U.S. Fish and Wildlife Service

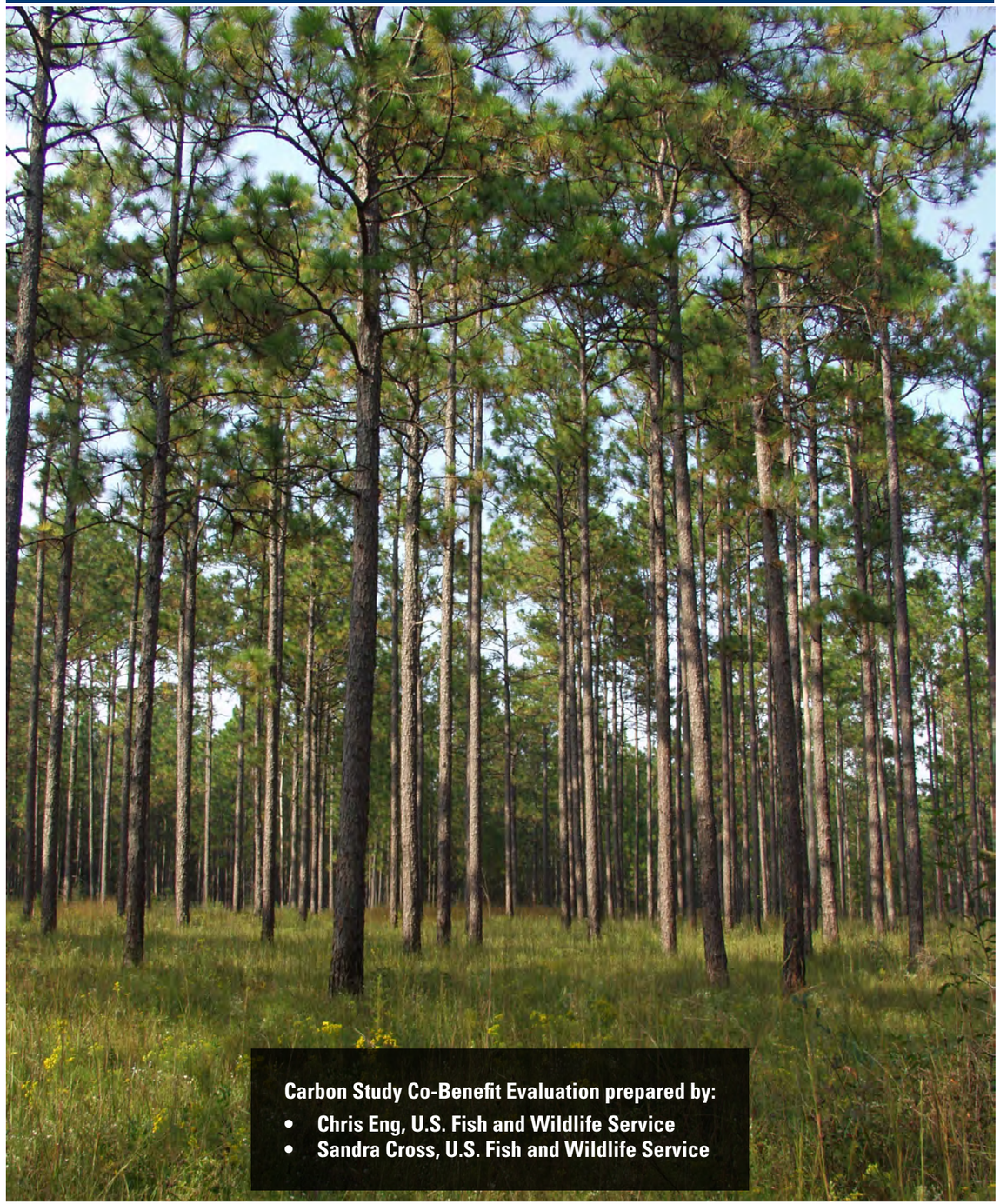
Coastal Program

Carbon Study

Data & Methods

Carbon Study

Data & Methods



Carbon Study Co-Benefit Evaluation prepared by:

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(Opposite Page) Longleaf pine forest / Randy Browning, USFWS

Nature-based Solutions

The U.S. Fish and Wildlife Service (Service) is responsible for managing more than 1,335,937 mi^2 (3,460,060 km^2) of terrestrial and marine habitat, including national wildlife refuges and marine protected areas. In addition, the Service has conservation delivery programs, such as the Coastal Program and Fish Passage Program, that work with partners and communities to implement habitat improvement and protection projects on public and private lands.

The Service has long recognized the importance of natural habitats and the goods and services supported by these habitats. In 2023, the Service formally adopted nature-based solutions (NbS) and other climate-smart conservation practices to improve the resilience of our Nation's lands, waters, wildlife, and communities in the face of increasing climate impacts. Informed by science and indigenous knowledge, NbS are actions that protect, manage, and restore natural goods and services to address societal challenges for the benefit of nature and people.

NbS is fundamental to the Coastal Program's delivery of on-the-ground conservation. Working with partners and communities, we use NbS to:

- Protect natural habitats that provide natural goods and services,
- Improve natural habitats to restore natural goods and services,
- Avoid greenhouse gas emissions associated with land use changes, and
- Help communities plan for and adapt to climate impacts.

As we increase our support of NbS, we are evaluating how we can maximize the natural goods and services delivered by our conservation efforts. We are also supporting the broader integration of NbS among Service programs by participating in the NbS Working Group and Enterprise Emissions Working Group, among other efforts.

Mangroves provide many ecosystem services, including carbon storage, flood protection, and fish and wildlife habitat.

A Conservation Leader

that works with communities to voluntarily protect and improve habitats that benefit fish, wildlife, and people. We also develop resources for decision makers, land managers, and restoration practitioners to better manage and deliver habitat conservation. By working together, we sustain the people and wildlife that rely on coastal and marine ecosystems.

Our Mission

is to achieve voluntary habitat conservation by providing technical and financial assistance, in collaboration with partners, for the benefit of federal trust species.

Working with Communities

along our nation's coasts, we conserve habitat on public and private lands to deliver landscape conservation, build resilient coasts and communities, and maintain habitat connectivity and continuity, from headwater streams to the ocean.

Find the Coastal Program online:

Webpage
bit.ly/3T1hptX

YouTube
bit.ly/3SKI7FF

(Opposite Page) Red Mangrove / Caroline Rogers, USGS

Introduction

Introduction

In collaboration with partners, the Coastal Program implements voluntary habitat conservation (e.g., habitat protection and improvement) on public and private lands. Our conservation benefits fish and wildlife and often provides a wide range of natural goods and services that benefit people, such as clean air, flood protection, and recreational opportunities. An often-overlooked benefit of conservation is the removal and storage of atmospheric carbon dioxide.

Carbon dioxide is the primary greenhouse gas released through human activities that contributes to climate change and ocean acidification. Natural habitats have an important role in mitigating carbon dioxide and other greenhouse gases. The Coastal Program and the broader conservation community have a responsibility to protect and improve habitats that support these natural services.

In 2022, the Coastal Program conducted a carbon study that evaluated carbon co-benefits delivered by a suite of habitat protection and improvement accomplishments completed between 2010 and 2020. We worked with the U.S. Geological Survey on the evaluation and consulted with other experts regarding carbon-related topics, including sequestration rates and stocks. A list of our partners and other experts who assisted with the carbon evaluation is provided in Appendix A.

Purpose

Thin-layer placement restores tidal marsh elevations and allows subsiding marshes to continue to sequester carbon.

Purpose

The purpose of the carbon study, which includes this data and methods document as well as a co-benefit evaluation, is to demonstrate the importance of habitat conservation in removing atmospheric carbon dioxide and more broadly mitigating a significant cause of climate change. By evaluating and communicating carbon co-benefits, the conservation community can engage a broader audience, better advocate for conservation, and maximize conservation benefits.

The *Coastal Program Carbon Study – Data & Methods* provides a detailed description of the data, data management decisions, and other steps used to calculate carbon co-benefits, including carbon sequestration rates and stocks. The carbon study results are provided in the *Coastal Program Carbon Study – Co-Benefit Evaluation*, which includes an abbreviated description of our methods. The reason for preparing separate documents is because the study methods are specific to the Coastal Program; however, the information can serve as a model for others seeking to evaluate the carbon co-benefits delivered by their habitat conservation.

Thin-layer sediment placement at Blackwater National Wildlife Refuge, Maryland / Dave Harp

Carbon Study

Evaluating carbon co-benefits associated with habitat conservation can be a nuanced process, so we established the following study conditions to make a large-scale evaluation possible. In addition, an overview of the study process is provided in Figure 1.

The study:

- **Evaluates only carbon dioxide co-benefits – the study does not evaluate other greenhouse gases (e.g., methane and nitrous oxide).**
- **Estimates annually sequestered carbon for habitat improvement accomplishments.**
- **Estimates annually sequestered carbon and total carbon stock for habitat protection accomplishments.**
- **Excludes carbon emissions associated with natural processes and conservation treatments, such as in the case of prescribed fires.**
- **Avoids comparison of carbon sequestration and storage potentials between impaired habitats and improved habitats, such as comparing carbon sequestration rates of invasive and native plants.**
- **Assumes annual carbon sequestration rates and stocks are uniform within regions and habitat types.**
- **Assumes habitats are functioning at a typical carbon storage and/or sequestration capacity.**

Data Management

The carbon study relied on accomplishment data in the Habitat Information Tracking System (HabITS) – a web-based, geo-spatial, project database that is only available to Service employees. The term "accomplishment" is specifically used by HabITS and is generally equivalent to the term "project". We reviewed accomplishment data, including ecological classifications and conservation treatments, to determine which accomplishments provide carbon co-benefits.

The following section describes the data conditions we established to work with the large and diverse dataset that was not designed specifically to evaluate carbon co-benefits. Future evaluations should review our data decisions to verify their applicability and review the new accomplishments for data conditions not represented in this study.

Accomplishment Data

The Coastal Program used conservation accomplishments from fiscal years 2010 to 2020 for this study. We queried the following information from HabITS:

- **Accomplishment Acres**
- **Accomplishment Completion Fiscal Year**
- **Accomplishment Miles**
- **Accomplishment Name**
- **Accomplishment Narrative**
- **Accomplishment Number**
- **Accomplishment Type**
- **Ecological Classification**
- **Habitat Type**
- **Physical State**
- **Program Name**
- **Project Narrative**
- **Treatment Category**
- **Treatment Name**

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Figure 1. Overview of Study Methods

Step 1	**Export HabITS accomplishment data for selected fiscal years.**
Step 2	**Review the exported data and compile a list of accomplishment types, ecological classifications, treatment categories, and physical (i.e., geographic) state.**
Step 3	**Determine which accomplishment types maintain or improve carbon co-benefits.**
Step 4	**Determine which ecological classifications support carbon co-benefits.**
Step 5	**Determine which treatments maintain or improve carbon co-benefits.**
Step 6	**Identify accomplishments that provide carbon co-benefits based on the data decisions above.**
Step 7	**Determine area of protected or improved habitat(s).**
Step 8	**Identify carbon sequestration rate and/or stock for the habitat(s) and accomplishment location(s).**
Step 9	**Calculate total carbon stock and/or annually sequestered carbon.**

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Beaches

Maritime Forests

For the study, we included accomplishments that met the data conditions and had all the necessary data to estimate carbon co-benefits. We excluded accomplishments reported in miles (e.g., re-opened stream accomplishments) because we could not estimate carbon co-benefits based on a linear measurement; however, we included this parameter in the query because it may be useful for future evaluations.

Accomplishment Type

In HabITS, accomplishment type identifies a broad category of conservation activities (e.g., protection and improvement) that can be implemented as an accomplishment. Habitat improvement refers to assessment, enhancement, establishment, maintenance, and restoration accomplishments. Not all accomplishment types were included in the study; we included the following accomplishment types:

- Protection
- Enhancement
- Restoration

We excluded certain accomplishment types for the following reasons:

- **Assessment activities** evaluate habitat conditions that can support future habitat protection or improvement accomplishments. These activities may not result in on-the-ground actions and therefore will not deliver carbon co-benefits. If an activity leads to on-the-ground action, the action will have a different accomplishment type.
- **Establishment activities** manipulate existing physical, chemical, or biological habitat characteristics to create new habitat conditions that did not previously exist in an area. We did not determine when these newly created habitats would reach their full carbon co-benefit potential.
- **Maintenance activities** maintain habitat conditions implemented by prior conservation accomplishments. We excluded these accomplishments to prevent double counting of carbon co-benefits delivered by another accomplishment.

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Rocky Outcrops

Tidal Flats

Ecological Classification

In HabITS, ecological classifications are primarily based on ecosystems identified in NatureServe Explorer. After reviewing NatureServe's ecosystem descriptions, we grouped ecological classifications with similar characteristics into broader habitat categories and determined which categories to include in the evaluation (Appendix B).

We excluded some habitat categories from the evaluation (Appendix C). These categories and their associated ecological classifications were excluded for the following reasons:

- **Aquatic beds** have highly variable habitat or vegetation conditions that make it difficult to use uniformed carbon sequestration rates and stocks.
- Beaches have a low carbon co-benefit potential based on soil conditions and plant species.
- Certain **maritime forests** have highly variable habitat or vegetation conditions that make it difficult to use uniformed carbon sequestration rates and stocks.
- **Mixed habitats** have highly variable habitat or vegetation conditions that make it difficult to use uniformed carbon sequestration rates and stocks.
- **Rocky outcrops** have a low carbon co-benefit potential based on soil conditions and plant species.
- **Tidal flats** have a low carbon co-benefit potential based on soil conditions and plant species.
- **Water** has an unknown carbon co-benefit potential based on the represented ecosystem descriptions.

There were several situations where we placed an ecological classification from an excluded habitat category into an included habitat category based on the classification description. For example, we categorized Alaskan Pacific Maritime Mountain Hemlock Forest as Upland Forest based on the U.S. Department of Agriculture's Forest Service description; even though we excluded other maritime habitats. The vegetation composition for the Alaskan Pacific Maritime Mountain Hemlock Forest is more characteristic of an upland forest than other maritime habitats.

(Opposite Page) Beach, Puerto Rico / Chris Eng, USFWS and Maritime forest on Cumberland Island National Seashore, Georgia / National Park Service
(Current Page) Rocky outcrop at Farallon Island National Wildlife Refuge, California / Eric Davis, USFWS and Tidal flat, Alaska / Firefly Imageworks, Inc.

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Fire management treatments were excluded from the carbon study.

Conservation Treatments

In HabITS, treatments describe specific conservation actions or techniques, such as floodplain reconnections or tree plantings, that were implemented for an accomplishment. HabITS organizes these treatments into broader treatment categories. We reviewed each treatment and associated accomplishment narratives to determine if they deliver carbon co-benefits.

We included all habitat protection accomplishments in this study, including those without an identified treatment, because regardless of the treatment, a protected habitat will continue to sequester carbon and maintain carbon stocks.

For habitat improvement accomplishments, we included treatments listed in Appendix D. We excluded improvement (e.g., restoration) accomplishments without an identified treatment, because we could not determine if carbon co-benefits were delivered by the treatment. We also excluded treatments that provide no, low, or undetermined carbon co-benefits (Appendix E).

The following are our reasons for excluding certain treatments under these treatment categories:

- **Assessments** under treatments do not result in carbon co-benefits.
- **Fencing treatments** may be implemented for reasons (e.g., invasive wildlife exclusion and restricted cave access) that may not result in carbon co-benefits.
- **Fire management treatments** were excluded because we could not determined when the habitats would reach their full carbon co-benefit potential.
- **Fish and aquatic species passage treatments** are typically reported in miles, which prevents us from making carbon co-benefit estimates without making assumptions about the conservation area.
- **Grazing and farm management treatments** can improve grass productivity and carbon sequestration; however, our grazing treatments are primarily associated with planning so they were excluded from the study. In addition, certain treatments (e.g., stream crossing and watering facility) do not result in carbon co-benefits.
- **Hazard removal treatments** (e.g., garbage and derelict gear removal) may not result in carbon co-benefits.
- **Human use exclusion or restriction treatments** may not result in carbon co-benefits.
- **Infrastructure removal treatments** (e.g., infrastructure removal and solid waste cleanup) may not directly result in carbon co-benefits.
- Certain **instream modification treatments** (e.g., nesting island and tree and shrub clearing) may not directly result in carbon co-benefits.
- **Invasive species control treatments** were excluded because certain treatments (e.g., animal biological control) may not result in carbon co-benefits. For other treatments (e.g., chemical plant control), we did not confirm an improvement in carbon co-benefits between the native and invasive vegetation.
- **Living shoreline treatments** (e.g., beach nourishment and feeder bluff activation) may not result in carbon co-benefits. However, other treatments implemented adjacent to living shoreline accomplishments may be included in the evaluation.
- Certain **planting treatments** (e.g., mulching and plant nursery) were excluded because these treatments may not result in carbon co-benefits.
- **Recreation and education treatments** (e.g., interpretive signs and recreational trails) do not result in carbon co-benefits.
- **Species translocations** may not result in carbon co-benefits.
- **Wildlife habitat structures** (e.g., hibernacula and nest boxes) do not result in carbon co-benefits.

Forest prescribed burn, South Carolina / Senior Airman Jensen Stidham, U.S. Air Force

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Wildlife habitat structures were excluded from the carbon evaluation.

Alpamado falcon nesting platform, Texas / Ken Rice

Planting native vegetation and other conservation treatments can improve carbon sequestration.

Although we may have excluded some accomplishments from the evaluation that could provide carbon co-benefits, broad study assumptions and decisions were necessary to work with a large dataset not designed specifically to evaluate carbon co-benefits. Furthermore, we sought to be conservative with our estimate and not overstate or misrepresent our carbon co-benefits. Despite excluding certain treatments, an accomplishment may have other treatments that are included in the study.

Carbon Sequestration Analysis

The following section describes the steps, data, and considerations we used to estimate carbon co-benefits for our habitat protection and improvement accomplishments.

Carbon Sequestration Rates and Stocks

We conducted literature searches and consulted experts to identify carbon sequestration rates and stocks for each habitat category. Once we selected the rates and stocks, we standardized units and established a reasonable scale (e.g., state or region) to apply rates and stocks based on the source and experts (Table 1). The rates and stocks in Table 1 were rounded to the nearest whole number, because a higher level of precision was not necessary for the scope of this study. Full literature citations for the rates and stocks are provided in Appendix F, including specific chapters for the ***Second State of The Carbon Cycle Report***. It may be useful to know that a metric ton (i.e., MT) is equal to a mega gram (i.e., Mg).

Students planting native vegetation at a schoolyard habitat project, California / USFWS

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Table 1. Carbon Sequestration Rates and Stocks

Habitats	Geography	Carbon Sequestration Rate (MTC/km²yr)	Carbon Sequestration Stock (MTC/km²)
Tidal Saltwater Wetlands & Tidal Freshwater, Non-Forested Wetlands [a]	Alaska	301 [b]	62,741 [c]
	California	104	32,000
	Lower Mississippi	272	34,000
	Mid-Atlantic	177	45,000
	New England	151	39,000
	Pacific Northwest	110	37,000
	South Atlantic (Gulf Coast)	124	34,000
	Texas	238	39,000
Tidal Freshwater Forested Wetlands & Forested Wetlands [b]	CONUS*	67	19,065
	Alaska	57	49,798
	Puerto Rico	120	20,000
Upland Forests	Alaska	8 [b]	4,800 [c]
Upland Forests [d]	Central States	38	5,770
	Great Plains	8	1,160
	Northeast	55	7,090
	Northern Lake States	40	4,390
	Pacific Northwest (East)	45	4,610
	Pacific Northwest (West)	174	13,000
	Pacific Southwest	58	7,660
	Rocky Mountains (North)	-7	4,020
	Rocky Mountains (South)	-18	2,010
	South Central	90	5,370
	Southeast	96	5,950

Table 1. (continued)

Habitats	Geography	Carbon Sequestration Rate (MTC/km²yr)	Carbon Sequestration Stock (MTC/km²)
Grasslands [b]	CONUS	21	2,786
Non-Forested Peatlands [b]	CONUS	135	90,903
	Alaska	57	74,489
	Puerto Rico	375	125,000
Forested Peatlands [b]	CONUS	120	107,782
	Alaska	52	69,602
Non-Tidal, Non-Forested Wetlands [b]	CONUS	102	13,730
	Alaska	57	48,434
	Puerto Rico	119	23,810
Mangroves	Southwest Florida and Gulf of Mexico	98 [e]	31,800 [b]
Shrublands [b]	CONUS	21	2,786
Submerged Aquatic Vegetation [b]	Atlantic Coast	43 [f] (Global)	2,000
	Gulf of Mexico		3,100
	High Latitude Sub-Regions		2,000
	Pacific Coast		1,400
Tundras [b]	Alaska	N/A	729

* CONUS = Contiguous United States

(a) Wang, F., Lu, X., Sanders, C.J., et al. 2019. Tidal wetland resilience to sea level rise increases their carbon sequestration capacity in United States. Nat Commun 10, 5434. (https://doi.org/10.1038/s41467-019-13294-z).

(b) U.S. Global Change Research Program. 2018. Second State of the Carbon Cycle Report (SOCCR 2): A Sustained Assessment Report. [Cavallaro, N., G. Shrestha, R. Birdsey, M. A. Mayes, R. G. Najjar, S. C. Reed, P. Romero-Lankao, and Z. Zhu (Eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 878 pp., doi: 10.7930/SOCCR2.(https://carbon2018.globalchange.gov/).

(c) Zhu, Z., and McGuire, A.D. (Eds). 2016. Baseline and projected future carbon storage and greenhouse-gas fluxes in ecosystems of Alaska. U.S. Geological Survey Professional Paper 1826, 196 p. (http://dx.doi.org/10.3133/pp1826). Data derived from USGS LandCarbon Assessment and National Land Cover Database.

(d) Hoover, C.M., Smith, J.E. 2021. Current aboveground live tree carbon stocks and annual net change in forests of conterminous United States. Carbon Balance Manage 16, 17. (https://doi.org/10.1186/s13021-021-00179-2).

(e) Marchio, D.A.; Savarese, M.; Bovard, B.; Mitsch, W.J. 2016. Carbon Sequestration and Sedimentation in Mangrove Swamps Influenced by Hydrogeomorphic Conditions and Urbanization in Southwest Florida. Forests 2016, 7, 116. (https://doi.org/10.3390/f7060116)

(f) Hiraishi, T., Krug, T., Tanabe, K., Srivastava, et. al (Eds). 2014. IPCC, Switzerland 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (https://www.ipcc.ch/publication/2013-supplement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories-wetlands/).

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Building oyster reefs and similar nature-based solutions can protect existing carbon stocks.

Carbon Co-Benefit Calculations

We calculated annually sequestered carbon for habitat improvement accomplishments. We did not calculate total carbon stock for habitat improvement accomplishments, because we could not determine the existing state of carbon storage or level of habitat degradation. For habitat protection accomplishments, we calculated annually sequestered carbon and total carbon stock. The total area for habitat improvement and protection accomplishments by habitat category are provided in Appendix G.

Annually Sequestered Carbon:

$$\text{Annually Sequestered Carbon for a Habitat Conservation Accomplishment or Habitat Type} \left(\frac{\text{MTC}}{\text{yr}} \right) =$$

$$\text{Carbon Sequestration Rate} \left(\frac{\text{MTC}}{\text{km}^2\text{yr}} \right) \times \text{Accomplishment or Habitat Category Area (km}^2\text{)}$$

Total Carbon Stock:

$$\text{Total Carbon Stock for a Habitat Protection Accomplishment or Habitat Type (MTC)} =$$

$$\text{Carbon Sequestration Stock} \left(\frac{\text{MTC}}{\text{km}^2} \right) \times \text{Accomplishment or Habitat Category Area (km}^2\text{)}$$

Carbon Co-Benefit Results

As previously mentioned, the purpose of this decision document is to describe the data, data management decisions, and calculations for the carbon co-benefits. Study results, interpretation of carbon co-benefits, and translation of carbon co-benefits are provided in the *Coastal Program Carbon Study - Co-Benefit Evaluation*.

Volunteers helping to build an oyster reef, Maryland / Chesapeake Bay Environmental Center

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Appendix A

Study Partners and Experts

U.S. Fish and Wildlife Service

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Appendix B

Included Ecological Classifications and Habitat Categories

Carbon Sequestration Habitat Category	Ecological Classification
Forested Peatland	Alaskan Pacific Maritime Poorly Drained Conifer Woodland
	Atlantic Coastal Plain Peatland Pocosin and Canebrake
	North Pacific Hardwood-Conifer Swamp
	Northern Atlantic Coastal Plain Basin Peat Swamp
Non-Forested Peatland	Acadian Maritime Bog
	Alaskan Pacific Maritime Wet Low Shrubland
	Boreal-Laurentian Bog
	North-Central Appalachian Seepage Fen
	South Florida Everglades Sawgrass Marsh
Forested Wetland	Alaskan Pacific Maritime Floodplain Forest and Shrubland
	Atlantic Coastal Plain Blackwater Stream Floodplain Forest
	Atlantic Coastal Plain Brownwater Stream Floodplain Forest
	Atlantic Coastal Plain Small Blackwater River Floodplain Forest
	Atlantic Coastal Plain Small Brownwater River Floodplain Forest
	California Central Valley Riparian Woodland and Shrubland
	Caribbean Floodplain Forest
	Caribbean Riparian Forest and Shrubland
	East Gulf Coastal Plain Freshwater Tidal Wooded Swamp
	East Gulf Coastal Plain Southern Loblolly-Hardwood Flatwoods
	Laurentian-Acadian Alkaline Conifer-Hardwood Swamp
	North Pacific Lowland Riparian Forest and Shrubland
	North Pacific Montane Riparian Woodland and Shrubland
	North-Central Interior Wet Flatwoods
Forested Wetland	Northern Atlantic Coastal Plain Basin Swamp and Wet Hardwood Forest
	Northern Atlantic Coastal Plain Pond
	Red River Large Floodplain Forest
	South Florida Hydric Hammock
	Southern Atlantic Coastal Plain Large River Floodplain Forest
	Southern Atlantic Coastal Plain Non-riverine Swamp and Wet Hardwood Forest
	Southern Atlantic Coastal Plain Wet Pine Savanna and Flatwoods
	Southern Coastal Plain Blackwater River Floodplain Forest
	Southern Coastal Plain Non-riverine Cypress Dome
	Southern Piedmont Small Floodplain and Riparian Forest
	West Gulf Coastal Plain Large River Floodplain Forest
	West Gulf Coastal Plain Small Stream and River Forest
	Western North American Boreal Riparian Stringer Forest and Shrubland
Grassland	California Central Valley and Southern Coastal Grassland
	California Central Valley Mixed Oak Savanna
	California Mesic Serpentine Grassland
	California Northern Coastal Grassland
	Central and Upper Texas Coast Dune and Coastal Grassland
	Florida Dry Prairie
	Great Lakes Wet-Mesic Lakeplain Prairie
	North Pacific Herbaceous Bald and Bluff
	Tamaulipan Savanna Grassland
	Willamette Valley Upland Prairie and Savanna

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Included Ecological Classifications and Habitat Categories

Carbon Sequestration Habitat Category	Ecological Classification
Mangrove	Caribbean Estuarine Mangrove Forest
	Caribbean Maritime Shore/Estuary Mouth Mangrove
	South Florida Mangrove Swamp
	Southwest Florida Perched Barriers Tidal Swamp and Lagoon
Non-Tidal Non-Forested Wetland	Alaska Arctic Wet Sedge Meadow
	Alaskan Pacific Maritime Coastal Meadow and Slough-Levee
	Alaskan Pacific Maritime Fen and Wet Meadow
	Alaskan Pacific Maritime Shrub and Herbaceous Floodplain Wetland
	Caribbean Freshwater Marsh
	Florida River Floodplain Marsh
	Floridian Highlands Freshwater Marsh
	Great Lakes Freshwater Estuary and Delta
	Laurentian-Acadian Freshwater Marsh
	Laurentian-Acadian Wet Meadow-Shrub Swamp
	Mediterranean California Coastal Interdunal Wetland
	North-Central Interior Freshwater Marsh
	North-Central Interior Wet Meadow-Shrub Swamp
	Northern Great Lakes Coastal Marsh
	Piedmont Seepage Wetland
	South Florida Depression Pondshore
	Southern Atlantic Coastal Plain Depression Pondshore
	Temperate Pacific Freshwater Emergent Marsh
	Texas-Louisiana Coastal Prairie
Non-Tidal Non-Forested Wetland	Texas-Louisiana Coastal Prairie Pondshore
	Texas-Louisiana Coastal Prairie Slough
	Western North American Boreal Shrub and Herbaceous Floodplain Wetland
Shrubland	Alaskan Pacific Maritime Subalpine Alder-Salmonberry Shrubland
	California Maritime Chaparral
	California Mesic Chaparral
	Caribbean Coastal Thornscrub
	Caribbean Montane Wet Short Shrubland
	Florida Peninsula Inland Scrub
	North Pacific Hypermaritime Shrub and Herbaceous Headland
	North-Central Oak Barrens
	Northern and Central California Dry-Mesic Chaparral
	Northern Atlantic Coastal Plain Heathland and Grassland
	Northern California Coastal Scrub
	Southern California Coastal Scrub
	Southern California Dry-Mesic Chaparral
	Tamaulipan Mixed Deciduous Thornscrub
Submerged Aquatic Vegetation	Atlantic Coastal Plain Embayed Region Seagrass Bed
	Atlantic Coastal Plain Indian River Lagoon Seagrass Bed
	Florida Keys Seagrass Bed
	Mediterranean California Eelgrass Bed
	North Pacific Maritime Eelgrass Bed
	Northern Atlantic Coastal Plain Seagrass Bed

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Included Ecological Classifications and Habitat Categories

Carbon Sequestration Habitat Category	Ecological Classification
Submerged Aquatic Vegetation	Northern Gulf of Mexico Seagrass Bed
	Southern Coastal Plain Spring-run Stream Aquatic Vegetation
Tidal Freshwater Forested Wetland	Northern Atlantic Coastal Plain Tidal Swamp
Tidal Freshwater Non-Forested Wetland	Atlantic Coastal Plain Embayed Region Tidal Freshwater Marsh
	Caribbean Emergent Herbaceous Estuary
	Central and Upper Texas Coast Fresh and Oligohaline Tidal Marsh
	Florida Big Bend Fresh and Oligohaline Tidal Marsh
	Hawaii Freshwater Marsh
	Mississippi Delta Fresh and Oligohaline Tidal Marsh
	North Pacific Intertidal Freshwater Wetland
	Northern Atlantic Coastal Plain Fresh and Oligohaline Tidal Marsh
	Southeastern Coastal Plain Interdunal Wetland
	Southern Atlantic Coastal Plain Fresh and Oligohaline Tidal Marsh
Tidal Saltwater Wetland	Acadian Coastal Salt Marsh
	Acadian Estuary Marsh
	Alaska Arctic Tidal Marsh
	Atlantic Coastal Plain Embayed Region Tidal Salt and Brackish Marsh
	Atlantic Coastal Plain Indian River Lagoon Tidal Marsh
	Central and Upper Texas Coast Salt and Brackish Tidal Marsh
	Florida Big Bend Salt and Brackish Tidal Marsh
	Gulf Coast Chenier Plain Salt and Brackish Tidal Marsh
	Mississippi Delta Salt and Brackish Tidal Marsh
Tidal Saltwater Wetland	Mississippi Sound Salt and Brackish Tidal Marsh
	Northern Atlantic Coastal Plain Brackish Tidal Marsh
	Northern Atlantic Coastal Plain Tidal Salt Marsh
	Southern Atlantic Coastal Plain Salt and Brackish Tidal Marsh
	Temperate Pacific Tidal Salt and Brackish Marsh
	Texas Saline Coastal Prairie
Tundra	Acadian-Appalachian Alpine Tundra
Upland Forest	Acadian Low-Elevation Spruce-Fir-Hardwood Forest
	Alabama Ketona Glade and Woodland
	Alaska Sub-boreal White Spruce-Hardwood Forest
	Alaskan Pacific Maritime Mountain Hemlock Forest
	Alaskan Pacific Maritime Sitka Spruce Forest
	Alaskan Pacific Maritime Western Hemlock Forest
	Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland
	Atlantic Coastal Plain Upland Longleaf Pine Woodland
	Boreal Aspen-Birch Forest
	California Coastal Closed-Cone Conifer Forest and Woodland
	California Coastal Live Oak Woodland and Savanna
	California Coastal Redwood Forest
	Caribbean Coastal Dry Evergreen Forest
	Caribbean Lowland Dry Semi-deciduous Forest
	Caribbean Seasonal Evergreen Lowland Forest

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Included Ecological Classifications and Habitat Categories

Carbon Sequestration Habitat Category	Ecological Classification	Carbon Sequestration Habitat Category	Ecological Classification
Submerged Aquatic Vegetation	Northern Atlantic Coastal Plain Subtidal Aquatic Bed	Upland Forest	North Pacific Mesic Western Hemlock-Silver Fir Forest
			North Pacific Mesic Western Hemlock-Yellow-cedar Forest
Upland Forest	Caribbean Wet Montane Forest		North Pacific Oak Woodland
	Caribbean Wet Submontane/Lowland Forest		North-Central Interior Beech-Maple Forest
	Central and South Texas Coastal Fringe Forest and Woodland		North-Central Interior Dry Oak Forest and Woodland
	Central and Southern California Mixed Evergreen Woodland		North-Central Interior Maple-Basswood Forest
	Central Appalachian Dry Oak-Pine Forest		Northeastern Interior Dry-Mesic Oak Forest
	East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest		Northeastern Interior Pine Barrens
	East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland		Northern Atlantic Coastal Plain Hardwood Forest
	East-Central Texas Plains Post Oak Savanna and Woodland		Northern Atlantic Coastal Plain Pitch Pine Barrens
	Florida Longleaf Pine Sandhill		Piedmont Hardpan Woodland and Forest
	Laurentian-Acadian Northern Hardwoods Forest		South Florida Hardwood Hammock
	Laurentian-Acadian Northern Pine-(Oak) Forest		South Florida Pine Flatwoods
	Laurentian-Acadian Pine-Hemlock-Hardwood Forest		South Florida Pine Rockland
	Mediterranean California Mixed Evergreen Forest		Southern Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest
	Mediterranean California Mixed Oak Woodland		Southern Atlantic Coastal Plain Mesic Hardwood Forest
	North Pacific Broadleaf Landslide Forest and Shrubland		Southern California Oak Woodland and Savanna
	North Pacific Dry Douglas-fir-(Madrone) Forest and Woodland		Southern Coastal Plain Dry Upland Hardwood Forest
	North Pacific Hypermaritime Western Red-cedar-Western Hemlock Forest		Southern Coastal Plain Oak Dome and Hammock
	North Pacific Lowland Mixed Hardwood-Conifer Forest		Southwest Florida Coastal Strand and Maritime Hammock
	North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest		West Gulf Coastal Plain Chenier and Upper Texas Coastal Fringe Forest and Woodland
	North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest		

Carbon Study
Appendix C

Excluded Ecological Classifications and Habitat Categories

Carbon Sequestration Habitat Category	Ecological Classification	Carbon Sequestration Habitat Category	Ecological Classification
Aquatic Bed	Temperate Pacific Freshwater Aquatic Bed	Maritime Forest	Northern Atlantic Coastal Plain Dune and Swale
Beach	Alaskan Pacific Maritime Coastal Dune Beach and Beach Meadow		Southeast Florida Coastal Strand and Maritime Hammock
	Caribbean Coastal Sandy Shore		Southern Atlantic Coastal Plain Maritime Forest
	Caribbean Stabilized Sand Dune		Southern Atlantic Coastal Plain Tidal Wooded Swamp
	East Gulf Coastal Plain Dune and Coastal Grassland	Maritime Shrubland	South Texas Lomas
	Florida Panhandle Beach Vegetation	Mixed Upland/Wetland	Central Appalachian River Floodplain
	Great Lakes Dune		Central Appalachian Stream and Riparian
	Great Lakes Wooded Dune and Swale		East Gulf Coastal Plain Near-Coast Pine Flatwoods
	Hawaii Dry Coastal Strand		Mediterranean California Foothill and Lower Montane Riparian Woodland
	Mediterranean California Northern Coastal Dune		Mediterranean California Serpentine Foothill and Lower Montane Riparian Woodland and Seep
	Mediterranean California Southern Coastal Dune		North-Central Interior Floodplain
	North Pacific Coastal Interdunal Wetland		Northern Atlantic Coastal Plain Maritime Forest
	North Pacific Maritime Coastal Sand Dune and Strand		Western North American Boreal Lowland Large River Floodplain Forest and Shrubland
	Northern Atlantic Coastal Plain Sandy Beach	Rocky Outcrops	Acadian-North Atlantic Rocky Coast
	South Florida Shell Hash Beach		Alaska Arctic Acidic Dwarf-Shrub Lichen Tundra
	South Texas Dune and Coastal Grassland		Alaskan Pacific Maritime Rocky Coastline
	Southeast Florida Beach		Caribbean Coastal Rocky Shore
	Southern Atlantic Coastal Plain Dune and Maritime Grassland		Great Lakes Alkaline Rocky Shore and Cliff
	Southern Atlantic Coastal Plain Sea Island Beach		Hawaii Alpine Bedrock and Scree
	Upper Texas Coast Beach		Mediterranean California Coastal Bluff
Maritime Forest	East Gulf Coastal Plain Maritime Forest	Tidal Flats	Caribbean Salt Flat and Pond
	Hawaii Mesic Coastal Forest		
	North Pacific Hypermaritime Seasonal Sitka Spruce Forest		

Carbon Study
Appendix C

Excluded Ecological Classifications and Habitat Categories

Carbon Sequestration Habitat Category	Ecological Classification	Carbon Sequestration Habitat Category	Ecological Classification
Tidal Flats	North Atlantic Tidal Sand Flat	Water	Hawaii Anchialine Pool
	South Texas Salt and Brackish Tidal Flat		Northern Atlantic Coastal Plain Stream and River
	Temperate Pacific Intertidal Flat		South Coastal California Vernal Pool
	Northern Atlantic Coastal Plain Tidal Swamp		

Carbon Study
Appendix D

Included Conservation Treatment Categories and Treatments

Treatment Category	Treatment	Treatment Category	Treatment
Instream Modification	Bank Armoring (e.g. rip-rap or concrete matting)	Vegetation Management	Mowing
Instream Modification Invasive Species Control	Bank Bioengineering (e.g. root wads or vegetation matting)	Water Management	Dike or Levee Construction
	Channel Creation or Relocation		Dike or Levee Removal or Improvement
	Channel Dimension Modification (e.g. channel dimension adjustments)		Ditch Plug
	Channel Planform Modification (e.g. beltwidth or radius of curvature)		Diversion or Headgate
	Channel Profile Modifications (e.g. reach or facet feature slope)		Drainage Tile Removal or Improvement
	Erosion Control Structure (e.g. cross vane or cribbing)		Drainage Management
	Floodplain Reconnection (e.g., bankfull bench)		Impoundment Construction or Repair
	Habitat Structure (e.g., spawning bed)		Irrigation System
	Riparian Habitat (e.g. oxbow, off-line pond, swale)		Moist Soil Management
	Streambank Stabilization		Pipeline
	Biological, Chemical, and Mechanical		Sediment Removal
Living Shoreline	Erosion Control Structure Construction or Improvement		Spring Development
Planting	Herbaceous Vegetation		Tidal Gate Installation or Removal
	Submerged Aquatic Vegetation		Tile Installation or Removal
	Trees or Shrubs		Water Control Structure Installation or Modification
	Vegetation Buffer		Water Pump System Installation or Modification
Vegetation Management	Chaining		Water Well
	Clearing and Snagging	Wildlife Habitat Structure	Reef Habitat Structure
	Disking		
	Dixie Harrow	N/A	Land Acquisition & Conservation Easement
	Forest Stand Improvement		

Carbon Study
Appendix E

Excluded Conservation Treatment Categories and Treatments

Treatment Category	Treatment	Treatment Category	Treatment
Assessment	Habitat Assessment	Infrastructure Removal	Land Reconstruction (e.g., abandoned mine or de-leveling)
Fencing	Cave Gate Installation		Pavement Removal
	Marking for Wildlife		Pier/dock removal
	Permanent		Shoreline Armoring Removal
	Temporary		Solid Waste Clean Up
Fire Management	Firebreak	Instream Modification	Habitat Structure (e.g., spawning bed)
	Fuel Reduction		Nesting Island and Sandbar
	Prescribed Burning		Stormwater and Sediment Management
Fish and Aquatic Species Passage	Barrier Bypass		Stream Crossing Improvements
	Barrier Installation		Tree and Shrub Clearing
	Barrier Modification	Invasive Species Control	Animal Biological
	Barrier Removal		Animal Chemical
	Fish Screen		Animal Mechanical
Grazing and Farm Management	Grazing Management Plan		Invasive Species Control (e.g., biological, chemical, or mechanical)
	Livestock Stream Crossing		
	Nutrient Management System		Plant Biological
	Runoff Management System		Plant Chemical
	Watering Facility		Plant Mechanical
Hazard Removal	Garbage Removal	Living Shorelines	Beach nourishment
	Light Levels Adjustment		Feeder bluff activation
	Derelict Gear Removal		Nesting Island Construction/Modification
Infrastructure Removal	Road Work (e.g., storm proofing or decommissioning)		Sand Dune Restoration
	Infrastructure Removal		Coral

Carbon Study
Appendix E

Excluded Conservation Treatment Categories and Treatments

Carbon Sequestration Habitat Category	Ecological Classification	Carbon Sequestration Habitat Category	Ecological Classification
Planting	Field Border/Hedgerow	Species Translocation	Oysters
	Mulching	Wildlife Habitat Structure	Hibernacula
	Plant Propagation/Nursery		Nest Boxes
	Site Preparation		Nesting Habitat Modification
	Woody Debris Establishment/Removal		Wildlife Escape Structure
Recreation and Education	Interpretive Sign		Human Use
	Recreation Trail and Walkway	N/A	Exclusion or Restriction
Species Translocation	Coral		
	Other		

Carbon Study
Appendix F

Carbon Sequestration Rates and Stocks from Source Literature

Habitats	Geography	Carbon Sequestration Rate	Carbon Sequestration Stock
Tidal Saltwater Wetlands & Tidal Freshwater Non-Forested Wetlands [a]	Alaska	301 $gC/m^2/yr$ [b1]	62,741 gC/m^2 [c]
	California	103.8 ± 8 $gC/m^2/yr$	0.032 gC/cm^3
	Lower Mississippi	271.9 ± 18 $gC/m^2/yr$	0.034 gC/cm^3
	Mid-Atlantic	176.5 ± 14 $gC/m^2/yr$	0.045 gC/cm^3
	New England	151.3 ± 11 $gC/m^2/yr$	0.039 gC/cm^3
	Pacific Northwest	110.2 ± 6 $gC/m^2/yr$	0.037 gC/cm^3
	South Atlantic (Gulf Coast)	123.6 ± 11 $gC/m^2/yr$	0.034 gC/cm^3
	Texas	237.8 ± 16 $gC/m^2/yr$	0.039 gC/cm^3
Tidal Freshwater Forested Wetlands & Forested Wetlands [b2]	CONUS*	6.70168E-05 $(TgC/yr)/km^2$	1.90651E-05 PgC/km^2
	Alaska	5.72681E-05 $(TgC/yr)/km^2$	4.97983E-05 PgC/km^2
	Puerto Rico	0.00012 $(TgC/yr)/km^2$	0.00002 PgC/km^2
Upland Forests	Alaska	7.99 $g/m^2/yr$ [c]	4.8 $PgC/106km^2$ [b3]
Upland Forests [d]	Northeast	0.55 tC/ha/yr	70.9 tC/ha
	Northern Lake States	0.4 tC/ha/yr	43.9 tC/ha
	South Central	0.9 tC/ha/yr	53.7 tC/ha
	Southeast	0.96 tC/ha/yr	59.5 tC/ha
	Central States	0.38 tC/ha/yr	57.7 tC/ha
	Great Plains	0.08 tC/ha/yr	11.6 tC/ha
	Rocky Mountains (North)	-0.07 tC/ha/yr	40.2 tC/ha
	Rocky Mountains (South)	-0.18 tC/ha/yr	20.1 tC/ha
	Pacific Northwest (East)	0.45 tC/ha/yr	46.1 tC/ha
	Pacific Northwest (West)	1.74 tC/ha/yr	130 tC/ha
	Pacific Southwest	0.58 tC/ha/yr	76.6 tC/ha
Grasslands [b4]	CONUS	20.56 $Tg/yr/106km^2$	2786.12782 $Tg/106km^2$
Non-Forested Peatlands [b2]	CONUS	0.000135189 $(TgC/yr)/km^2$	9.09027E-05 PgC/km^2
	Alaska	5.68828E-05 $(TgC/yr)/km^2$	7.44894E-05 PgC/km^2

Carbon Study
Appendix F

Carbon Sequestration Rates and Stocks from Source Literature

Habitats	Geography	Carbon Sequestration Rate	Carbon Sequestration Stock
Non-Forested Peatlands [b2]	Puerto Rico	0.000375 $(TgC/yr)/km^2$	0.000125 PgC/km^2
Forested Peatlands [b2]	CONUS	0.00012003 $(TgC/yr)/km^2$	0.000107782 PgC/km^2
	Alaska	5.22011E-05 $(TgC/yr)/km^2$	6.96015E-05 PgC/km^2
Non-Tidal, Non-Forested Wetlands [b2]	CONUS	0.000101893 $(TgC/yr)/km^2$	1.37302E-05 PgC/km^2
	Alaska	5.6767E-05 $(TgC/yr)/km^2$	4.84342E-05 PgC/km^2
	Puerto Rico	0.000119048 $(TgC/yr)/km^2$	2.38095E-05 PgC/km^2
Mangroves	Southwest Florida and Gulf of Mexico	98 ± 12 $gC/m^2/yr$ [e]	31.8 kgC/m^3 [d]
Shrublands [b4]	CONUS	20.56 $Tg/yr/106km^2$	2786.12782 $Tg/106km^2$
Submerged Aquatic Vegetation [b2]	Atlantic Coast	0.43 tC/ha/yr) [f] (Global)	2 kgC/m^3
	High Latitude Sub-Regions		2 kgC/m^3
	Gulf of Mexico		3.1 kgC/m^3
	Pacific Coast		1.4 kgC/m^3
Tundras [b3]	Alaska	N/A	0.729166667 $(PgC/(106km^2)$

* CONUS = Contiguous United States

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Appendix G

Habitat Improvement and Protection Total Area by Habitat Category

Habitats	Geography	Habitat Improvement Area (km²)	Habitat Protection Area (km²)
Tidal Saltwater Wetlands & Tidal Freshwater Non-Forested Wetlands	Alaska	0	0.21
	California	18.38	0.01
	Lower Mississippi	0.74	0
	Mid-Atlantic	0.16	8.98
	New England	0.53	16.40
	Pacific Northwest	14.16	1.48
	South Atlantic (Gulf Coast)	0.60	4.81
	Texas	23.84	10.86
Tidal Freshwater Forested Wetlands & Forested Wetlands	CONUS	7.40	32.18
	Alaska	0	0.10
	Puerto Rico	0.10	0
Upland Forests	Alaska	0.01	36.72
	Central States	0	0
	Great Plains	0.27	0
	Northeast	1.27	130.33
	Northern Lake States	2.09	0
	Pacific Northwest (East)	0.00	0
	Pacific Northwest (West)	1.46	3.85
	Pacific Southwest	0.85	29.91
	Rocky Mountains (North)	0	0
	Rocky Mountains (South)	0	0
	South Central	0.05	0
	Southeast	10.40	32.11
Grasslands	CONUS	1.02	0.49

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Appendix G

Habitat Improvement and Protection Total Area by Habitat Category

Habitats	Geography	Habitat Improvement Area (km²)	Habitat Protection Area (km²)
Non-Forested Peatlands	CONUS	0	1.51
	Alaska	0	2.08
	Puerto Rico	0	0
Forested Peatlands	CONUS	169.6	0
	Alaska	0	0.05
Non-Tidal, Non-Forested Wetlands	CONUS	15.3	21.40
	Alaska	0	26.95
	Puerto Rico	0.90	0
Mangroves	Southwest Florida and Gulf of Mexico	1.20	0
Shrublands	CONUS	11.20	0.71
Submerged Aquatic Vegetation	Atlantic Coast	0	0
	Gulf of Mexico	0.10	35.26
	High Latitude Sub-Regions	0	0
	Pacific Coast	0.10	0.40
Tundras	Alaska	0	0

* CONUS = Contiguous United States

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