Blue Carbon Stocks
Northeast United States
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Prepared for:
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1. INTRODUCTION

These data products were developed in collaboration with the U.S. Environmental Protection Agency, Region 1 (EPA R1). As part of an 18-month project, EPA R1 convened multiple meetings of an expert work group to both update regional (ME to NY) coastal vegetation datasets on the Northeast Ocean Data Portal (eelgrass meadows and tidal wetlands) and to determine appropriate methods for mapping blue carbon stocks in these habitats.

Blue carbon is the term used to define carbon sequestered in marine habitats, i.e., seagrasses, marshes, and mangroves. Research has shown the carbon storage potential of these habitats are much greater than those of other global carbon sinks. Therefore, it is critical these habitats are conserved to allow for continued carbon storage and sequestration into the future. A broad cross section of coastal and marine stakeholders will gain access to updated and enhanced coastal habitat data; this effort will help to support ocean planning, management, and blue carbon assessment in the Northeast U.S.

To map blue carbon stocks in eelgrass meadows and in tidal marsh habitats, the work group compiled carbon bulk density and organic carbon concentration data collected within these habitats throughout the northeast region from 21 studies published between 1993-2022 over 189 sites: 114 within high and low salt marsh; 40 within Phragmites; and 35 within eelgrass. The available data allowed for the calculation of carbon stocks to a depth of 30 cm. The three vegetation types (marsh, Phragmites, eelgrass) showed significant differences in sediment carbon density.

The mean carbon density was calculated for each vegetation type, and heat maps of mean carbon stocks were generated to represent areas of greatest carbon accumulation. The work group used the March 2021 composite Eelgrass Meadows layer and the “high marsh”, “low marsh”, and “Phragmites” categories of the Tidal Marsh Vegetation Classification layer on the Portal for this analysis. The project's area of interest was from Maine to Long Island Sound, New York.

Both the Eelgrass Meadows layer and the Tidal Marsh Vegetation Classification layer were each generated from multiple data sources. The data user is encouraged to read this and the metadata of each individual layer carefully, as the methods to produce vegetation classes, geometry, attribute details, and timeliness are not necessarily consistent among datasets used to develop blue carbon stock estimates.

2. PURPOSE

The purpose of mapping the estimated blue carbon stocks within coastal vegetated habitats is to determine areas where and quantities of carbon stored and sequestered by eelgrass meadows and tidal marshes throughout coastal New England waters for coastal and ocean planning.

3. IMPORTANT DATA CONSIDERATIONS

The limitations of these data should be understood prior to use. The data user is encouraged to read additional details about the field data collection and analysis of each of the input data, most of which can be gleaned from the EPA report "The Blue Carbon Reservoirs from Maine to Long Island, NY", as well as the metadata for the individual habitat input layers available on the Northeast Ocean Data Portal.

4. SOURCES AND AUTHORITIES

- Eelgrass distribution and abundance
    - Maine Department of Marine Resources, Bureau of Resource Management
    - Maine Department of Environmental Protection
    - University of New Hampshire
    - New Hampshire Department of Environmental Services
    - NH GRANIT (New Hampshire Geographically Referenced Analysis and Information Transfer System)
    - Piscataqua Region Estuary Partnership
    - Massachusetts Department of Environmental Protection
    - Massachusetts Division of Marine Fisheries
    - MassGIS
    - Rhode Island Eelgrass Task Force
    - Connecticut Department of Energy and Environmental Protection
    - Peconic Estuary Partnership
    - New York Natural Heritage Program

- Tidal marsh vegetation

- SHARP 2017. “Marsh Habitat Zonation Map”. Saltmarsh Habitat and Avian Research Program. Ver: 26 Oct 2017. https://www.tidalmarshbirds.org; “DEM” and “No DEM” layers also available as web services via https://www.sciencebase.gov/catalog/item/5a4d4db3e4b0d05ee8c4d195 and https://www.sciencebase.gov/catalog/item/5a68c9d1e4b06e28e9c721b6; The methods for developing this layer as well as suggestions for appropriate uses are detailed in: Correll, MD, W Hantson, TP Hodgman, BB Cline, CS Elphick, WG Shriver, EL Tymkiw, and BJ Olsen. 2019. Fine-scale mapping of coastal plant communities in the northeastern USA. Wetlands 39(1): 17-28.
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- Carbon stocks in eelgrass meadows and tidal marshes
  - Barry, A; Ooi, SK; Helton, AM; Steven, B; Elphick, CS; and Lawrence, BA. (2022). Vegetation Zonation Predicts Soil Carbon Mineralization and Microbial Communities in Southern New England Salt Marshes. Estuaries and Coasts. 45(1), pp.168-180.
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  - Kulesza, AL. (2021). Assessing the amount of carbon stored in Maine salt marshes. Standard Theses. 42. Available from Bates College: https://scarab.bates.edu/geology_theses/42
  - Novak, AB; Pelletier, MC; Colarusso, P; Simpson, J; Gutierrez, MN; Arias-Ortiz, A; Charpentier, M; Masque, P; Vella, P. (2020). Factors Influencing Carbon Stocks and Accumulation

Rates in Eelgrass Meadows Across New England, USA. Estuaries and Coasts. 43(8): 2076-2091.

- Novak, AB. Soil organic carbon stocks – 2018. Unpublished data. Novak, AB. Soil organic carbon stocks – 2020. Unpublished data.
- O'Keefe Suttles, JA; Eagle, MJ; Mann, AG; Moseman-Valtierra, S; Pratt, SE; Kroeger, KD. (2021). Collection, analysis, and age-dating of sediment cores from salt marshes, Rhode Island, 2016 (data set). Available from U.S. Geological Survey: https://doi.org/10.5066/P94HIDVU
- O'Keefe Suttles, JA; Eagle, MJ; Mann, AG; Spivak, A; Sanks, K; Roberts, D; Kroeger, KD. (2021). Collection, analysis, and age-dating of sediment cores from natural and restored salt marshes on Cape Cod, Massachusetts, 2015-16 (data set). Available from U.S. Geological Survey: https://doi.org/10.5066/P9R154DY
- O'Keefe Suttles, JA; Eagle, MJ; Mann, AG; Wang, F; Tang, J; Roberts, D; Sanks, K; Smith, TP; Kroeger, KD. (2021). Collection, analysis, and age-dating of sediment cores from Herring River wetlands and other nearby wetlands in Wellfleet, Massachusetts, 2015–17 (data set). Available from U.S. Geological Survey: https://doi.org/10.5066/P95RXPHB
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- Röhr, ME; Holmer, M; Baum, JK; Björk, M; Boyer, K; Chin, D; Chalifour, L; Cimon, S; Cusson,M; Dahl, M; Deyanova, D; Duffy, JE; Eklöf, JS; Geyer,JK; Griffin, JN; Gullström, M; Hereu, CM; Hori, M; Hovel, KA; Hughes, AR; Jorgensen, P; Kiriakopolos, S; Moksnes, PO; Nakaoka, M; O'Connor, MI; Peterson, B; Reiss, K; Reynolds, PL; Rossi, F; Ruesink, J; Santos, R; Stachowicz,JJ; Tomas, F; Lee, KS; Unsworth, RKF; Boström, C. (2018). Blue carbon storage capacity of temperate eelgrass (Zostera marina) meadows. Global Biogeochemical Cycles. 32(10), 1457–1475. Available from: https://doi.org/10.1029/2018GB005941
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- Yellen, B; Woodruff, J. (2020). Hudson River Estuary Tidal Marsh Sediment Data, Data and Datasets. 108. https://doi.org/10.7275/dh3v-0x33 https://scholarworks.umass.edu/data/108

5. DATABASE DESIGN AND CONTENT

Dataset Status: Complete

(this example represents data details specific to the Blue Carbon Stocks - Eelgrass Meadows dataset; other products have similar information.)

Native storage format: ESRI ArcGIS GRID
Columns and rows: 16887, 17593
Number of bands: 1
Cell size: 30m, 30m
Pixel type: floating point
Linear Unit: Meter (1.000)
Angular Unit: Degree (0.01745329)
Statistics:

Minimum: 0.0130
Maximum: 0.1169
Mean: 0.0936
Standard deviation: 0.0349

6. SPATIAL REPRESENTATION

Reference System: GCS_North_American_1983
Horizontal Datum: North American Datum 1983
Ellipsoid: Geodetic Reference System 1980

XY Resolution: XY Scale is .000000001
Tolerance: 0.0000000089831583

Geographic extent: -73.96 to -66.97, 40.67 to 45.10

IS0 19115 Topic Category: environment, oceans, biota

Place Names:
Atlantic Ocean, Cape Cod Bay, Connecticut, Gulf of Maine, Hudson River, Long Island Sound, Maine, Massachusetts, Massachusetts Bay, New Hampshire, New York, Rhode Island, Rhode Island Sound, United States

Recommended Cartographic Properties:
(Using ArcGIS ArcMap nomenclature)

Standard deviations stretch; n = 2.5
Viridis magma color scheme
Low = 0, 0, 5 (R, G, B)
High = 251, 252, 189 (R, G, B)

7. DATA PROCESSING

Processing environment: ArcGIS 10.8, Windows 10 Professional, Intel Core i7 CPU

Eelgrass meadows data
A description of each states' datasets and the subsequent processing are described in the metadata for the Eelgrass Meadows layer. For this analysis, the Eelgrass Meadows data were filtered to exclude polygons that were classified as "Ruppia" or "Zostera and Ruppia". Only those features classified as "Zostera" were retained. This step excluded any submerged aquatic vegetation that was not eelgrass (*Zostera marina*).

Tidal marsh data
A description of the datasets that the work group combined to develop the Tidal Marsh Vegetation Classification layer are described in the metadata for the Tidal Marsh Vegetation Classification layer. For this analysis, the work group selected only the Tidal Marsh Vegetation data from Maine to Long Island New York (i.e., Analysis Zones 1 – 3 + Massachusetts Conceptual Marsh Units Data), and recommended extracting and using only the "High Marsh", "Low Marsh", and "Phragmites" vegetation classes.

Carbon data
Carbon stock data were grouped by vegetation type and the mean, standard error, and 90% confidence interval min, max, and width were calculated:

		OC Stock (kg m^{-2})				
Vegetation Type	**Sample Size**	**Mean**	**StErr**	**Lower Limit**	**Upper Limit**	**90% CI Width**
Eelgrass	86	3.44	0.42	2.7494	4.1343	1.3849
High and Low Marsh	186	11.04	0.37	0.0352	11.6574	11.6222
Phragmites australis	18	11.00	1.19	0.0315	13.0039	12.9724

For mapping purposes, the mean carbon stock and 90% CI values were converted to a carbon stock units of Megagrams (equivalent to metric tons) Carbon per hectare. The resulting conversions are:

- Eelgrass Meadows Mean = 34.4 Mg C / ha
- Eelgrass Meadows Width of 90% confidence interval = 13.8 Mg C / ha

- High & Low Marsh Mean = 110.0 Mg C / ha
- High & Low Marsh Width of 90% confidence interval = 116.2 Mg C / ha
- Phragmites Mean: 110.0 Mg C / ha
- Phragmites Width of 90% confidence interval = 129.7 Mg C / ha

Developing blue carbon "heat maps"

Eelgrass Meadows

The eelgrass meadows data were converted from shapefile to a raster dataset with 3 meter pixels using the Polygon to Raster tool in the ArcGIS Conversion toolbox. The resulting raster datasets had two classes, "Zostera" and "Zostera, Ruppia". Only the "Zostera" class was used for this analysis.

The raster was reclassified so that the values for Zostera corresponded to the carbon stock and 90% confidence interval width values listed in the previous section. Grid cells classified as "Zostera, Ruppia" were reclassified as "No data".

To create an eelgrass blue carbon heat map, the data within the 3m grid cells were summarized by first taking the sum within a 10x10 grid cell window and then averaging across all of those cells to generate a 30m-resolution heatmap. The was accomplished by first applying the focal statistics tool in the ArcGIS Spatial Analyst toolbox to calculate a sum for each cell representing a 10x10 grid cell window around it. Next, the aggregate tool was used to calculate the mean of all of these sums across the same 10x10 grid cell window. The resulting raster had a grid cell size of 30m, with each grid cell representing a blended mean of blue carbon stocks from eelgrass habitats aggregated across 100 grid cells.

These processes produced:

1) Blue carbon stocks (MgC) – Eelgrass Meadows
2) Blue carbon stocks width of 90% confidence interval (MgC) – Eelgrass Meadows

High/Low Marsh, and Phragmites

The Tidal Marsh Vegetation Classification layer was reclassified so that all classes other than High Marsh, Low Marsh, and Phragmites were removed.

The raster was reclassified so that the values for High Marsh, Low Marsh, and Phragmites corresponded to the carbon stock and 90% confidence interval width values listed in the previous section.

To create a tidal marsh blue carbon heat map, the data within the 3m grid cells were summarized by first taking the sum within a 10x10 grid cell window and then averaging across all of those cells to generate a 30m-resolution heatmap.

The was accomplished by first applying the focal statistics tool in the ArcGIS Spatial Analyst toolbox to calculate a sum for each cell representing a 10x10 grid cell window around it. Next, the aggregate tool was used to calculate the mean of all of these sums across the same 10x10 grid cell window. The resulting raster had a grid cell size of 30m, with each grid cell representing a blended mean of blue carbon stocks from multiple tidal marsh habitat types aggregated across 100 grid cells.

These processes produced:

3) Blue carbon stocks (MgC) – Tidal Marsh
4) Blue carbon stocks width of 90% confidence interval (MgC) – Tidal Marsh

Eelgrass Meadows, High & Low Tidal Marsh, Phragmites
Layers 1 and 3 above were combined using the Mosaic to New Raster tool in the ArcGIS Raster Processing toolbox with Mosaic Operator = SUM. This function ensured that blue carbon stocks from eelgrass meadows and tidal marsh habitats were added together where these habitats overlapped.

Layers 2 and 4 above were combined using the Mosaic to New Raster tool in the ArcGIS Raster Processing toolbox with Mosaic Operator = MAXIMUM. This function ensured that the width of the 90% confidence interval from eelgrass meadows and tidal marsh habitats reflected the highest value where these habitats overlapped.

These processes produced:

5) Blue carbon stocks (MgC) – Eelgrass Meadows & Tidal Marsh
6) Blue carbon stocks width of 90% confidence interval (MgC) – Eelgrass Meadows & Tidal Marsh

Layers 1, 3, 5, and 6 represent the suite of Blue Carbon data products added to the Portal.

8. QUALITY PROCESS

Attribute Accuracy: Original content was acquired from authoritative sources. Any attribute editing was informed by specific information in the metadata.

Logical Consistency: This dataset integrates coastal vegetation habitat data from numerous separate sources. Common themes were identified across attribute fields that unify the datasets, and these were incorporated to provide consistency and efficient communication of information.

Completeness: Data are based upon the most recent available eelgrass habitat GIS datasets, tidal marsh habitat GIS dataset, and coastal carbon density dataset available for coastal New England states. Not all records have complete information for each field due to the differences in sampling and recording programs for each state.

Positional Accuracy: May vary by dataset. The user should consult the metadata of each individual dataset for positional accuracy information.

Timeliness: This dataset is based on best available information as of September 30, 2021; however, the timeliness of the dataset varies by state. Due to the biological characteristics of coastal vegetated habitats, the user should not assume that all sites are up to date and should consult each dataset's metadata for more detailed information as to the timeliness of the data.

Use restrictions: Data are presented as is. Users are responsible for understanding the metadata prior to use.

Distribution Liability: All parties receiving these data must be informed of caveats and limitations.