Ocean Service (NOS), and Oceanic and Atmospheric Research (OAR). The NOAA National Environmental Satellite, Data, and Information Service (NESDIS) and other earth and ocean observing satellites contribute to global environmental observations needed for research, applications, and decision-making on blue carbon concerns (e.g., land cover/land use, sea surface temperature, and chlorophyll). NOAA supports cutting-edge science and research as well as federal policymaking and regulation to grow an ecologically and economically sustainable marine aquaculture industry in the United States that is compatible with blue carbon goals.

Utilizing data provided by the agency's Coastal Change Analysis Program (C-CAP), NOAA contributed to the first inclusion of coastal blue carbon in the EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks in 2017 (*5*). NOAA continues to support the coastal wetlands component of the U.S. greenhouse gas inventory, a process that positioned the agency to share this foundational information nationally and internationally through capacity building activities, including a recently established partnership between NOAA, the U.S. Department of State, and the EPA called the Blue Carbon Inventory (BCI) Project.

Partnerships with other Federal agencies, states, NGOs, countries, and international organizations are critical to NOAA's efforts to better understand and address the geographic distribution, temporal dynamics, condition of, and threats to blue carbon habitats, as well as their role as nature-based climate solutions with multiple co-benefits. For example, NOAA works closely with other Federal agencies, including the Environmental Protection Agency, the U.S. Geological Survey, the U.S. Department of Agriculture, the National Aeronautics and Space Administration, and the U.S. Department of State. Through these collaborations the agency has made significant contributions to coastal blue carbon science as well as to advancements in domestic and international blue carbon policy and management initiatives, including its role as a promising nature-based climate solution.

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