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Coastal Blue Carbon as a Carbon Dioxide Removal Approach: Selected Issues for Congress

August 5, 2024

Congressional Research Service
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R48148

CRS REPORT
Prepared for Members and
Committees of Congress

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Coastal Blue Carbon as a Carbon Dioxide Removal Approach: Selected Issues for Congress

SUMMARY

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Recent Congresses and Administrations have shown increased interest in the ability of certain coastal and marine ecosystems to reduce atmospheric carbon dioxide (CO_2) levels. According to the National Oceanic and Atmospheric Administration (NOAA), the ocean absorbs about 31% of global CO_2 emissions released into the atmosphere.

Coastal ecosystems provide benefits (also known as *ecosystem services*) to the human population, such as reducing coastal erosion and flooding and supporting recreation, tourism, and other activities. Certain coastal ecosystems—mangrove forests, tidal marshes, and seagrass meadows—naturally capture and store CO_2 (i.e., act as a carbon sink). Stakeholders have termed the CO_2 captured and stored in certain coastal ecosystems *coastal blue carbon*. Although coastal blue carbon ecosystems represent 1% of the ocean area, these ecosystems store an estimated 50% of all carbon stored in the ocean.

Some governments, including the U.S. government, have identified and accounted for the potential carbon dioxide removal (CDR) capacity of mangrove forests, tidal marshes, and seagrass meadows in national greenhouse gas (GHG) inventories and in *Nationally Determined Contributions*, voluntary actions a country pledges to take to reduce its carbon emissions under the Paris Agreement. However, the scientific community's understanding of the potential CDR capacity of coastal blue carbon ecosystems is incomplete. Research continues regarding these ecosystems' *carbon sequestration*, the rate at which the ecosystem can remove CO_2 from the atmosphere; *carbon storage*, the ecosystem's ability to store carbon and keep it from reentering the environment; and *durability*, the amount of time the ecosystem can store the carbon with a low risk of the carbon being reintroduced into the environment.

Stakeholders contend that improved mapping of coastal blue carbon ecosystems and additional research about the carbon stock and sequestration rates of mangrove forests, tidal marshes, and seagrass meadows are needed to better understand these ecosystems' current and potential CO_2 removal capacity. Mapping provides information about the present geographic coverage of a coastal blue carbon ecosystem. The ecosystem's geographic coverage, coupled with analysis of soil samples collected from the ecosystem, provides information about the sequestration and storage of the coastal blue carbon at the scale of study (e.g., local or regional). Coastal blue carbon ecosystems also may serve as GHG sources if they are degraded or lost due to human activities or natural causes. Several federal agencies (e.g., Department of Energy [DOE], National Aeronautics and Space Administration, NOAA, National Science Foundation, U.S. Geological Survey) support coastal blue carbon science related to mapping and estimating coastal blue carbon storage and sequestration, as well as coordinating and collaborating on these efforts. This information may inform policy decisions related to the conservation, restoration, and creation (or expansion) of coastal blue carbon ecosystems to preserve or grow their carbon sink capacity. Given competing priorities for a finite area of coastline, among other considerations, some stakeholders may question the relative priority of coastal blue carbon considerations in these areas.

Some Members of Congress have introduced legislation related to coastal blue carbon ecosystem mapping, carbon estimates, and federal research on the topic. In its deliberation of these bills, Members may consider providing additional direction to agencies, such as priorities for which ecosystems to map (e.g., seagrass meadows, tidal marshes), the scale at which these ecosystems should be mapped (e.g., state-level, regional, national), and the method for mapping (e.g., satellite or field-survey). Other bills would direct certain agencies (e.g., NOAA, DOE) to include monitoring, quantification, and verification of coastal CDR, as well as other marine CDR approaches, in their research activities. Congress also may debate how to best structure federal agency coordination and collaboration on coastal blue carbon science and the extent to which appropriated funding for coastal blue carbon science activities meet congressional goals.

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Coastal ecosystems provide benefits and services to the human population (known as *ecosystem services*).[1] One ecosystem service provided by certain coastal ecosystems is the ability to capture and store carbon dioxide (CO_2) from the atmosphere, thereby constituting a portion of the *global carbon cycle*.[2] Scientists have termed the CO_2 captured and stored in these ecosystems *coastal blue carbon*.[3] Coastal ecosystems that support coastal blue carbon—mangrove forests, tidal marshes,[4] and seagrass meadows[5]—are collectively referred to as *coastal blue carbon ecosystems*. In addition to helping reduce atmospheric CO_2 levels, coastal blue carbon ecosystems provide additional ecosystem services, such as providing habitat for aquatic, terrestrial, and avian species; filtering rainfall and terrestrial runoff; protecting coastal communities from erosion and flooding; dampening storm surge events; and supporting recreation, tourism, and other activities.[6]

Coastal blue carbon ecosystems can reduce the impact of rising CO_2 on the atmosphere by naturally taking in carbon.[7] Because the marine soils found in coastal blue carbon ecosystems can remove carbon from the atmosphere for hundreds to thousands of years, these ecosystems serve as an active natural carbon sink.[8] The National Oceanic and Atmospheric Administration (NOAA) estimates the amount of carbon stored in an average year by coastal ecosystems in the continental United States is about equal to the carbon emitted by 1.7 million cars and trucks annually.[9]

Some stakeholders contend that restoration or creation of coastal blue carbon ecosystems in certain areas may help remove more CO_2 from the atmosphere and mitigate climate change risks.[10] In general, the conservation, restoration, or creation of coastal blue carbon ecosystems as a carbon dioxide removal (CDR) approach is considered distinct from marine CDR (refer to the "Marine Carbon Dioxide Removal Approaches" textbox, below). The degradation and loss of coastal blue carbon ecosystems may return additional greenhouse gases (GHG)—including CO_2,

[1] National Academies of Sciences, Engineering, and Medicine (NASEM), "Chapter 2: Coastal Blue Carbon," in *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda* (Washington, DC: The National Academies Press, 2019), p. 70 (hereinafter referred to as NASEM, "Chapter 2: Coastal Blue Carbon").

[2] The *global carbon cycle* is the exchange, or flux, of carbon among the atmosphere, ocean, land surface, and living things. For an overview of the carbon cycle, see CRS Report R47214, *The Carbon Cycle: Key Component of the Climate System, with Implications for Policy*, by Jonathan D. Haskett.

[3] National Oceanic and Atmospheric Administration (NOAA), "Understanding Blue Carbon," September 29, 2022, https://www.climate.gov/news-features/understanding-climate/understanding-blue-carbon (hereinafter referred to as NOAA, "Understanding Blue Carbon").

[4] *Tidal marsh* includes *salt marsh*, often used interchangeably. However, not all tidal marshes are salt marshes. Tidal marshes lie more inland and have lower salinity levels than salt marshes but are still under a tidal influence. Some stakeholders include salt marshes (because marsh salinity influences greenhouse gas fluxes) as part of coastal blue carbon ecosystems, whereas other stakeholders include tidal marshes generally. For example, see Maria Fernanda Adame et al., "All Tidal Wetlands Are Blue Carbon Ecosystems," *BioScience*, vol. 74, no. 4 (April 2024), pp. 253-268.

[5] *Seagrass bed* is another commonly used term. This report uses the term *seagrass meadows* to refer to this type of coastal blue carbon ecosystem.

[6] Intergovernmental Panel on Climate Change (IPCC), "Chapter 3: Oceans and Coastal Ecosystems and Their Services," in *Climate Change 2022: Impacts, Adaptation and Vulnerability*, eds. Hans-Otto Pörtner et al., 2022, p. 464 (hereinafter referred to as IPCC, "Chapter 3: Oceans and Coastal Ecosystems"); and NASEM, "Chapter 2: Coastal Blue Carbon," p. 48.

[7] NOAA, "Fast Facts: Blue Carbon," https://coast.noaa.gov/states/fast-facts/blue-carbon.html.

[8] NOAA, "Protecting Coastal Blue Carbon Through Habitat Conservation," https://www.fisheries.noaa.gov/national/habitat-conservation/protecting-coastal-blue-carbon-through-habitat-conservation.

[9] NOAA, "Digital Coast Program Gets 'Blue Carbon' Added to U.S. Emissions Inventory," https://coast.noaa.gov/states/stories/digital-coast-program-gets-blue-carbon.html.

[10] For example, Nathalie Hilmi et al., "The Role of Blue Carbon in Climate Change Mitigation and Carbon Stock Conservation," *Frontiers in Climate*, vol. 3 (2021), pp. 1-18.

methane, and nitrous oxide—to the atmosphere. Human activities and natural causes may contribute to the alteration of coastal blue carbon ecosystems.[11] Coastal blue carbon ecosystem alteration also may affect other ecosystem services, such as species' habitat and use.[12] To prevent the degradation of coastal blue carbon ecosystems and to maintain their ecosystem services, including their ability to act as a carbon sink, various stakeholders have advocated for the protection, conservation, sustainable management, and restoration of these ecosystems.[13]

The executive branch and some Members of Congress have increasingly turned their attention to coastal blue carbon to mitigate increases in atmospheric CO_2 concentrations due to human-caused emissions. For example, the Biden Administration's *Ocean Climate Action Plan* stated that the sustainable management of coastal blue carbon ecosystems can reduce emission of GHGs while providing other co-benefits.[14] The United States incorporates blue carbon and coastal resiliency projects in its *Nationally Determined Contribution* (NDC),[15] voluntary action a country pledges to take to reduce its carbon emissions under the Paris Agreement.[16] Some Members have shown interest in conserving and restoring coastal blue carbon ecosystems and have introduced legislation in the 117th and 118th Congresses directing certain federal agencies to conduct and support research aimed at estimating the potential CDR capacity of mangrove forests, tidal marshes, and seagrass meadows, among other related activities.[17]

This report focuses on coastal blue carbon and discusses the ecosystems that support it. The report also discusses the outstanding research gaps in understanding, conserving, and restoring existing coastal blue carbon ecosystems as well as creating new coastal blue carbon ecosystems as a CDR approach. In addition, the report describes the federal government's role in coastal blue carbon science and considerations for Congress, including outstanding research needs, coordination among federal agencies, federal and nonfederal collaboration, and funding for coastal blue carbon-related activities.

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[11] For example, see National Aeronautics and Space Administration (NASA), "Mapping the Roots of Mangrove Loss," https://earthobservatory.nasa.gov/images/147142/mapping-the-roots-of-mangrove-loss.

[12] For example, the U.S. Fish and Wildlife Service (FWS) identified that manatees along the Atlantic Coast of Florida have experienced a large and ongoing mortality event associated with the loss of seagrass meadows and other environmental factors. FWS, *Budget Justification and Performance Information Fiscal Year 2025*, p. ES-23.

[13] For example, NOAA, "Coastal Wetland Habitat," https://www.fisheries.noaa.gov/national/habitat-conservation/coastal-wetland-habitat.

[14] White House Ocean Policy Committee, *Ocean Climate Action Plan: A Report by the Ocean Policy Committee*, March 2023, p. 47. Hereinafter referred to as White House Ocean Policy Committee, *Ocean Climate Action Plan*.

[15] After rejoining the Paris Agreement, the United States submitted its Nationally Determined Contribution (NDC) to the U.N. Framework Convention on Climate Change (UNFCCC) secretariat on April 22, 2021. See *The United States of America Nationally Determined Contribution: Reducing Greenhouse Gases in the United States: A 2030 Emissions Target*, April 21, 2021, p. 5, https://unfccc.int/sites/default/files/NDC/2022-06/United%20States%20NDC%20April%2021%202021%20Final.pdf. The Paris Agreement is a subsidiary agreement to the UNFCCC, which the United States ratified in 1992. For more information, see CRS Report R46204, *The United Nations Framework Convention on Climate Change, the Kyoto Protocol, and the Paris Agreement: A Summary*, by Richard K. Lattanzio.

[16] In 2013, the IPCC released guidance for how countries participating in the Paris Agreement should account for coastal blue carbon in their NDCs. NOAA, "Understanding Blue Carbon."

[17] For example, H.R. 5457, H.R. 2950, S. 1381, and S. 2812 in the 118th Congress and H.R. 843, H.R. 2750, H.R. 3764, S. 8013, and S. 3245 in the 117th Congress.

Marine Carbon Dioxide Removal Approaches

The Intergovernmental Panel on Climate Change's *Sixth Assessment Report* and the U.S. Global Change Research Program's *Fifth National Climate Assessment* identified that carbon dioxide removal (CDR) approaches are likely to be needed to mitigate rising atmospheric carbon dioxide (CO_2) and the impacts of climate change, in addition to an energy transition. Scientists have investigated how certain coastal ecosystems may mitigate rising atmospheric CO_2 levels by storing carbon in coastal vegetation and soils (i.e., *coastal blue carbon*) as well as how marine CDR (mCDR, also referred to as ocean or ocean-based CDR) approaches may augment the ocean's ability to take up atmospheric CO_2 in coastal and open water environments.

mCDR approaches are generally categorized as (1) those that increase the growth of marine plants to sequester CO_2 through marine *biological pathways* and (2) those that enhance ocean *alkalinity* (i.e., the ocean's ability to resist pH changes) in order to absorb more CO_2 through marine *chemical pathways*. The National Oceanic and Atmospheric Administration (NOAA) has developed a strategy for CDR research that includes and land-based approaches, ocean-based approaches, and coastal approaches (i.e., coastal blue carbon).

The mCDR approaches that augment marine biological pathways are as follows:

- *Biological Carbon Pump Enhancement* stimulates primary producers (i.e., microalgae) to take up CO_2 from the surface water. Once dead, the primary producers sink into the ocean, transporting carbon out of the surface ocean. A small portion of this carbon may be buried in ocean sediments. For more information about ocean fertilization, see CRS Report R47172, *Geoengineering: Ocean Iron Fertilization*, by Caitlin Keating-Bitonti.
- *Macroalgal Cultivation for Carbon Sequestration* uses fast-growing marine plants to take up CO_2 from surface waters through photosynthesis. Once dead, these plants must sink and be buried in ocean sediments for decades or longer to be an effective CDR approach.

The mCDR approaches that augment marine chemical pathways are as follows:

- *Direct Ocean Removal* uses technologies to remove and capture CO_2 directly from the ocean water by changing the pH of the treated water. The treated (decarbonized) water is returned to the ocean, where it can absorb more CO_2 from the environment.
- *Ocean Alkalinity Enhancement* increases seawater alkalinity to enhance the ocean's ability to absorb more atmospheric CO_2. This approach also has the co-benefit of mitigating *ocean acidification*. For more information about ocean acidification, see CRS Report R47300, *Ocean Acidification: Frequently Asked Questions*, by Caitlin Keating-Bitonti and Eva Lipiec.

In addition to mCDR and coastal blue carbon as a CDR approach, some experts have considered the natural ability of marine animals, such as fish, whales, and zooplankton, to take up carbon and "pump" it to the deep ocean (via the settling of feces and dead animal carcasses; e.g., whale fall). The transport of this carbon to the deep ocean and sediments would remove the carbon from the atmosphere for tens to hundreds of years due to the amount of time for ocean water mixing and circulation. Although some experts propose that collective carbon in these animals could be increased through protection and restoration of marine ecosystems (i.e., *wild blue biomass*) and through aquaculture (i.e., *farmed blue biomass*), its potential contribution to carbon mitigation efforts remains not completely understood.

Sources: Jessica N. Cross et al., *Strategy for NOAA Carbon Dioxide Removal Research: A White Paper Documenting a Potential NOAA CDR Science Strategy as an Element of NOAA's Climate Interventions Portfolio*, NOAA Special Report, May 2023; S. J. Davis et al., "Chapter 32: Mitigation," in *Fifth National Climate Assessment*, eds. A. R. Crimmins et al., (Washington, DC), 2023, p. 32-21; Intergovernmental Panel on Climate Change, "Chapter 3: Oceans and Coastal Ecosystems and Their Services," in *Climate Change 2022: Impacts, Adaptation and Vulnerability*, eds. Hans-Otto Pörtner et al., 2022, p. 464; J. J. Middleburg et al., "Understanding Alkalinity to Quantify Ocean Buffering," *Eos*, July 29, 2020, https://eos.org/editors-vox/understanding-alkalinity-to-quantify-ocean-buffering; and NOAA, "New System Uses Seawater to Capture and Store CO_2," https://research.noaa.gov/2023/09/08/new-system-uses-seawater-to-capture-and-store-co2/.

Use of Coastal Blue Carbon as a Carbon Dioxide Removal Approach

To determine the full potential of a system to take up and store carbon from the atmosphere, experts estimate the system's carbon storage and sequestration capacity and how long the system can keep the carbon from reentering the atmosphere. Coastal blue carbon ecosystems' capacity to sequester and store carbon is based on the ecosystems' condition. Carbon storage, sequestration, and durability are factors used to evaluate a CDR approach.

- *Carbon storage* refers to a system's ability to store carbon and keep it from reentering the environment.[18] Carbon storage is measured as the total carbon content of a carbon stock. A *carbon stock* (or *carbon pool*) is a system that has the capacity to store or release carbon. The coastal blue carbon stock is composed of the carbon stored in vegetated ecosystems, such as mangrove forests, tidal marshes, and seagrass meadows.
- *Carbon sequestration* refers to the process of removing CO_2 from the atmosphere and storing it in carbon stocks.[19] Carbon sequestration is measured as a rate of carbon uptake per year.
- The *durability* of a carbon stock refers to the amount of time the system can store carbon with a low risk that the removed carbon will be reintroduced into the environment (e.g., by a natural disaster)."[20]

For several reasons, there is growing interest in the use of coastal blue carbon as a CDR approach. First, while coastal blue carbon ecosystems represent less than 2% of global ocean area, their sediments bury about 50% of all carbon stored in the ocean.[21] Second, these ecosystems sequester and store carbon at much higher rate per unit area than terrestrial ecosystems.[22] According to the *Fifth National Climate Assessment*, "Acre for acre, [coastal ecosystems such as mangroves, tidal marshes, and seagrass meadows] are estimated to store about twice as much carbon belowground than terrestrial vegetation."[23] Coastal blue carbon ecosystems primarily store carbon in marine soils, whereas forests primarily store carbon in above-ground plant material. Above-ground plant material is more susceptible to natural and human disturbances (e.g., fire), which release carbon into the atmosphere.[24] Third, NOAA estimates the conservation, sustainable management, and restoration of coastal blue carbon ecosystems to have a lower cost per ton of CO_2 removed when compared with other CDR approaches that rely on modifying marine biological and chemical pathways.[25] Fourth, coastal blue carbon ecosystems provide additional co-benefits to coastal communities, including protection from storm surges and hurricane events, soil retention, biodiversity, and prevention of salt water intrusion.[26]

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[18] NOAA, "Coastal Blue Carbon," https://oceanservice.noaa.gov/ecosystems/coastal-blue-carbon/.

[19] Ibid.

[20] Cross et al., *Strategy for NOAA Carbon Dioxide Removal Research*, p. 20.

[21] For example, Carlos M. Duarte et al., "Major Role of Marine Vegetation on the Oceanic Carbon Cycle," *Biogeosciences*, vol. 2 (2005), pp. 173-180, see p. 178.

[22] Cross et al., *Strategy for NOAA Carbon Dioxide Removal Research*, p. 45.

[23] Christine L. May, "Focus on Blue Carbon," in *Fifth National Climate Assessment*, eds. Allison R. Crimmins et al. (Washington, DC: U.S. Global Change Research Program, 2023), p. F5-3. Hereinafter referred to as NCA5, "Focus on Blue Carbon."

[24] Peter I. Macreadie et al., "Blue Carbon as a Natural Climate Solution," *Nature Reviews Earth & Environment*, vol. 2 (2021), p. 826. Hereinafter referred to as Macreadie et al., "Blue Carbon as a Natural Climate Solution."

[25] Coastal blue carbon is estimated to cost $10-$50 per ton of CO_2 removed. Cross et al., *Strategy for NOAA Carbon Dioxide Removal Research*, p. 22.

[26] For instance, ocean alkalinity enhancement, a marine CO_2 removal approach, has a co-benefit of mitigating ocean acidification. Seagrass meadows also have been shown to buffer against ocean acidification. Ocean acidification can harm certain marine species and impact coastal fisheries and food supply for humans. Cross et al., *Strategy for NOAA Carbon Dioxide Removal Research*, p. 39. For more information about ocean acidification, see CRS Report R47300, *Ocean Acidification: Frequently Asked Questions*, by Caitlin Keating-Bitonti and Eva Lipiec.

Conversely, there are several challenges associated with coastal blue carbon as a CDR approach. These challenges include establishing a scientific understanding of baseline natural carbon fluxes in these ecosystems, accounting for possible natural or anthropogenic disturbances of the carbon stock, and identifying sufficient coastal area to provide ecosystem benefits through conservation, restoration, and creation efforts.[27]

Coastal Blue Carbon Ecosystems

For coastal ecosystems to effectively sequester and store large amounts of carbon, they need to have rooted vegetation that is under a tidal influence.[28] The frequent (if not near-constant) flooding of these ecosystems, coupled with salty water, lowers oxygen levels, making it difficult for microorganisms to break down plant material.[29] These conditions allow carbon to accumulate rather than be released into the atmosphere. Three ecosystems that support such sequestration and storage are mangrove forests, tidal marshes, and seagrass meadows (**Figure 1**):

- Mangrove forests are composed of salt-tolerant trees or shrubs that grow in the intertidal zones (i.e., the area between land and sea) of tropical, subtropical, and warm temperate regions.[30]
- Tidal marshes are coastal marine wetlands with deep soils composed of mud and peat (i.e., a thick layer of decomposing plant material) that are flooded by tides.[31]
- Seagrass meadows are composed of submerged flowering plants (not seaweed) with deep roots occurring in salty and brackish shallow coastal waters.[32]

Plants remove CO_2 from the atmosphere via photosynthesis. The absorbed carbon is incorporated into the plant, increasing the plant's biomass. In coastal blue carbon ecosystems, plants sequester carbon in their biomass throughout their total lifespan, typically tens to hundreds of years.[33] When a plant dies, carbon from the plant is deposited in coastal marine soils and sediments.[34] Marine soils and sediments also can collect carbon derived from other areas in the watershed

[27] Nadine Mengis et al., "Counting (on) Blue Carbon—Challenges and Ways Forward for Carbon Accounting of Ecosystem-Based Carbon Removal in Marine Environments," *PLOS Climate*, vol. 2, no. 8 (2023), p. e0000148; and Read Porter et al., "Legal Issues Affecting Blue Carbon Projects on Publicly-Owned Coastal Wetlands," Restore America's Estuaries and the Marine Affairs Institute, February 2020, https://estuaries.org/wp-content/uploads/2022/06/Legal-Issues-Affecting-Blue-Carbon-Projects.pdf.

[28] IPCC, "Chapter 3: Oceans and Coastal Ecosystems", p. 464.

[29] NOAA, "Coastal Blue Carbon," https://oceanservice.noaa.gov/ecosystems/coastal-blue-carbon/.

[30] Macreadie et al., "Blue Carbon as a Natural Climate Solution," p. 827.

[31] The salinity level of a marsh is negatively correlated to methane emissions (methane emissions tend to decrease as salinity increases) and can influence whether a particular marsh acts as a net carbon sink (sequestering more carbon than it emits) or source (emitting more carbon than it sequesters). Email correspondence from the Nicholas Institute for Energy, Environment & Sustainability, Duke University, to CRS, July 3, 2024; and NOAA, "What Is a Salt Marsh?," https://oceanservice.noaa.gov/facts/saltmarsh.htm.

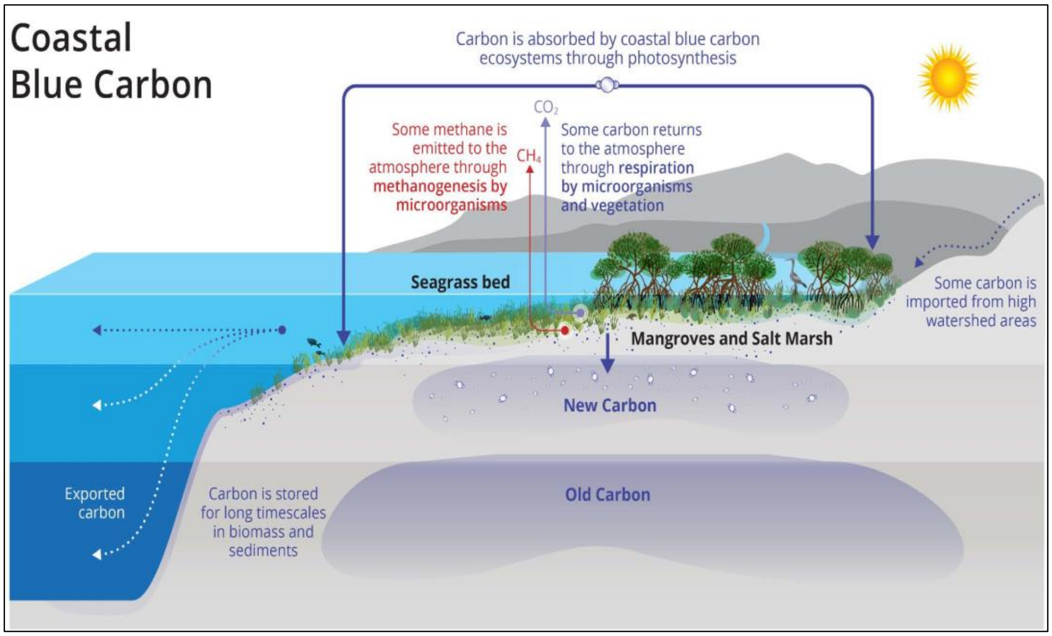
[32] Smithsonian Institution, "Seagrasses and Seagrass Beds," https://ocean.si.edu/ocean-life/plants-algae/seagrass-and-seagrass-beds.

[33] Elizabeth Mcleod et al., "A Blueprint for Blue Carbon: Toward an Improved Understanding of the Role of Vegetated Coastal Habitats in Sequestering CO_2," *Frontiers in Ecology*, vol. 9, no. 10 (June 2011), p. 554. Hereinafter referred to as Mcleod et al., "Blueprint for Blue Carbon."

[34] NASEM, *Coastal Blue Carbon Approaches*, p. 2. In general, *soils* are characterized by a depth profile (known as horizons) reflecting the products of in situ weathering and are capable of supporting vegetation. *Sediments* are unconsolidated particles that have been removed from the place where they were originally weathered and redeposited elsewhere. Sediments can subsequently be weathered in situ to produce soils. See, "Soils, Sediments, and Geomorphology," in *The Archaeologist's Laboratory. Interdisciplinary Contributions to Archaeology*, eds. M. A. Jochim and R. S. Dickens (Boston, MA: Springer), p. 235, doi.org/10.1007/0-306-47654-1_12.

(**Figure 1**). Because the soils of coastal blue carbon ecosystems generally are anaerobic (i.e., containing little to no oxygen),[35] the accumulated carbon in plant material decomposes very slowly and can remain in the soil (i.e., stay out of the atmosphere) for hundreds to thousands of years.[36] Local factors such as ocean circulation, temperature, nutrients, and light can alter the amount and timescale of carbon storage in the soil.[37]

Figure 1. Coastal Blue Carbon Sequestration and Storage



Source: Jessica N. Cross et al., *Strategy for NOAA Carbon Dioxide Removal Research: A White Paper Documenting a Potential NOAA CDR Science Strategy as an Element of NOAA's Climate Interventions Portfolio*, NOAA Special Report, May 2023, p. 46.

Notes: CO_2 = carbon dioxide; CH_4 = methane. The figure illustrates how carbon is incorporated into plant biomass via *photosynthesis* and carbon returns to the atmosphere via *respiration* (Jörg Kruse et al., "Chapter 7: Soil Respiration and Soil Organic Matter Decomposition in Response to Climate Change," in *Developments in Environmental Science*, eds. R. Matyssek et al., (2013), pp. 131-149). Carbon also is imported by terrestrial runoff from high watershed areas and accumulates in the soils of the coastal blue carbon ecosystems.

Globally, these three ecosystems collectively occur as far north as Alaska and as far south as southern Australia.[38] The United States is 1 of 71 countries that have all three coastal blue carbon ecosystems.[39] The United States has one of the largest areas of seagrass meadows and tidal marshes in the world.[40] Coastal ecosystems associated with the Florida Everglades, San Francisco Bay, and Chesapeake Bay have potentially high carbon removal capacity and rates, according to scientists.[41]

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[35] Macreadie et al., "Blue Carbon as a Natural Climate Solution," p. 826.

[36] Cross et al., *Strategy for NOAA Carbon Dioxide Removal Research*, p. 45.

[37] Mcleod et al., "Blueprint for Blue Carbon," p. 555.

[38] NOAA, "Understanding Blue Carbon."

[39] D. Herr and E. Landis, *Coastal Blue Carbon Ecosystems. Opportunities for Nationally Determined Contributions. Policy Brief*, The Nature Conservancy and International Union for Conservation of Nature, 2016, p. 6, https://www.nature.org/content/dam/tnc/nature/en/documents/BC_NDCs_FINAL.pdf.

[40] Ibid., pp. 829-830.

[41] NCA5, "Focus on Blue Carbon," p. F5-3.

Estimating Carbon Stocks and Sequestration in Coastal Blue Carbon Ecosystems

Estimates of the potential carbon removal capacity of coastal blue carbon ecosystems vary significantly because scientific understanding of how such removal works is uncertain.[42] To determine the potential carbon removal capacity of coastal blue carbon ecosystems and these ecosystems' contributions to climate mitigation efforts, scientists would need to measure the carbon stock and carbon burial rates (sequestration), as well as accurately map the geographic coverage, of existing coastal blue carbon ecosystems.[43]

Estimating Carbon Stock and Carbon Sequestration

Scientists estimate the carbon stock of a coastal blue carbon ecosystem by taking a vertical soil or sediment core (**Figure 2**) from a study site within the ecosystem. A vertical soil or sediment core reflects the carbon stock across a period of time at the site, with the surface layer reflecting the present-day accumulation of carbon material and the deeper layers reflecting older buried material. A sample collected from a specific depth in a vertical soil profile or sediment core represents the carbon stock at a specific point in time at the study location. Analyses of multiple samples taken from a core coupled with an age dating technique (e.g., *isotopic analysis*[44]) provides information about the rate of carbon burial, which may be extrapolated to estimate annual carbon sequestration rates of coastal blue carbon ecosystems (**Table 1**).

[42] Mcleod et al., "Blueprint for Blue Carbon," p. 554; and NOAA, "Understanding Blue Carbon."

[43] NASEM, "Chapter 2: Coastal Blue Carbon," p. 48; and Macreadie et al., "Blue Carbon as a Natural Climate Solution," p. 827.

[44] *Isotopes* are members of a family of an element that all have the same number of protons but different numbers of neutrons. Some isotopic analyses can be used as radiometric dating methods. For example, "radiocarbon dating uses the decay of a radioactive isotope of carbon [carbon-14, made up of 6 protons and 8 neutrons] to measure time and date objects containing carbon-bearing material" (Irka Hajdas et al., "Radiocarbon Dating," *Nature Reviews Methods Primers*, vol. 1, no. 62 [September 9, 2021], pp. 1-26). Radiocarbon dating is a useful tool for determining the age of a specimen formed over the past 55,000 years. Department of Energy (DOE), "DOE Explains…Isotopes," https://www.energy.gov/science/doe-explainsisotopes.

Figure 2. Coastal Tidal Marsh Soil Core

Source: Photo by Genevieve Noyce, Smithsonian Environmental Research Center (SERC), "As Sea Level Rises, Wetlands Crank Up Their Carbon Storage," March 9, 2019, https://www.si.edu/newsdesk/releases/sea-level-rises-wetlands-crank-their-carbon-storage.

Notes: A vertical soil core collected from a Chesapeake Bay tidal marsh, located at SERC's Global Change Research Wetland. The surface layer (leftmost part of the core) reflects the present-day accumulation of carbon material and the deeper layers reflects older buried material. Scientists study vertical soil cores collected from coastal blue carbon ecosystems to estimate carbon stock and carbon sequestration rates.

Some scientists have used remote sensing technologies to analyze the carbon stock of wetland ecosystems.[45] These technologies provide an alternative method that is less time-consuming, labor-intensive, and costly compared with traditional field methods to quantify carbon stock from soil and sediment samples. Remote sensing technologies also may be applicable to coastal blue carbon ecosystems.

Several studies have estimated the global annual carbon sequestration rates for mangrove forests, tidal marshes, and seagrass meadows (see **Table 1**). Estimates of global annual sequestration rates vary across the selected studies included in **Table 1**. In addition, some of these estimates span an order of magnitude. The variability in the global annual sequestration rates draws into question the ability to estimate the potential carbon removal capacity of coastal blue carbon ecosystems. Accurate estimates may contribute to stakeholders' understanding of these ecosystems as a carbon sink and may inform decisionmakers deliberating the conservation, restoration, and creation of coastal blue carbon ecosystems as a CDR strategy.

Table 1. Estimates of Global Geographic Coverage and Annual Carbon Sequestration Rates of Coastal Blue Carbon Ecosystems

Study	Geographic Area (millions of ha)	Annual Carbon Sequestration Rate (Mt C per year)
Mangrove Forests		
Christianson et al., 2022	8.3	93
IPCC, 2022	13.7	41

[45] For example, Liangguan Jia et al., "Prediction of Wetland Soil Carbon Storage Based on Near Infrared Hyperspectral Imaging and Deep Learning," *Infrared Physics & Technology*, in press (April 6, 2024).

Study	Geographic Area (millions of ha)	Annual Carbon Sequestration Rate (Mt C per year)
NASEM, 2017 (Mcleod et al., 2011)	13.8	31-34
Tidal Marshes		
Christianson et al., 2022	5.5	12-103
IPCC, 2022	5.5	13
NASEM, 2017 (Mcleod et al., 2011)	2.2-40.0	5-87
Seagrass Meadows		
Christianson et al., 2022	16.0	35-76
IPCC, 2022	16.0	35
NASEM, 2017 (Mcleod et al., 2011)	17.7-60.0	48-112

Sources: Anne B. Christianson et al., "The Promise of Blue Carbon Climate Solutions: Where the Science Supports Ocean-Climate Policy," *Frontiers in Marine Science*, vol. 9 (2022); Intergovernmental Panel on Climate Change (IPCC), "Chapter 3: Oceans and Coastal Ecosystems and Their Services," in *Climate Change 2022: Impacts, Adaptation and Vulnerability*, eds. Hans-Otto Pörtner et al., 2022, p. 464; and National Academies of Sciences, Engineering, and Medicine (NASEM), "Chapter 2: Coastal Blue Carbon," in *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda* (Washington, DC: The National Academies Press, 2019), p. 70.

Notes: ha = hectares (100 meters x 100 meters); Mt C = million metric tons (each metric ton is 1,000 kilograms) of carbon. The NASEM report uses estimates of the geographic areas and carbon burial rates published by Elizabeth Mcleod et al., "A Blueprint for Blue Carbon: Toward an Improved Understanding of the Role of Vegetated Coastal Habitats in Sequestering CO_2," *Frontiers in Ecology*, vol. 9, no. 10 (June 2011), pp. 552-560, see p. 555.

Mapping Coastal Blue Carbon Ecosystems

Federal agencies, academic researchers, and nongovernmental organizations map coastal blue carbon ecosystems or provide funding to support mapping activities. Federal agencies that map or fund mapping efforts include the Federal Emergency Management Agency (FEMA), National Aeronautics and Space Administration (NASA), NOAA, National Park Service, National Science Foundation (NSF), U.S. Army Corps of Engineers (USACE), U.S. Fish and Wildlife Service (FWS), and U.S. Geological Survey (USGS).[46]

The geographic coverage of coastal blue carbon ecosystems can be estimated through field mapping surveys, analysis of aerial and satellite imagery, or a combination of these approaches. The approaches have different advantages and drawbacks. For example, field mapping can provide detailed, accurate, and reliable information about the coverage of an ecosystem, and these mapping efforts can be both time intensive and costly. Field mapping studies also tend to have a narrower geographic scope compared with studies that use aerial and satellite imagery to map larger areas. Some stakeholders contend that analysis of aerial and satellite imagery provides a more cost-effective, efficient alternative to field mapping,[47] and USGS researchers have

[46] For more information about the U.S. government's role in coastal and ocean mapping, see CRS Report R47623, *Frequently Asked Questions: Mapping of U.S. Ocean and Coastal Waters*, coordinated by Caitlin Keating-Bitonti.

[47] For example, U.S. Geological Survey (USGS), "Case Study: Monitoring Coastal Change via Satellite Imagery at Regional Scale in the Pacific Northwest," March 21, 2024, https://www.usgs.gov/programs/cmhrp/news/case-study-monitoring-coastal-change-satellite-imagery-regional-scale-pacific.

demonstrated that satellite imagery can be used to accurately and reliably map coastal ecosystems.[48] At the same time, the instruments required to map coastal blue carbon ecosystems at the necessary spatial resolution to differentiate between vegetation types may be a part of few satellites that have competing research uses.[49] In addition, new technology used for Earth observations, such as high-resolution imagery for coastal blue carbon mapping, can be costly and may take years to launch into space. Some stakeholders contend that uncrewed aerial vehicles (i.e., drones) may have greater flexibility compared with satellites. For example, as remote sensing technologies evolve, sensors may be updated or replaced more easily on drones.[50]

Collectively, coastal blue carbon ecosystems are estimated to cover 36-185 million hectares globally (or 89-457 million acres).[51] Incomplete mapping, low-quality mapping data, or outdated maps, among other factors, limit scientists' ability to more accurately estimate the areal coverage of these ecosystems (see **Table 1**). Of the three coastal blue carbon ecosystems, the geographic extent of mangrove forests is better known than that of tidal marshes and seagrass meadows.[52]

Estimating the Capacity of Coastal Blue Carbon Ecosystems to Store and Sequester Carbon

Researchers couple carbon stock and sequestration data with estimates of coastal blue carbon ecosystems' geographic coverage to estimate the potential carbon removal capacity of these ecosystems. Some experts have estimated that the coastal blue carbon ecosystems of the United States, Australia, and Indonesia have the largest potential carbon removal capacity due to their long coast lines (**Figure 3**).[53] Some Asian countries are estimated to have large potential carbon removal capacity because they contain large areas of mangrove forests and seagrass meadows.[54] Mangrove forests have high carbon removal capacity relative to seagrass meadows, because mangrove trees store carbon in both their wood and their leaves in addition to accumulating carbon in the soils in which they grow. Although seagrass meadows have lower carbon removal capacity than mangrove forests and tidal marshes, seagrass meadows are estimated to have the greatest global areal coverage of the three coastal blue carbon ecosystems.[55]

Estimates of the capacity of coastal blue carbon ecosystems to store and sequester carbon may vary widely for two reasons. First, carbon stock and carbon sequestration rates are not uniform and may vary within a specific coastal blue carbon ecosystem due to variations in salinity, terrestrial nutrient runoff, and the diversity and density of the vegetation, among other factors.[56]

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[48] Ibid.

[49] Some propose a spatial resolution of 0.5 to 5 meters. For example, European Space Agency, "Coastal Blue Carbon," https://eo4society.esa.int/projects/coastal-blue-carbon/.

[50] Dana Lanceman et al., "Blue Carbon Ecosystem Monitoring Using Remote Sensing Reveals Wetland Restoration Pathways," Frontiers in Environmental Science, vol. 10 (2022).

[51] The large range is due to uncertainties in the distribution of seagrass meadows and tidal marshes. Macreadie et al., "Blue Carbon as a Natural Climate Solution," p. 827.

[52] Ibid., p. 827, and Supplemental Data accompanying Brian Buma et al., "Expert Review of the Science Underlying Nature-Based Climate Solutions," *Nature Climate Change*, vol. 14 (February 20, 2024), pp. 402-406 (hereinafter referred to as Buma et al., "Expert Review of the Science").

[53] Christine Bertram et al., "The Blue Carbon Wealth of Nations," *Nature Climate Change*, vol. 11 (August 2021), pp. 704-709.

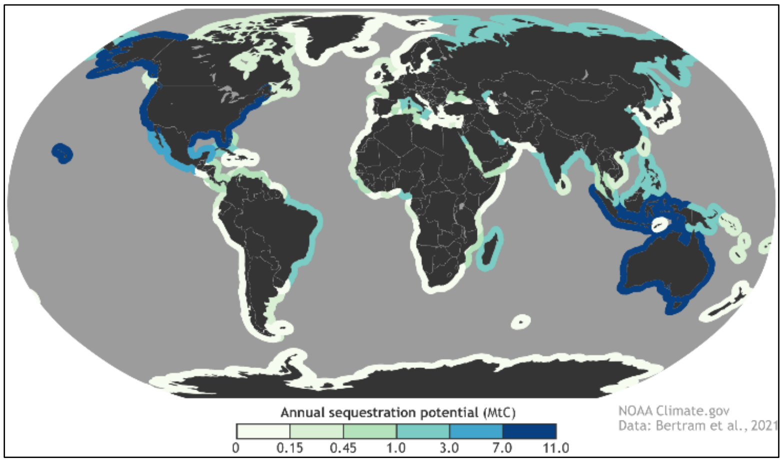
[54] Ibid., p. 705.

[55] Chuancheng Fu et al., "Substantial Blue Carbon Sequestration in the World's Largest Seagrass Meadow," *Communications Earth & Environment*, vol. 4, no. 474 (December 13, 2023), pp. 1-9. Hereinafter referred to as Fu et al., "Substantial Blue Carbon Sequestration."

[56] Mcleod et al., "Blueprint for Blue Carbon," p. 555.

Second, as described above, estimates of the present-day geographic coverage of coastal blue carbon ecosystems have large uncertainties. Coupling these two estimates together to calculate potential carbon removal capacity of an ecosystem likely would mean that those removal capacity estimates also have large uncertainties. Relying on these removal capacity estimates for quantitative analysis may be misleading.

Figure 3. Average Annual Coastal Blue Carbon Sequestration Potential by Country



Source: National Oceanic and Atmospheric Administration, "Understanding Blue Carbon," https://www.climate.gov/news-features/understanding-climate/understanding-blue-carbon.

Notes: Annual coastal blue carbon sequestration shown in megatonnes of carbon (MtC). Australia, the United States, Indonesia, and Mexico have the highest coastal blue carbon sequestration potential (Christine Bertram et al., "The Blue Carbon Wealth of Nations," Nature Climate Change, vol. 11 (2021), pp. 704-709, see Figure 1 on p. 706).

Federal Agency Policy and Authorities Related to Coastal Blue Carbon Science

Some Administrations have identified ways for federal agencies to support coastal blue carbon ecosystems science. For example, the Biden Administration's 2023 *Ocean Climate Action Plan* noted the benefit of coastal blue carbon ecosystems and identified priority actions, including supporting research and development initiatives for coastal blue carbon ecosystems; conducting research, exploration, and mapping to determine coastal blue carbon ecosystem potential; developing standards for coastal blue carbon ecosystem monitoring and management; and conserving and restoring coastal blue carbon ecosystems, among others.[57] The Biden Administration also established the Marine Carbon Dioxide Removal Fast Track Action Committee in October 2023 (described further in "Coastal Blue Carbon-Focused Working Groups and Committees," below).[58] In addition, the Administration released its *National Strategy for a*

[57] To be implemented by agencies such as DOE, FWS, NASA, the National Park Service, NOAA, and USGS. White House Ocean Policy Committee, *Ocean Climate Action Plan*, pp. 49-50.

[58] White House, "Marine Carbon Dioxide Removal: Potential Ways to Harness the Ocean to Mitigate Climate Change," October 6, 2023, https://www.whitehouse.gov/ostp/news-updates/2023/10/06/marine-carbon-dioxide-removal-potential-ways-to-harness-the-ocean-to-mitigate-climate-change/.

Sustainable Ocean Economy, which includes activities related to marine CDR (mCDR; also referred to as ocean or ocean-based CDR) monitoring, among other actions, in June 2024.[59]

Congress has directed agencies to work on science—including mapping, observations, monitoring, modeling, and research—indirectly and directly related to coastal blue carbon ecosystems. Congress has not used the term *blue carbon* in statute, in reference to coastal ecosystems and their potential carbon removal capacity.[60] It has directed multiple agencies to study the carbon cycle and carbon sequestration in coastal ecosystems. For example, Congress directed the National Science and Technology Council (NSTC), Committee on Environment, Subcommittee on Ocean Science and Technology (Subcommittee) to develop and periodically update a strategic research plan to include "modeling to predict changes in the ocean carbon cycle," among other topics related to ocean acidification.[61] As another example, Congress directed the Secretary of the Interior to complete a national assessment of

- the quantity of carbon stored in and released from ecosystems (i.e., any terrestrial, freshwater aquatic, or coastal ecosystem) and
- the annual flux of CO_2, nitrous oxide, and methane.[62]

Congress also directed the Secretary of the Interior to work with the Secretary of Commerce to conduct such assessments in ocean and coastal ecosystems.[63]

In addition, Congress has directed agencies, through authorizing legislation, to support science activities as part of programs focused on coastal ecosystems broadly. For example, NOAA has identified agency observing networks and modeling capabilities used for oceanic, atmospheric, and ecosystem research that can be and have been applied to mCDR research.[64]

Congress has increasingly directed agencies to support science activities related to coastal blue carbon sequestration or other related activities (i.e., "ocean-based carbon dioxide removal") in appropriations law and related report language. For example, in FY2024, Congress

- directed NOAA to use funds to support a "pilot program on blue carbon to advance NOAA's work to assess the carbon sequestration potential of various coastal habitats, account for regional differences, and identify some of the

[59] White House Ocean Policy Committee, *National Strategy for a Sustainable Ocean Economy*, June 2024, pp. 21-22.

[60] Congress directed the Secretary of Defense, in coordination with other agency heads, to carry out a program on research, development, testing, evaluation, study, and demonstration of technologies related to blue carbon capture and direct air capture. The statute defines *blue carbon capture* as "the removal of dissolved carbon dioxide from seawater through engineered or inorganic processes, including filters, membranes, or phase change systems" (10 U.S.C. §4001 note). Under this definition, blue carbon ecosystems would not qualify as blue carbon capture.

[61] 33 U.S.C. §3704(c)(3). For example, see National Science and Technology Council, Committee on Environment, Subcommittee on Ocean Science and Technology, Interagency Working Group on Ocean Acidification, *Strategic Plan for Federal Research and Monitoring of Ocean Acidification*, September 2023, https://oceanacidification.noaa.gov/wp-content/uploads/2023/09/StrategicPlanforFederalResearchandMonitoringofOceanAcidification.pdf.

[62] 42 U.S.C. §17272. Resulting reports include USGS, *Baseline and Projected Future Carbon Storage and Greenhouse-Gas Fluxes in Ecosystems in the Great Plains Region of the United States*, USGS Professional Paper 1787, 2011, https://doi.org/10.3133/pp1787; USGS, *Baseline and Projected Future Carbon Storage and Greenhouse-Gas Fluxes in Ecosystems of the Western United States*, USGS Professional Paper 1797, 2012, https://doi.org/10.3133/pp1797; USGS, *Baseline and Projected Future Carbon Storage and Greenhouse-Gas Fluxes in Ecosystems of the Eastern United States*, USGS Professional Paper 1804, 2014, http://dx.doi.org/10.3133/pp1804; and USGS, *Baseline and Projected Future Carbon Storage and Greenhouse-Gas Fluxes in Ecosystems of Alaska*, USGS Professional Paper 1826, 2016, http://dx.doi.org/10.3133/pp1826.

[63] Ibid.

[64] Cross et al., *Strategy for NOAA Carbon Dioxide Removal Research*.

biophysical, social, and economic pathways and impediments to coastal blue carbon ecosystem protection, management, or restoration,"[65] and

- recognized "the benefits of a clear regulatory process for ocean carbon dioxide removal pathways" and provided funding to the Department of Energy (DOE) to work with other federal agency and industry partners to "develop, test, and evaluate ocean-based carbon dioxide removal technologies."[66]

In addition to science-related activities, Congress has authorized federal agencies to have a role in conserving some existing coastal and marine ecosystems.[67] For example, federal agencies have created marine sanctuaries and refuges for various purposes, including habitat conservation, that may have the co-benefit of preserving coastal blue carbon.[68] Congress also has authorized federal agencies to provide funding to nonfederal entities through grant programs to restore degraded ecosystems or prevent future land use changes of existing ecosystems.[69] These actions, when applied to coastal blue carbon ecosystems, may help ensure these ecosystem remain a carbon sink and not a source. In many instances, carbon sequestration is not the main goal and is often secondary to habitat conservation for species or other benefits.

Federal Agency Research Coordination and Collaboration on Coastal Blue Carbon Ecosystems

Federal agencies have used their authorities to collaborate and coordinate with each other, and with other entities, on coastal blue carbon science-related activities. Federal agency collaboration can take different forms, including individual projects and larger working groups. For example, NOAA launched the Blue Carbon Inventory Project in 2020 to help partner countries incorporate coastal blue carbon ecosystems in their inventories of GHG emission sources and sinks, among other activities.[70] Project partners include the Department of State, NASA, the Smithsonian Environmental Research Center (SERC), the U.S. Environmental Protection Agency (EPA), the U.S. Forest Service (FS), the U.S. Agency for International Development (USAID), and nonfederal organizations.[71]

Federal agencies also address coastal blue carbon science activities via working groups or committees, some of which include nonfederal entities. These groups and others sometimes work beyond blue carbon science questions and focus on conserving and restoring blue carbon

[65] "Explanatory Statement Submitted by Sen. Murray, Chair of the Senate Committee on Appropriations, Regarding H.R. 4366, Consolidated Appropriations Act, 2024," *Congressional Record*, vol. 170, No. 39 (March 5, 2024), p. S1401.

[66] Ibid., p. S1575. The explanatory statement used but did not define the term *ocean-based carbon dioxide removal*. The term is not defined in statute or regulation, although the term *blue carbon capture* is defined in statute but does not encompass the concept described here.

[67] For examples of federal land designations, see CRS Report R43429, *Federal Lands and Related Resources: Overview and Selected Issues for the 118th Congress*.

[68] For example, see FWS, "Mangroves on the Move: Wetland Habitats Responding to Changes in Climate," https://storymaps.arcgis.com/stories/ee2242de7aba4c27a62d21e6ec480f83.

[69] For examples of existing ecosystem restoration programs, see CRS Report R47263, *Ecosystem Restoration in the Infrastructure Investment and Jobs Act: Overview and Issues for Congress*, coordinated by Anna E. Normand and Pervaze A. Sheikh.

[70] NOAA Climate Program Office, *NOAA Blue Carbon Inventory Project*, 2023, https://cpo.noaa.gov/wp-content/uploads/2023/08/NOAA_BCIproject_BriefingSheet_2023_07_13.pdf.

[71] Ibid.

ecosystems, among other activities.[72] The groups may be categorized into two types: those focused on the carbon cycle broadly, and those more specifically focused on coastal blue carbon ecosystems. Selected groups' memberships, goals, and establishment are described below, listed in the order of establishment (from oldest to youngest).

Carbon Cycle-Focused Working Groups and Committees

Federal agencies participate in national and international-level interagency working groups and programs focused broadly on the carbon cycle, which include the following.

- **Carbon Cycle Interagency Working Group**. Established in 1998 by the U.S. Global Change Research Program,[73] the working group is composed of representatives from 15 federal agencies and departments and is "responsible for defining program goals, setting research priorities, and reviewing the progress of the research programs that contribute to carbon cycle science."[74] The working group established the U.S. Carbon Cycle Science Program in 1999 and an Interagency Carbon Dioxide Removal Research Coordination Workstream in 2021.[75]
  - **U.S. Carbon Cycle Science Program**. The program was established to coordinate and facilitate carbon cycle science activities. Funding for the program is provided by NASA, NOAA, and the U.S. Department of Agriculture (USDA), including FS.[76] The program launched the North American Carbon Program in 2002 and the Ocean Carbon and Biogeochemistry Program in 2006.
    - **North American Carbon Program**. The program is a scientific research program focused on carbon sources and sinks in North America and its adjacent oceans.[77] Authors of its 2022 Science Implementation Plan included scientists from DOE, EPA, NASA, the National Institute of Standards and Technology (NIST), NOAA, USDA, USGS, nongovernmental organizations, academic institutions, and agencies of foreign countries.[78]

[72] For example, NOAA is a partner in the International Partnership for Blue Carbon, which connects entities to "protect, sustainably manage and restore global coastal blue carbon ecosystems" (https://bluecarbonpartnership.org/the-partnership/blue-carbon-partner-organisations/).

[73] Email correspondence from the U.S. Global Change Research Program (USGCRP) to CRS, May 22, 2024.

[74] Member agencies and departments include the Departments of Agriculture (USDA), Commerce (DOC), Defense (DOD), DOE, Health and Human Services, Homeland Security (DHS), Housing and Urban Development, the Interior (DOI), State, and Transportation, U.S. Environmental Protection Agency (EPA), NASA, National Science Foundation (NSF), Smithsonian Institution, and U.S. Agency for International Development (USAID). USGCRP, "Carbon Cycle Interagency Working Group," https://www.globalchange.gov/our-work/interagency-groups/cciwg.

[75] Ibid.; U.S. Carbon Cycle Science Program, "About the U.S. Carbon Cycle Science Program," https://www.carboncyclescience.us/about; Christopher A. Williams et al., *2022 North American Carbon Program Science Implementation Plan*, 2023, p. 3, https://www.nacarbon.org/nacp/implementation_plan.html (hereinafter referred to as Williams et al, *2022 North American Carbon Program Science Implementation Plan*); USGCRP, "CCIWG Interagency Carbon Dioxide Removal Research Coordination Workstream," https://www.globalchange.gov/our-work/interagency-groups/cciwg/icdrc.

[76] U.S. Carbon Cycle Science Program, "About the U.S. Carbon Cycle Science Program," https://www.carboncyclescience.us/about.

[77] North American Carbon Program, "Overview," https://www.nacarbon.org/nacp/overview.html.

[78] Williams et al, *2022 North American Carbon Program Science Implementation Plan*, pp. 158-159.

    - **Ocean Carbon and Biogeochemistry Program**. The program aims to understand the ocean's role in the global carbon cycle and the responses of marine ecosystems to environmental changes by bringing together scientific disciplines and developing domestic and international partnerships.[79] Program Science Steering Members have included scientists from NASA, NOAA, and academic institutions.[80] Funding is provided by NASA and NSF.
- **Interagency Carbon Dioxide Removal Research Coordination Workstream**. The group seeks to advance interagency CDR research coordination and is working to compile information on "the feasibility, carbon removal potential, and risks and benefits of various carbon removal strategies."[81] It aims to prepare a high-level overview of how and where CDR science and development intersects with various agencies' missions.[82]

Coastal Blue Carbon-Focused Working Groups and Committees

Federal agencies participate in regional, national, and international level working groups, networks, and committees focused on coastal blue carbon, including the following.

- **Blue Carbon Scientific Working Group**. Established by the nongovernmental organization Blue Carbon Initiative in 2011, the Blue Carbon Scientific Working Group is a group of scientists from the United States (including from NASA and SERC) and other countries.[83] The group's objectives are to create internationally applicable standards for quantifying and monitoring coastal blue carbon; to develop internationally acceptable standards for data collection, quality control, and archiving; and to identify priority research on coastal blue carbon dynamics, among other activities. The group co-founded and is supporting the Coastal Carbon Research Coordination Network.[84]
    - **Coastal Carbon Research Coordination Network**. Established by SERC in 2017,[85] the Coastal Carbon Research Coordination Network partners with the U.S. Carbon Cycle Science Program, USGS, and nongovernmental organizations to "advance the synthesis of coastal

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[79] Ocean Carbon and Biogeochemistry Program (OCB), "About," https://www.us-ocb.org/about/.

[80] OCB, "Scientific Steering Committee [SSC]," https://www.us-ocb.org/about/scientific-steering-committee/ and OCB, *OCB SSC Membership: Past and Present*, March 2017, https://www.us-ocb.org/wp-content/uploads/sites/43/2017/03/Previous-OCB-SSC-Members.pdf.

[81] The workstream includes members from DOC (National Institute of Standards and Technology [NIST] and NOAA), DOI (Bureau of Safety and Environmental Enforcement, FWS, and USGS), EPA, DOE, NASA, USAID, and USDA. USGCRP, "CCIWG Interagency Carbon Dioxide Removal Research Coordination Workstream," https://www.globalchange.gov/our-work/interagency-groups/cciwg/icdrc.

[82] Cross et al., *Strategy for NOAA Carbon Dioxide Removal Research*, p. 79. The White House Office of Science and Technology Policy stated that the group is working on an overview but did not identify a public release date (personal correspondence with the White House Office of Science and Technology Policy, May 7, 2024).

[83] Blue Carbon Initiative, "Blue Carbon Scientific Working Group," https://www.thebluecarboninitiative.org/scientific-working-group.

[84] Ibid.

[85] Email correspondence from Smithsonian Institution Office of Government Relations to CRS, November 10, 2019. The Smithsonian Institution Office of Government Relations noted that the project is conducted under 20 U.S.C. §41 and 20 U.S.C. §42.

wetland carbon cycle data."[86] The network is funded by NOAA, NSF, USGS, and the nongovernmental organization Pew Charitable Trusts.

- **Pacific Northwest Blue Carbon Working Group**. Established in 2014 by representatives from the South Slough National Estuarine Research Reserve (NERR), NERR Science Collaborative, FWS, and nongovernmental organization Environmental Science Associates, the working group aims to conduct research to quantify carbon sequestration rates for Pacific Northwest tidal wetlands, among other goals.[87] The Pacific Northwest Blue Carbon Working Group includes scientists, practitioners, and policymakers from DOE, EPA, FWS, NOAA (and NOAA-funded entities), USGS, and nonfederal entities.[88]
- **Blue Carbon National Working Group**. Established by NOAA and the nongovernmental organization Restore America's Estuaries in 2015, the Blue Carbon National Working Group's objectives include increasing communication on blue carbon work at the local, regional, and national scales; improving coordination; and providing a platform for discussions of science needs, information gaps, and priorities.[89] The working group comprises scientists and practitioners from EPA, FS, FWS, NOAA, NOAA-funded entities (such as NERR), USDA, USGS, and nonfederal entities.[90]
- **Marine Carbon Dioxide Removal Fast Track Action Committee (MCDR-FTAC)**. Established by action of NSTC in 2023, the MCDR-FTAC is charged with developing an implementation plan to advance federal research and a scaled testing program for mCDR and a U.S. mCDR initiative to coordinate public-private funded research, among other things.[91] The MCDR-FTAC solicited input from the public on the development of an implementation plan to advance recommendations under the *Ocean Climate Action Plan* in February 2024.[92] The committee is to terminate by November 15, 2024, unless renewed by the NSTC Subcommittee on Ocean Science and Technology.[93]

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[86] Smithsonian Environmental Research Center (SERC), "Coastal Carbon Network," https://serc.si.edu/coastalcarbon. Hereinafter referred to as SERC, "Coastal Carbon Network."

[87] Pacific Northwest (PNW) Blue Carbon Working Group, "Background," https://www.pnwbluecarbon.org/background and PNW Coastal Blue Carbon Working Group, *Biophysical Research Framework*, undated, p.2, https://www.pnwbluecarbon.org/_files/ugd/43d666_5d46888c53094ffa91faf74084df9f25.pdf.

[88] PNW Coastal Blue Carbon Working Group, *Participants and Affiliations*, August 31, 2021, https://www.pnwbluecarbon.org/_files/ugd/43d666_0418150a792c43508279c4cc87e95530.pdf.

[89] Restore America's Estuaries (RAE), "Blue Carbon National Working Group," https://estuaries.org/coastal-blue-carbon/bcn/; and RAE, *Recommendations from the Blue Carbon National Working Group*, January 2016, https://estuaries.org/wp-content/uploads/2019/01/Blue-Carbon-National-Recommendations2015-6_FINAL.pdf.

[90] Ibid.

[91] The Marine Carbon Dioxide Removal Fast Track Action Committee is composed of representatives from DOC (including NOAA and NIST), DOE, DOI (including the Bureau of Safety and Environmental Enforcement, Bureau of Ocean Energy Management, and USGS), EPA, NASA, NSF, Office of Naval Research, Smithsonian Institution, Department of State, USACE, and USDA. *Charter of the Marine Carbon Dioxide Removal Fast Track Action Committee of the Subcommittee on Ocean Science and Technology, National Science and Technology Council*, September 2023, pp. 1-5, https://www.noaa.gov/sites/default/files/2023-10/mCDR_FTAC_charter_2023_09_19_approved.pdf. Hereinafter referred to as MCDR-FTAC Charter, September 2023.

[92] NSF, "Marine Carbon Dioxide Removal Research Plan," 89 *Federal Register* 13755, February 23, 2024.

[93] MCDR-FTAC Charter, September 2023.

Issues for Congress

Congress has shown interest in the services of coastal ecosystems, including the ability of these ecosystems to capture and store CO_2.[94] Congress also may consider several issues that address coastal blue carbon ecosystems, including those related to mapping coastal ecosystems, conserving, restoring, and creating coastal blue carbon ecosystems, and estimating their carbon sequestration and storage. Congress also may debate how best to structure federal interagency coordination and collaboration to research coastal blue carbon science and whether federal funding for blue carbon science activities is sufficient to meet congressional goals.

Mapping Coastal Blue Carbon Ecosystems

Experts contend that better estimates of the carbon removal capacity of coastal blue carbon ecosystems will require accurate mapping of these ecosystems.[95] Furthermore, mapping of coastal blue carbon ecosystems can help stakeholders identify drivers of coastal blue carbon ecosystem loss (i.e., natural or human-driven) and prioritize whether (and, if so, where) to protect or restore these ecosystems. To that end, the Biden Administration released a January 2023 strategy to map, and eventually value, various *natural capital*, including coastal ecosystems such as seagrass meadows and tidal marshes.[96] In March 2023, the Administration's *Ocean Climate Action Plan* explicitly identified the need to expand the mapping of coastal blue carbon ecosystems to determine their carbon removal capacity.[97] Other stakeholders have expressed interest in mapping coastal blue carbon ecosystems, as described in the sections below. Some stakeholders could argue that these mapping initiatives may be used to limit future development or increase regulation of certain coastal areas.

Some Members have introduced legislation to support coastal blue carbon ecosystem mapping. In the 118th Congress, the Carbon Dioxide Removal Research and Development Act of 2023 (H.R. 5457/S. 2812) would establish a whole-of-government approach to support CDR research and development, among other purposes. These bills would direct NASA, using satellite imagery, to "carry out mapping and evaluation of coastal marine ecosystems for carbon dioxide removal potential—including (i) wetlands; (ii) peatlands; and (iii) seagrass beds."[98] In addition, these bills would direct NOAA, in collaboration with NASA, to "carry out mapping and evaluation of coastal marine ecosystems for carbon dioxide removal potential."[99] Some stakeholders may question the relative priority of mapping coastal blue carbon ecosystems over other activities related to coastal blue carbon (e.g., conservation and restoration) and other federal activities. Other stakeholders may contend that the analysis of sequential (e.g., annual) aerial or satellite

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[94] For example, see U.S. Congress, House Select Committee on the Climate Crisis, *America's Natural Solutions: The Climate Benefits of Investing in Healthy Ecosystems*, 117th Cong., 2nd sess., April 1, 2022 (Washington, DC: GPO, 2022) and multiple bills introduced in the 117th and 118th Congresses, for example, as described throughout the "Issues for Congress" section.

[95] For example, see Macreadie et al., "Blue Carbon as a Natural Climate Solution," p. 830; and NASEM, *Coastal Blue Carbon Approaches*, p. 5.

[96] In general, *natural capital* refers to stocks of natural resources that include geology, soil, air, water, and all living things (Convention on Biological Diversity, "Natural Capital," https://www.cbd.int/business/projects/natcap.shtml). Office of Science and Technology Policy, Office of Management and Budget (OMB), and DOC, *National Strategy to Develop Statistics for Environmental-Economic Decisions: A U.S. System of Natural Capital Accounting and Associated Environmental-Economic Statistics*, January 2023, pp. 55 and 62.

[97] White House Ocean Policy Committee, *Ocean Climate Action Plan*, p. 48.

[98] §801 of Title VIII of H.R. 5457/S. 2812 in the 118th Congress.

[99] §301 of Title III of H.R. 5457/S. 2812 in the 118th Congress.

imagery for coastal blue carbon ecosystem mapping can be used to provide timely analysis of land use change. Land use change trends within these ecosystems can inform projections of future potential carbon removal capacity and relevant policy decisions related to conservation and restoration. For example, a 2020 study led by NASA scientists found mangrove loss in some parts of the world, such as in the United States, Brazil, and Australia, is driven primarily by natural causes, whereas other parts of the world, such as Mexico and some countries in southeast Asia, are experiencing human-driven losses.[100]

Other bills introduced in the 118th Congress provide direction for the mapping of coastal blue carbon ecosystems but do not specify the use of satellite imagery. For example, S. 3785 would establish an Interagency Working Group (IWG) on Vegetated Coastal Ecosystems and Great Lakes Ecosystems. *Vegetated coastal ecosystems* in this context include "mangroves, tidal marshes, seagrasses, kelp forests, and other tidal, freshwater, or salt-water wetlands." The IWG would be responsible for producing, updating, and maintaining a "national-level map and inventory of vegetated coastal and Great Lakes ecosystems" that includes information about the ecosystem's size, condition, protection status, and land use change. The inventory would also include an "assessment of the carbon sequestration potential, methane production, and net greenhouse gas reductions with respect to such ecosystems, including consideration of—(A) quantification, (B) verifiability, (C) comparison to a historical baseline as available, and (D) permanence of those benefits."

Bills introduced in the 117th Congress, such as H.R. 2750, H.R. 3764, and S. 3245, also proposed establishing an IWG to produce and maintain a national map and inventory of coastal blue carbon ecosystems,[101] or coastal and marine blue carbon ecosystems within U.S. ocean waters, among other proposals.[102] As an alternative to establishing a new IWG, Congress may consider codifying existing working groups or committees (refer to "Federal Agency Research Coordination and Collaboration on Coastal Blue Carbon Ecosystems," above) that are working to develop a national map and inventory of coastal blue carbon ecosystems. For example, the Coastal Carbon Research Coordination Network, established by SERC, developed and maintains the Coastal Carbon Atlas, a web-based global tidal wetland database, and the Blue Carbon Data Inventory, a database of U.S. coastal blue carbon soil information.[103] A national map and inventory of coastal blue carbon ecosystems may improve the federal government's quantification of U.S. GHG emissions and sinks. For example, EPA considers coastal wetlands, including coastal blue carbon ecosystems, in its annual national inventory of GHG emissions and sinks.[104]

Congress continues to consider initiatives and programs that aim to restore coastal ecosystems.[105] For example, H.R. 2950/S. 1381, introduced in the 118th Congress, would direct certain federal agencies to develop and implement monitoring protocols to track coastal ecosystem restoration.[106] Congress may consider amending authorizing language to explicitly require mapping as part of

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[100] See footnote 11. Liza Goldberg, et al., "Global Declines in Human-Driven Mangrove Loss," *Global Change Biology*, vol. 26, no. 10 (2020), pp. 5844-5855.

[101] §2 of H.R. 2750 in the 117th Congress.

[102] §102 of Title I of H.R. 3764, §3 of H.R. 2750, and §4 of S. 3245 in the 117th Congress.

[103] The Blue Carbon Data Inventory provides state-level report cards ranking all coastal states and the District of Columbia on the quantity, quality, and coverage of coastal blue carbon data. SERC, "Coastal Carbon Network."

[104] EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks," https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks; and NOAA, "Digital Coast Program Gets "Blue Carbon" Added to U.S. Emissions Inventory," https://coast.noaa.gov/states/stories/digital-coast-program-gets-blue-carbon.html.

[105] For example, H.R. 5457, H.R. 2950, S. 1381, and S. 2812 in the 118th Congress and H.R. 843, H.R. 3764, S. 8013, and S. 3245 in the 117th Congress.

[106] H.R. 2950 and S. 1381 in the 118th Congress.

monitoring protocols. In addition, Congress could require federal agencies funding conservation or restoration of coastal blue carbon ecosystems to share collected data, such as mapping information, with an IWG or a data management entity (e.g., SERC).

The Obama, Trump, and Biden Administrations and Congress have shown interest in commercial data purchase programs and partnerships between federal agencies and the U.S. commercial space industry, which could include data relevant to coastal blue carbon.[107] Several federal agencies already purchase Earth observation remote sensing data for various purposes, from science to national intelligence, but the terms of those purchases, unless renegotiated, may not allow use of the data for purposes beyond their original scope (e.g., mapping of coastal ecosystems).[108] These purchases and partnerships could be used to bolster the mapping of coastal blue carbon ecosystems. For example, NASA's Commercial Smallsat Data Acquisition Program, which has data purchase agreements with several commercial satellite companies, can use these data only in research (i.e., NASA may not use the data to develop products or for agency regulatory purposes).[109] In addition, federal agencies can request use of the Department of Defense (DOD) and the U.S. intelligence community remote sensing data, which may include commercial sources, through the Civil Application Committee.[110] Congress may consider whether federal agencies might expand use commercial data for purposes beyond these original purposes. One potential drawback of expanding the use of commercial data to other purposes is that companies may renegotiate contracts at a higher price, which could limit the federal agency's ability to continue the data purchase program. When renegotiating end-user license agreements, federal agencies and commercial providers may need to balance scientific factors (e.g., data use and sharing) and commercial interests.[111]

Conservation, Restoration, and Creation of Coastal Blue Carbon Ecosystems

Congress might consider whether to support existing efforts or authorize new efforts to conserve, restore, and create coastal blue carbon ecosystems. Some stakeholders have supported actions that aim to maintain or increase CO_2 sequestration in coastal blue carbon ecosystems.[112] These actions aim to maintain or grow carbon sink capacity and include

- conserving existing blue carbon ecosystems;
- restoring degraded coastal blue carbon ecosystems; and

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[107] For example, see §301 of Title III, H.R. 6093, in the 118th Congress; White House, *National Space Policy of the United States of America*, June 28, 2010, pp. 10-11; White House, *National Space Policy of the United States of America*, December 9, 2020, pp. 20-23; *United States Space Priorities Framework*, December 2021; and National Science and Technology Council, Subcommittee on U.S. Group on Earth Observations Committee on the Environment, *United States Government Earth Observations Data Purchases: Perspectives from the Earth Observations Enterprise*, July 2022, pp. 1-29.

[108] NASA, "Commercial SmallSat Data Acquisition Program Pilot: Evaluation Report," April 2020, p. 8, https://www.earthdata.nasa.gov/s3fs-public/imported/CSDAPReport0420.pdf. Hereinafter referred to as NASA, "Commercial SmallSat Data Acquisition Program Pilot."

[109] NASA, "Commercial Smallsat Data Acquisition (CSDA) Program," https://www.earthdata.nasa.gov/esds/csda.

[110] The Civil Application Committee allows data to be used for monitoring environmental conditions, conducting Earth system scientific research, and contributing to land use and natural resource management, among other uses. See USGS, "Civil Applications Committee," https://pubs.usgs.gov/fs/2022/3002/fs20223002.pdf.

[111] NASA, "Commercial SmallSat Data Acquisition Program Pilot," p. 8.

[112] For example, NASEM, "Chapter 2: Coastal Blue Carbon," p. 54.

- creating new or expanding existing coastal blue carbon ecosystems into areas, within their environmental thresholds, that currently do not have these ecosystems.

In some cases, the primary goal of these activities is carbon sequestration; in other cases, carbon sequestration is a co-benefit of an intended goal. For example, the Biden Administration's *Ocean Climate Action Plan* identified advancing conservation and restoration of coastal blue carbon ecosystems as a key element of U.S. climate mitigation goals through nature-based solutions.[113] It also identified conservation and restoration of coastal blue carbon ecosystems as a priority in coastal resource planning and management decisions.[114] The *Ocean Climate Action Plan* also supported investments in coastal habitat restoration and conservation to improve coastal climate resilience, which may have the co-benefit of maintaining or increasing coastal blue carbon sequestration.[115]

If Congress is interested in increasing the conservation and restoration of existing coastal blue carbon ecosystems or creating new coastal blue carbon ecosystems, it could consider several policy approaches. Congress could indirectly support carbon sequestration in coastal blue carbon ecosystems by reauthorizing and funding existing programs that conserve, restore, and create coastal blue carbon ecosystems (e.g., NOAA's Community-Based Habitat Restoration program).[116] Alternatively, Congress could prioritize coastal blue carbon sequestration by creating new programs to support the conservation, restoration, and creation of coastal blue carbon ecosystems. For example, H.R. 1196 in the 118th Congress would establish a NOAA grant program for projects to restore coastal blue carbon ecosystems. In another instance, H.R. 3764 in the 117th Congress would have created a grant program to "protect and restore blue carbon stocks … and blue carbon ecosystems and increase the long-term carbon storage and sequestration." Additionally, Congress could amend statutes or direct agencies to consider or prioritize carbon sequestration in existing coastal blue carbon ecosystem-related programs or appropriations laws. For instance, H.R. 7106 in the 118th Congress would broaden the eligible uses of an existing fund to include "restoration, protection, or maintenance of living ocean, coastal, and Great Lakes resources and their habitats, including habitats and ecosystems that provide blue carbon benefits."[117] In addition, H.R. 3764 in the 117th Congress would have directed NOAA to use existing programs to "ensure the conservation and enhancement of each blue carbon area of significance," as defined by the bill, and FWS, NPS, and NOAA to "conduct coastal and marine restoration and protection activities on land and water managed by each" to achieve sequestration of additional CO_2, among other goals.

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[113] White House Ocean Policy Committee, *Ocean Climate Action Plan*, p. 21.

[114] Ibid.

[115] Ibid, p. 23. Existing grant programs with similar goals include the National Fish and Wildlife Foundation's (NFWF's) National Coastal Resilience Fund, which "invests in conservation projects that restore or expand natural features such as coastal marshes and wetlands … that minimize the impacts of storms and other naturally occurring events on nearby communities." NFWF receives funding for the program from EPA, NOAA, and the Department of Defense, as well as nonfederal entities (NFWF, "National Coastal Resilience Fund," https://www.nfwf.org/programs/national-coastal-resilience-fund).

[116] NOAA, "Community-Based Habitat Restoration," https://www.fisheries.noaa.gov/national/habitat-conservation/community-based-habitat-restoration. For other examples of existing ecosystem restoration programs, see CRS Report R47263, *Ecosystem Restoration in the Infrastructure Investment and Jobs Act: Overview and Issues for Congress*, coordinated by Anna E. Normand and Pervaze A. Sheikh and examples of federal land and water conservation designations, see CRS Report R43429, *Federal Lands and Related Resources: Overview and Selected Issues for the 118th Congress*.

[117] §2 of H.R. 7106 defines *blue carbon benefits* as "the carbon sequestered and stored by coastal and marine ecosystems, including salt marshes, mangroves, and seagrasses."

Congress also might consider some of the complexities of conserving, restoring, and creating coastal blue carbon ecosystems when deciding whether or how to address this issue. Efforts addressing coastal blue carbon ecosystems are complex due to multiple factors. Such factors include ownership of the land on which the ecosystem sits and competing priorities for a finite area of coastline (e.g., how to balance development, species and habitat protection, recreation, carbon sequestration, and other ecosystem services).[118] For example, federal grant programs that support conservation, restoration, or expansion of coastal blue ecosystems often require public access to such ecosystems, a potential issue for private landowners. Alternatives could include supporting such ecosystems on non-private land or paying landowners for perpetual access, through easements, for example, which may pose fiscal considerations. In addition, stakeholders may need to consider current and projected environmental stressors and changes to coastal areas due to climate change impacts, such as changes to the frequency and intensity of extreme weather events, sea level rise, and ocean acidification, among other issues.[119] Some may question whether investments in these coastal areas are prudent in light of the uncertainty of how these ecosystems may change in the long term. Federal and nonfederal entities alike may evaluate these factors and the tradeoffs of supporting coastal blue carbon ecosystems. H.R. 2750 and S. 3245 in the 117th Congress would have directed NOAA to consider these factors and others to identify "national coastal blue carbon ecosystem protection and restoration priorities," among other things. Such efforts might intersect with activities undertaken by states and other nonfederal entities. For example, the state of California aims to restore and conserve coastal wetlands to increase carbon sequestration and storage, among other goals.[120]

Estimating Coastal Blue Carbon Stocks and Sequestration Rates

Research findings suggest the need for location-specific measurements of coastal blue carbon stocks and sequestration rates.[121] Location-specific field measurements of stocks and sequestration rates might be more accurate than generalized estimates that span a region or several ecosystems. Further, location-specific measurements might reveal specific factors affecting ecosystems relevant for implementing policies, such as constructing accurate national carbon inventories or identifying priority coastal blue carbon ecosystems for conservation and restoration efforts. The National Academies of Sciences, Engineering, and Medicine (NASEM) has identified that basic research on the fate of carbon sequestered and stored in coastal blue carbon ecosystems "will address some of the key uncertainties in understanding and using coastal ecosystems as a [negative emissions technology]."[122] For example, a 2024 research study of Bahamian seagrass meadows (the largest seagrass meadow ecosystem in the world) revealed lower-than-predicted carbon stock capacity.[123] The researchers attributed this finding to multiple environmental and human factors.[124] These findings could be interpreted as evidence of need for more location-specific measurements of coastal blue carbon.

[118] NASEM, "Chapter 2: Coastal Blue Carbon," pp. 83-85.

[119] Ibid, p. 51.

[120] California Natural Resources Agency, *Natural and Working Lands Climate Smart Strategy*, April 22, 2022, pp. 36-37, https://resources.ca.gov/-/media/CNRA-Website/Files/Initiatives/Expanding-Nature-Based-Solutions/CNRA-Report-2022—Final_Accessible.pdf.

[121] For example, see Buma et al., "Expert Review of the Science."

[122] NASEM, "Chapter 2: Coastal Blue Carbon," p. 75.

[123] Fu et al., "Substantial Blue Carbon Sequestration."

[124] Ibid.

Some Members of Congress have expressed interest in directing federal agencies to improve estimates of coastal blue carbon through basic research. For example, in the 118th Congress, the Carbon Dioxide Removal Research and Development Act of 2023 (H.R. 5457/S. 2812) was introduced to support a whole-of-government approach for CDR research and development, among other purposes. Part of the legislation would direct NOAA to conduct "enhanced ocean, coastal, and atmospheric monitoring, quantification, and verification of carbon dioxide removal."[125] The quantification of CDR would entail estimating coastal blue carbon stocks and sequestration rates. If enacted, NOAA might identify a range of estimates for carbon stock and sequestration rates for certain coastal blue carbon ecosystems (e.g., mangrove forests) or for a national inventory of the three coastal blue carbon ecosystems. Congress may direct NOAA on the scale of study—that is, ecosystem scale, such as the Florida Everglades; regional scale, such as the U.S. Gulf Coast; or national scale—and the intended application, if any, of these data to EPA's annual national inventory of GHG emissions and sinks.

In addition, in the 118th Congress, some Members introduced the Carbon Removal and Emissions Storage Technologies Act of 2023 (S. 1576). This legislation would amend Section 962(b) of the Energy Policy Act of 2005 (EPAct 2005; P.L. 109-58, 42 U.S.C. §16298d), as amended, to include coastal blue carbon and mCDR approaches as part of the DOE's research, development, and demonstration (RD&D) program.[126] Section 969D of EPAct 2005, as amended, directs the Secretary of Energy, in coordination with other federal agency heads, to "establish a research development and demonstration program to test, validate, or improve technologies and strategies to remove carbon dioxide from the atmosphere on a large scale." If amended to include an mCDR approach, the validation would require knowledge about the carbon system's stock and sequestration rate.

Coordinating Federal Coastal Blue Carbon Science

Federal agencies have various roles in conducting coastal blue carbon science. Some stakeholders note that establishing and maintaining research projects, partnerships, and cross-federal collaborations remains challenging because of different agency missions and mandates, among other things.[127] Some Members have introduced bills in the 118th Congress (e.g., H.R. 5457/S. 2812) that would direct certain agencies to support CDR research and development, including mCDR.[128] The bills would direct agencies and programs within the Departments of Commerce (NOAA and NIST), Energy, Defense (USACE), the Interior (USGS), Transportation (Federal Highway Administration), and Agriculture (Agricultural Research Service, FS, National Institute of Food and Agriculture, and Natural Resources Conservation Service), as well as EPA, NASA, and NSF, to undertake certain RD&D activities on CDR research and to implement intra- and interagency coordination under new authorities.

Congress also could consider amending existing federal agency authorities to initiate or expand their coastal blue carbon science activities. In addition, Congress may deliberate whether to create a new or designate an existing federal program to lead coastal blue carbon science. This program could track and coordinate agency activities, administer funding for coastal blue carbon science

[125] §301 of Title III of H.R. 5457/S. 2812 in the 118th Congress.

[126] S. 1576 in the 118th Congress. This bill describes blue carbon as "the management of vegetated coastal habitats (including mangroves, tidal marshes, seagrasses, kelp forests, and other tidal, freshwater, or saltwater wetlands) that sequester carbon (including autochthonous carbon and allochthonous carbon) from the atmosphere, accumulate carbon in biomass, and store the carbon in soils."

[127] Williams et al., *2022 North American Carbon Program Science Implementation Plan*, p. 143.

[128] The bills use the term *ocean-based carbon removal* but do not define the term. The term is not defined in statute or regulation.

activities, and convene an interagency working group and/or advisory board, among other actions. A dedicated program potentially could lead to improved coordination and reduced duplication across federal agencies but also could require changes to long-standing federal agency programs and activities.

Some stakeholders question how federal agencies are coordinating efforts to study mCDR and whether there is a need for formal federal coordination mechanisms for mCDR and coastal blue carbon activities. For example, NASEM has noted that "there is no single, comprehensive legal framework specific to ocean CDR research."[129] Some federal agencies have attempted to increase coordination on coastal blue carbon activities by creating or participating in working groups focused on the carbon cycle broadly or on coastal blue carbon specifically, as described above.[130] Some stakeholders have advocated for the President to establish a coordination mechanism for federal CDR or coastal blue carbon activities. For example, one stakeholder group recommended the creation of a Committee on Large-Scale Carbon Management, with cochairs from DOE, NOAA, the Office of Science and Technology Policy, and USDA, as "a centralized process will be essential to maximize the effectiveness of [the] whole-of-government approach."[131] The committee would be tasked to develop a government-wide CDR RD&D plan and oversee its implementation, among other things.

Another stakeholder group has advocated for the establishment of an IWG for coastal blue carbon under the U.S. Global Change Research Program, as "there is no formal mechanism to coordinate and leverage" federal efforts, which "limits the ability to concentrate funding, build out complementary programs, and accelerate progress."[132] The IWG would be tasked with developing a national strategic plan to coordinate federal funding and activities, among other activities.[133] It is unclear whether the MCDR-FTAC, established in 2023, fulfills either stakeholder group's objectives.

Some Members of Congress also have advocated for the establishment of federal working groups on CDR broadly and blue carbon sequestration specifically in recent Congresses. For example, multiple bills in the 117th and 118th Congresses, including S. 2002, would create an IWG on large-scale carbon management, as described above.[134] The bills would establish a sub-working group focused on CDR from oceans and coastal areas, with representatives from DOD, the Department of the Interior (DOI), EPA, NASA, NOAA, and NSF, among others. Other Members of Congress have introduced bills focused on establishing an IWG on coastal blue carbon.[135] The bills differ, but working group responsibilities could include the development and maintenance of a national map and inventory of coastal blue carbon ecosystems, a national strategy for coastal blue carbon "foundational science," and a strategic plan for federal investments in coastal blue carbon

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[129] NASEM, "Chapter 2: Crosscutting Considerations on Ocean-Based CDR R&D," in *A Research Strategy for Ocean-Based Carbon Dioxide Removal and Sequestration* (Washington, DC: The National Academies Press, 2022), p. 39.

[130] See the section entitled "Federal Agency Research Coordination and Collaboration on Coastal Blue Carbon Ecosystems."

[131] Energy Futures Initiative (EFI) Foundation, *Clearing the Air: A Federal RD&D Initiative and Management Plan for Carbon Dioxide Removal Technologies*, 2019, p. 155, https://efifoundation.org/wp-content/uploads/sites/3/2022/03/ClearingTheAir_Report_compressed.pdf. Hereinafter referred to as EFI, *Clearing the Air*.

[132] Restore America's Estuaries, *A National Blue Carbon Action Plan: Opportunities and Recommendations*, 2022, p. 7, https://estuaries.org/wp-content/uploads/2022/02/Blue-Carbon-National-Action-Plan-Final.pdf.

[133] The group also would be responsible for developing (1) a map of "high priority" coastal blue carbon ecosystems to conserve and restore, (2) a national research program, and (3) models to estimate ecosystem GHG emissions, as described in the "Mapping Coastal Blue Carbon Ecosystems" section.

[134] H.R. 843 and S. 8013 in the 117th Congress. The bills use the terms *ocean-based carbon dioxide removal* or *ocean-based carbon removal* but do not define the terms. The terms are not defined in statute or regulation.

[135] H.R. 2750, H.R. 3764, and S. 3245 in the 117th Congress.

ecosystem RD&D, among other topics.[136] Under the bills, members of the working group could include representatives from the Council on Environmental Quality, DOD (including USACE), DOE, DOI (including the Bureau of Indian Affairs, Bureau of Reclamation, FWS, National Park Service, and USGS), Department of Transportation, EPA, FEMA, NASA, NOAA, NSF, Smithsonian Institution, Department of State, USAID, and USDA, among others. Alternatively, Congress could specify how the agencies should work together, for how long, and on which congressional priorities, rather than leaving those decisions to the discretion of the executive branch.

Federal and Nonfederal Collaboration on Coastal Blue Carbon Science

Federal agencies and nonfederal entities collaborate on coastal blue carbon science activities in multiple ways, as described above. Some observers advocate for the participation of local communities in research on coastal blue carbon science (and mCDR more broadly) from the outset.[137] NASEM, for instance, states that justifications for public engagement may include that "dialogue is an important part of democracy," that it "can improve research quality," and it can "increase [the public's] legitimacy and trust."[138] Some federal agencies and stakeholders assert that collaboration between federal and nonfederal stakeholders is a necessary element of mCDR; for example, NOAA stated its intention to "facilitate consistent stakeholder engagement" through communication, data and information-sharing, and *co-production* of research strategies and recommendations.[139] NOAA has identified several steps, including continuing to work through its regional partnerships (i.e., Sea Grant College Programs, Integrated Ocean Observing System Regional Associations), industry partners, and academic communities of practice and civil society organizations.[140] Previously introduced legislation would have required collaboration between federal agencies and nonfederal groups, such as the scientific community, stakeholder groups, federal and state agencies, Indian tribes, and Native American Pacific Islander and nongovernmental organizations, to advance blue carbon research.[141]

Other stakeholders may question the additional emphasis on federal and nonfederal collaboration and whether such collaboration is necessary to advance the science. These stakeholders may argue that the existing efforts are adequate, that there are competing priorities of higher importance, that additional collaboration may slow down efforts, and a cost-share requirement among parties or lack thereof may create a barrier to participation, among other reasons.

Congress also may consider whether to require federal agencies, as part of a working group or individually, to work with nonfederal entities on coastal blue carbon science in other ways.

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[136] Ibid.

[137] NASEM, "Chapter 9: Synthesis and Research Strategy," *A Research Strategy for Ocean-Based Carbon Dioxide Removal and Sequestration* (Washington, DC: The National Academies Press, 2022), p. 244. Hereinafter referred to as NASEM, "Chapter 9: Synthesis and Research Strategy."

[138] Ibid, p. 62.

[139] Cross et al., *Strategy for NOAA Carbon Dioxide Removal Research*, pp. 76-77. The term *co-production* is not defined in the strategy, in statute, or federal regulation. The Merriam-Webster Dictionary defines coproduce as "to produce something jointly." NASEM defines co-production as "a methodology that leverages the expertise of practitioners and community members to develop holistic solutions to multifaceted problems at the intersection of society and the environment" (NASEM, "Co-Production of Environmental Knowledge, Methods, and Approaches," https://www.nationalacademies.org/our-work/co-production-of-environmental-knowledge-methods-and-approaches).

[140] Ibid., p. 80.

[141] H.R. 3764 and H.R. 8013 in the 117th Congress.

Mechanisms could include the establishment of working groups with federal and nonfederal participants, the creation of advisory councils with nonfederal members, continued funding of nonfederal research or stakeholder outreach and engagement through existing programs, or other means.

In addition, some stakeholders have argued for greater collaboration between the United States and international research communities. For example, NASEM states that "it is critical that research in [the mCDR] area be international" for multiple reasons, including for "social legitimacy, for research that is applicable to multiple cultural and geographic contexts, and for research that addresses the priorities of communities where [mCDR] may be used."[142] As noted above, some federal agencies are already working with international partners in working groups or on individual projects.[143] For example, the Blue Carbon Scientific Working Group aspires to create international standards for quantifying and monitoring coastal blue carbon and for data collection, quality control, and archiving, ultimately allowing data collected in various countries to be comparable and useful in a regional or global context.[144] Some Members of Congress have introduced legislation that would require federal agencies to plan work with international partners; for example, the Carbon Dioxide Removal Research and Development Act of 2023 (H.R. 5457/S. 2812) would require the Office of Science and Technology Policy to establish a plan for international coordination on CDR RD&D, in coordination with DOE and the Department of State. Congress also might consider whether certain agencies should be directed to work with international stakeholders on coastal blue carbon science through existing mechanisms or new agreements. Congressional direction could require international collaboration on certain topics related to blue carbon, either multilaterally or through an international organization.

Funding for Coastal Blue Carbon Science

Congress may consider whether and, if so, how much federal funding is needed to advance coastal blue carbon science and whether existing funding is sufficient. Federal agency coastal blue carbon science activities occur under various authorities and budget line items, making it difficult to estimate how much Congress has appropriated for blue carbon activities and how much federal agencies have spent on such activities. Some agencies, such as DOE, have developed a CDR-focused cross-agency crosscut.[145] Some groups have advocated for mechanisms to track carbon dioxide removal, including coastal blue carbon science, activities across agencies more broadly. For example, one group recommended that the President require the Office of Management and Budget (OMB) to "conduct an annual budget crosscut of CDR RD&D budget proposals as part of the President's budget formulation process" and publish the crosscut in supporting documents for the President's budget.[146] Some Members have introduced legislation, including S. 2002 in the 118th Congress, directing OMB to conduct an annual review of agency-requested budgets for CDR activities to "ensure that [CDR-related] budget proposals … are integrated within the overall budget for each Federal department and agency

[142] NASEM, "Chapter 9: Synthesis and Research Strategy," p. 245.

[143] See section entitled "Federal Agency Research Coordination and Collaboration on Coastal Blue Carbon Ecosystems."

[144] The Blue Carbon Initiative, "Blue Carbon Scientific Working Group," https://www.thebluecarboninitiative.org/scientific-working-group.

[145] DOE, *FY2024 Department of Energy Crosscuts Overview,* https://www.energy.gov/sites/default/files/2023-03/doe-fy2024-budget-volume-2-crosscutting-v3.pdf. A crosscut budget is typically a document that organizes and reports the activities and funding of several entities working within the same broad initiative in a way that *cuts across* organizational boundaries.

[146] EFI, *Clearing the Air,* p. 157.

participating."[147] Congress also may consider directing federal agencies to estimate their coastal blue carbon science-related proposed or actual spending through crosscut budgets, or other mechanisms, at the agency level or across agencies.[148]

Congress has directed some federal agencies to utilize appropriations for blue carbon science-related activities; for instance, for FY2025, the House Appropriations Committee would direct NOAA to "support the blue carbon research program, to advance NOAA's work to assess the carbon sequestration potential of various coastal habitats, account for regional differences," among other tasks.[149] Some stakeholders contend that increased funding to certain federal agencies or specific federal programs would improve understanding of coastal blue carbon ecosystems. One group has advocated for additional funding for NSF, and other agencies, to support fundamental research focused on understanding carbon sequestration in coastal ecosystems, such as those that support blue carbon.[150] In another example, NOAA's *Strategy for NOAA CDR Research* identified increased funding for the agency's Coastal Change Analysis Program as a way to improve seagrass meadow mapping.[151] Several Members introduced H.R. 7106 in the 118th Congress that would broaden the eligible uses of the National Oceans and Coastal Security Fund, an account funded by appropriations and nongovernmental contributions, to include projects related to "procedures and accounting methodology to quantify blue carbon benefits."[152] Some stakeholders may argue that funding should instead support higher-priority topics; for example, in deliberations on the FY2025 budget, the House Appropriations Committee noted that "many agencies with important missions are subject to reductions [in the proposed bill], because Congress must act immediately to reverse the unsustainable growth of the Federal Government."[153]

Some experts have estimated the cost of conducting coastal blue carbon research activities more broadly. For example, NASEM estimated that basic research, development, demonstration, and deployment of a coastal blue carbon research agenda would require at least $65 million per year for up to 20 years across agencies such as DOE, EPA, FS, FWS, NASA, NOAA, NSF, and USACE.[154] Another group estimated that $769 million would be needed over 10 years to fund coastal blue carbon-related RD&D across NASA, NOAA, NSF, and USACE.[155] In addition, stakeholders have proposed that Congress provide new multiyear authorizations to guide future appropriations that support coastal blue carbon science.[156] Some Members of Congress have introduced legislation that would authorize appropriations for agency CDR activities; for example, H.R. 5457/S. 2812 would authorize up to $105 million per year from FY2024 to

[147] H.R. 843 and S. 8013 in the 117th Congress.

[148] For an example of a crosscut budget report focused on actual spending, see OMB, *Chesapeake Bay Restoration Spending Crosscut*, December 2023, at https://www.whitehouse.gov/wp-content/uploads/2024/01/Final-2023-Chesapeake-Bay-Crosscut.pdfhttps://www.whitehouse.gov/wp-content/uploads/2024/01/Final-2023-Chesapeake-Bay-Crosscut.pdf.

[149] U.S. Congress, House Appropriations Committee, *Commerce, Justice, Science, and Related Agencies Appropriations Bill, 2025*, Report Together with Minority Views to Accompany H.R. 9026, 118th Cong., 2nd sess., July 11, 2024, H.Rept. 118-582 , p. 29. Hereinafter H.Rept. 118-582.

[150] EFI, *Clearing the Air*, p. 81.

[151] Cross et al., *Strategy for NOAA Carbon Dioxide Removal Research*, p. 47.

[152] §2 of H.R. 7106 defines *blue carbon benefits* as "the carbon sequestered and stored by coastal and marine ecosystems, including salt marshes, mangroves, and seagrasses."

[153] H.Rept. 118-582, p. 2.

[154] NASEM, "Chapter 2: Coastal Blue Carbon," pp. 76-77.

[155] EFI, *Clearing the Air*, p. 192.

[156] Ibid., p. 156.

FY2033 for NOAA's CDR RD&D activities. Congress also may consider whether to modify the amount of funding it authorizes and appropriates toward existing or new coastal blue carbon science activities. It may determine whether to do so through existing budget line items or to direct agencies to form new coastal blue carbon science-related line items. In addition, Congress may consider other funding mechanisms to support coastal blue carbon science, such as fees collected for certain private activities.[157]

Stakeholders have identified other ongoing challenges related to research funding, including administrative constraints on funding duration and mechanisms (e.g., limitations on type of institution or cross-agency transfer of funds).[158] Congress may consider whether to grant federal agencies the ability to combine available funding to prioritize research needs or set up other mechanisms for agencies to use federal funding for coastal blue carbon science. For example, Congress might consider authorizing an agency to transfer funding to other agencies to conduct blue carbon science. The transfers could be based on research needs articulated by an interagency task force or working group.[159]

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[157] For example, fees for recreation in conserved or restored coastal blue carbon ecosystems. Experts also have discussed other potential avenues, such as bonds, payments for ecosystem services, and ecosystem service insurance, among others (Daniel A. Friess et al., "Capitalizing on the Global Financial Interest in Blue Carbon," *PLOS Climate*, vol. 1, no. 8 (2022)).

[158] Williams et al., *2022 North American Carbon Program Science Implementation Plan*, p. 143.

[159] For example, Congress provided EPA the authority to pass through funding from its Great Lakes Restoration Initiative to other federal agencies involved in the effort, in line with an interagency action plan (11 U.S.C. §1268(c)(7)(D)(ii)).