COLLABORATIVE SCIENCE FOR ESTUARIES

WEBINAR SERIES

A Collaborative Approach to Advancing Blue Carbon Research and Data Applications

(Part 2: **Blue Carbon Data Applications**)

Date: Thursday, March 7, 2024

Time: 2:00pm-3:00 pm EST

Chris Janousek

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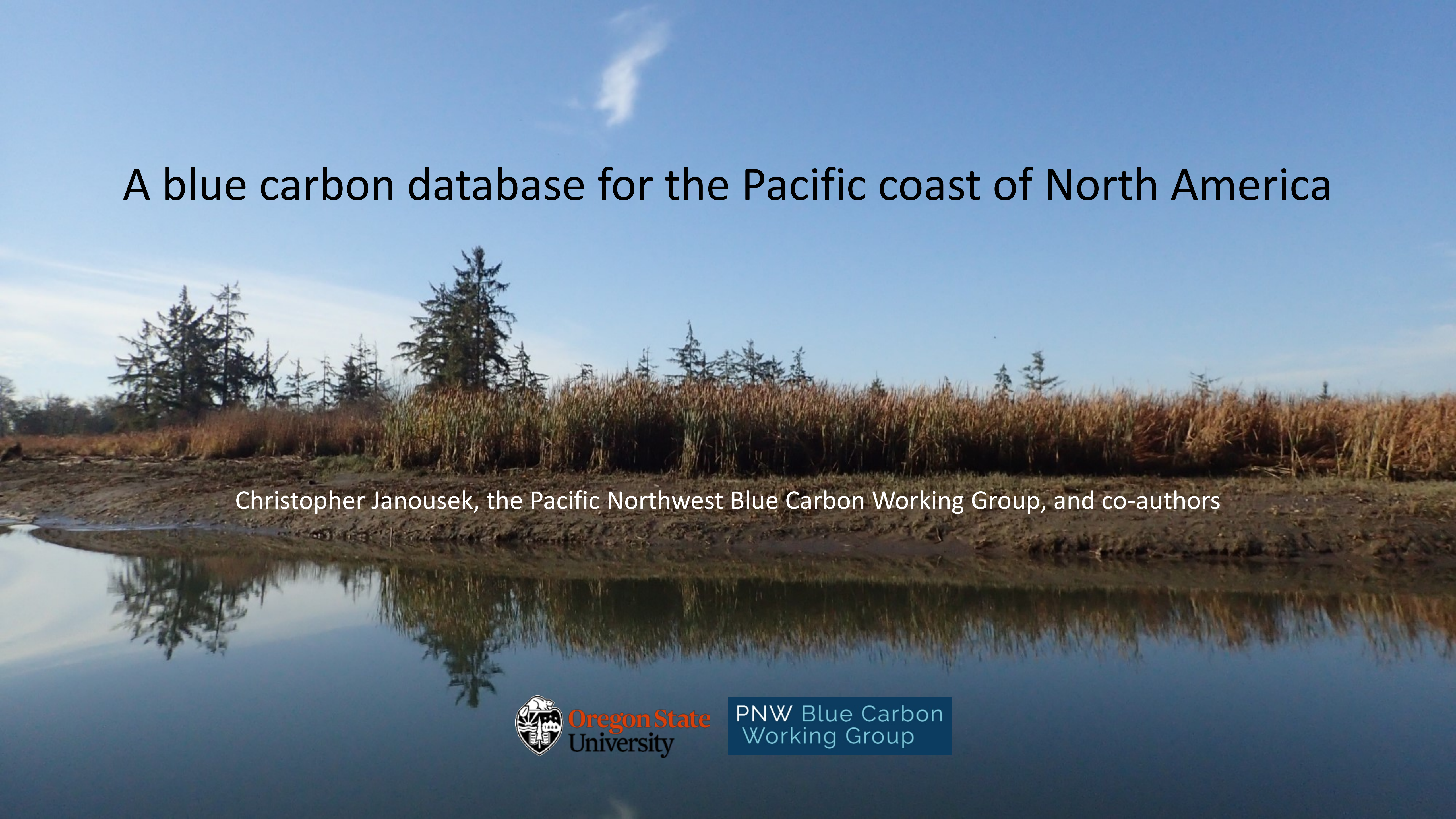
National Estuarine Research Reserve System Science Collaborative

A blue carbon database for the Pacific coast of North America

Christopher Janousek, the Pacific Northwest Blue Carbon Working Group, and co-authors

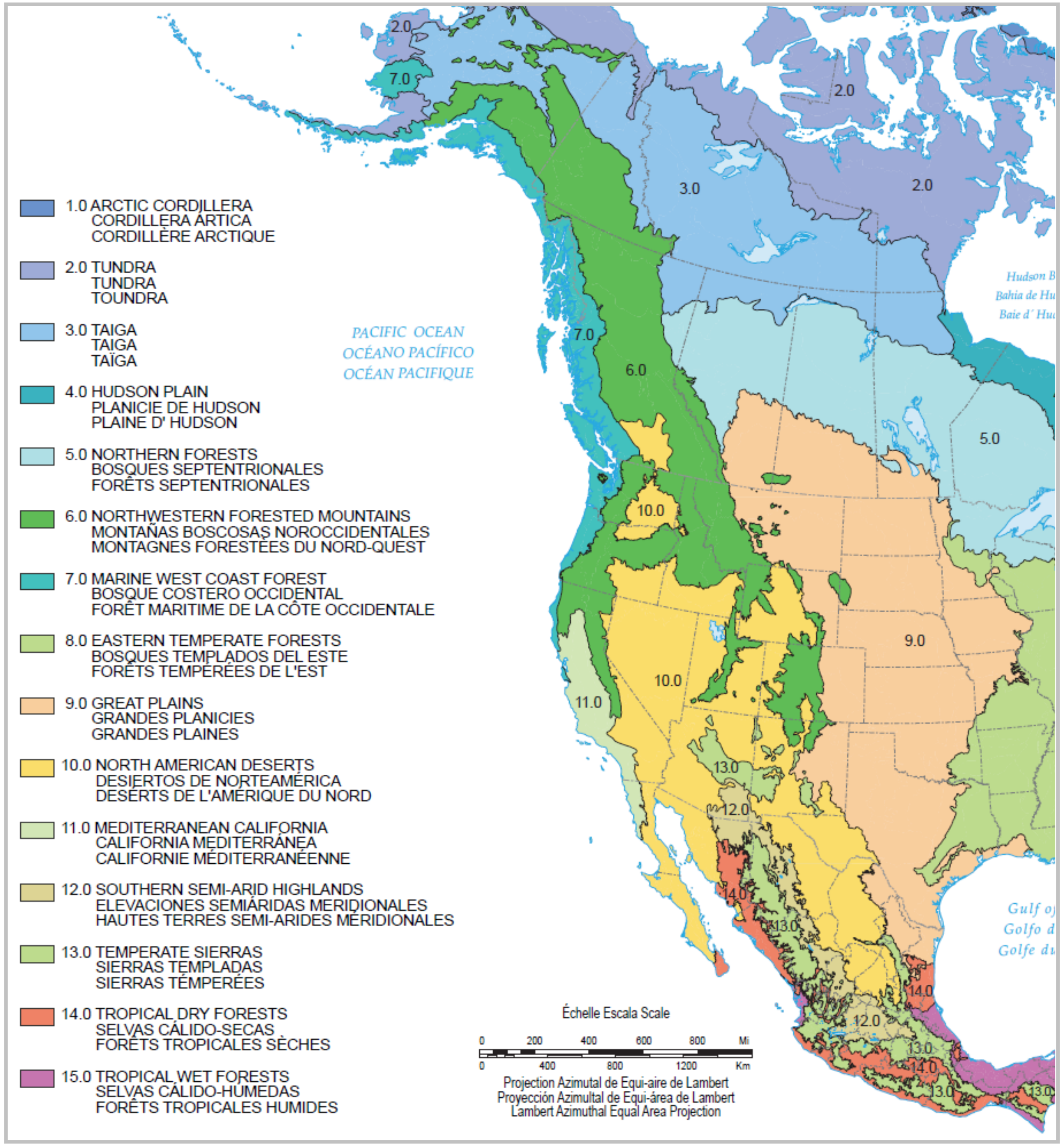


Oregon State University

PNW Blue Carbon Working Group

Northeast Pacific blue carbon database

- Established ~2018, starting with stocks data from the PNW
- Expanded to all of western North America
- A “living” database with on-going data addition



CEC

Varying precipitation

Increasing temperature

Increasing tide range

Changes in species composition

Database objectives

Summary stocks data by wetland type and geographic sub-region

Wetland managers, restoration planners, researchers

Carbon sequestration potential

Restoration practitioners, finance market developers, researchers

NA	NA	NA	CHN/LOI	NA	NA	NA	NA	NA	NA	NA
0-5	0-5	5	CHN/LOI	0.51	13.55	4.15	0.02	*0.069*	*0.021*	*0.027*
5-10	5-10	5	CHN/LOI	0.41	15.07	4.26	0.02	*0.062*	*0.017*	*0.024*
10-15	10-15	5	CHN/LOI	0.54	12.01	3.34	0.02	*0.065*	*0.018*	*0.025*
15-20	15-20	5	CHN/LOI	0.7	13.28	4.01	0.03	*0.093*	*0.028*	*0.036*
NA	NA	NA	CHN/LOI	NA	NA	NA	NA	NA	NA	NA
0-5	0-5	5	CHN/LOI	0.46	18.22	5.74	0.03	*0.084*	*0.026*	*0.032*
5-10	5-10	5	CHN/LOI	0.32	17.5	5.33	0.02	*0.056*	*0.017*	*0.022*
10-15	10-15	5	CHN/LOI	0.26	23.41	8.9	0.02	*0.061*	*0.023*	*0.023*
15-20	15-20	5	CHN/LOI	0.36	26.94	11.14	0.04	*0.097*	*0.040*	*0.037*
NA	NA	NA	CHN/LOI	NA	NA	NA	NA	NA	NA	NA
0-5	0-5	5	CHN/LOI	0.15	51.06	24.37	0.04	*0.077*	*0.037*	*0.029*
5-10	5-10	5	CHN/LOI	0.27	29.94	12.02	0.03	*0.081*	*0.032*	*0.031*
10-15	10-15	5	CHN/LOI	0.22	35.96	15.66	0.03	*0.079*	*0.034*	*0.030*
15-20	15-20	5	CHN/LOI	0.29	33.74	13.99	0.04	*0.098*	*0.041*	*0.038*
NA	NA	NA	CHN/LOI	NA	NA	NA	NA	NA	NA	NA
0-5	0-5	5	CHN/LOI	0.16	52.98	27.74	0.04	*0.085*	*0.044*	*0.033*
5-10	5-10	5	CHN/LOI	0.22	43.98	19.84	0.04	*0.097*	*0.044*	*0.037*
10-15	10-15	5	CHN/LOI	0.22	39.87	17.92	0.04	*0.088*	*0.039*	*0.034*
15-20	15-20	5	CHN/LOI	0.23	49.92	23.65	0.05	*0.115*	*0.054*	*0.044*
NA	NA	NA	CHN/LOI	NA	NA	NA	NA	NA	NA	NA
0-5	0-5	5	CHN/LOI	0.19	51.49	23.4	0.04	*0.098*	*0.044*	*0.038*
5-10	5-10	5	CHN/LOI	0.26	34.94	15.37	0.04	*0.091*	*0.040*	*0.035*
10-15	10-15	5	CHN/LOI	0.28	45.02	20.72	0.06	*0.126*	*0.058*	*0.048*
15-20	15-20	5	CHN/LOI	0.25	40.22	18.03	0.05	*0.101*	*0.045*	*0.039*

Regional data for inventories or blue carbon tools

Policy makers, researchers

Identification of regional data gaps

Researchers, funders

Uncertainty analyses

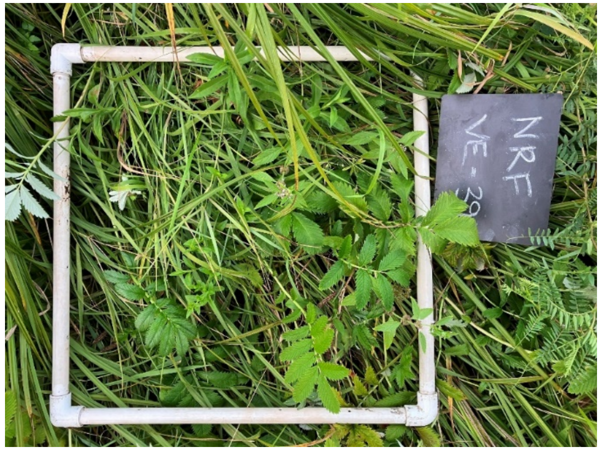
Researchers, policy makers

Types of information

- >70 data sources (published and unpublished)

Blue carbon data type	*Status*
Soil C and N stocks	>1600 cores
Soil accretion rate	On-going
GHG emissions	On-going
Plant biomass	NA

Ecosystem drivers	*Status*
Ecosystem type	Largely complete
Geographic location	Largely complete
Wetland elevation	Partial
Disturbance status	Largely complete
Plant species composition	Partial (qualitative)
Salinity	Partial
Grain size	Partial

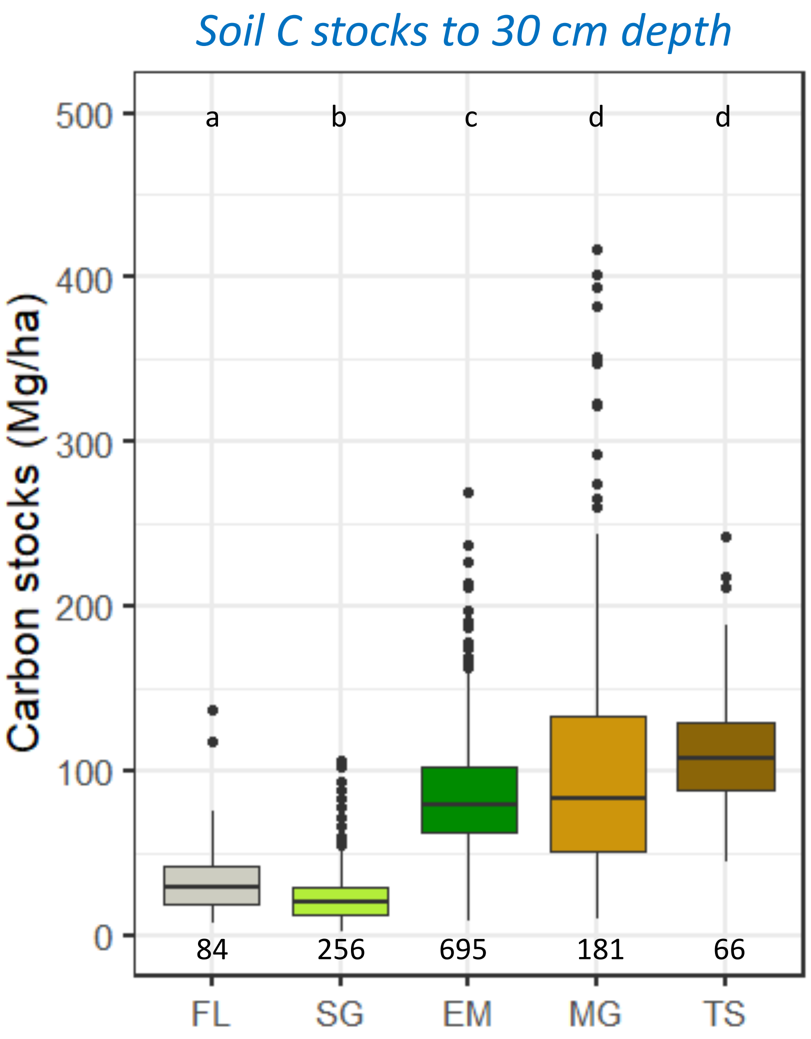


Blue carbon ecosystems in the database

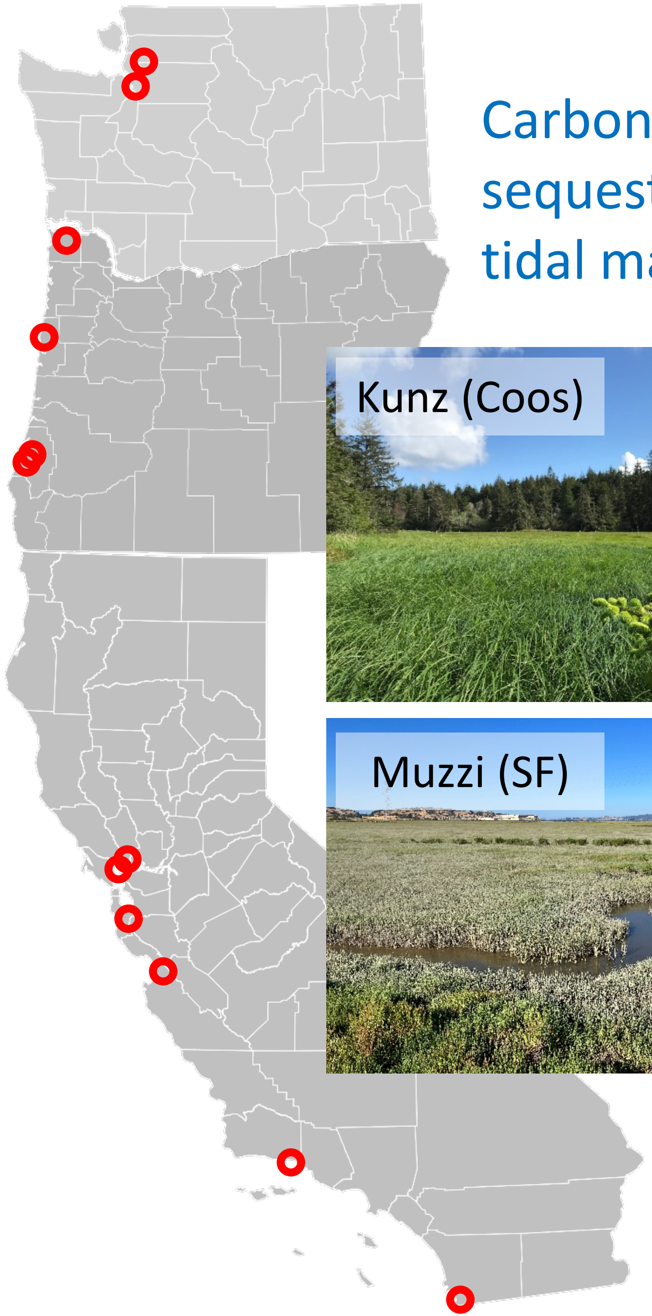
Wetland type	**Tideflats**	**Seagrass**	**Mangrove**	**Tidal marsh**	**Tidal swamps**
Vegetation	Algae	Emergent	Shrubs-trees	Emergent	Shrubs-trees
Elevation	Subtidal to low intertidal	Subtidal to low intertidal	Intertidal	Usually upper intertidal	Upper intertidal
Salinity	Fresh to euhaline	Brackish to euhaline	Euhaline	Fresh to euhaline	Fresh to brackish
Distribution	Throughout N America	Throughout N America	Mexico	Throughout N America	SF Delta to Pacific Northwest

- + former tidal wetlands

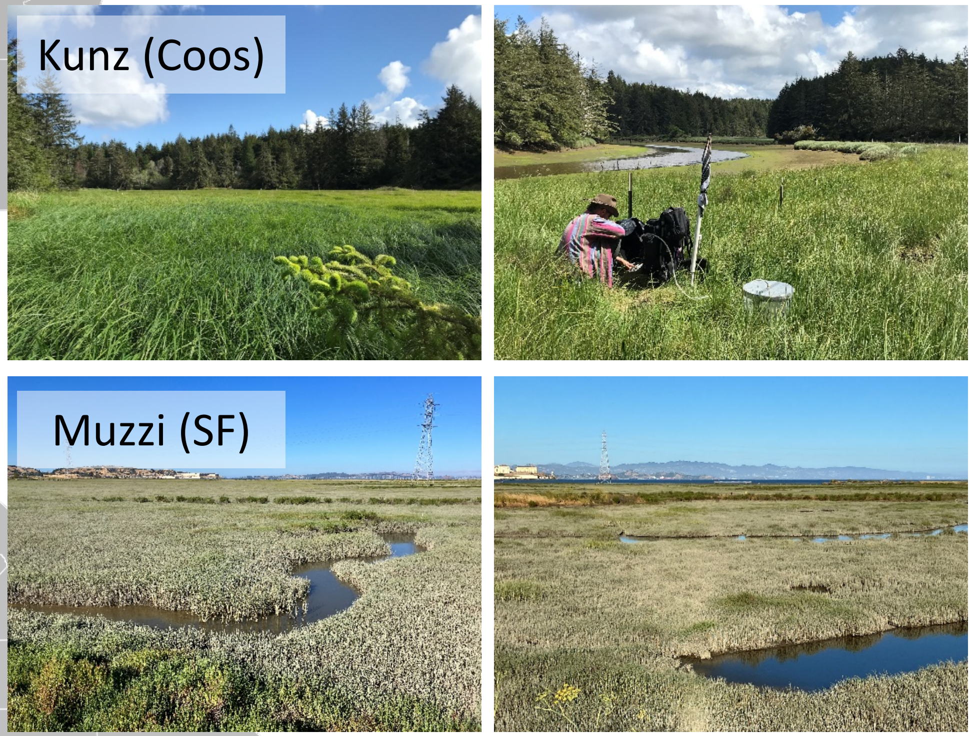
Uses of the database: informing research syntheses



Janousek et al. in prep



Carbon stocks and sequestration rates in mature tidal marsh restoration projects



Uses of the database: State-level analyses

- Silvestrum Climate Associates: Soil carbon stocks for determining state-wide emissions in Oregon for multiple blue carbon ecosystems
- Silvestrum Climate Associates: Stocks, sequestration rate, methane emissions data in support of blue carbon mapping for Coos Bay and a blue carbon calculator for Oregon
- San Francisco Estuary Institute: Carbon accumulation rates for Pacific coast tideflat and seagrass ecosystems for work on California seagrass sequestration

Data transfer

- Working with SERC's Coastal Carbon Network

- Kauffman et al. (2020): 168 soil cores from CA, OR, WA
- Darienzo & Peterson (1990): 6 soil cores from OR
- Sanborn & Coxson (2020): 33 soil cores from BC
- Poppe et al. (in prep): 62 soil cores from OR, WA
- Williams et al. (in prep): GHG emissions at 34 sites in OR, WA

SERC

Summary

- The Northeast Pacific Blue Carbon Database is a growing resource for blue carbon research and application along the Pacific coast of North America
- Supports a growing number of applications
- Working with the Smithsonian Environmental Research Center to help ensure long-term preservation and access to data
- Funding welcome to help with database maintenance and growth

National Estuarine Research Reserve System Science Collaborative

NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Pew Charitable Trusts

OWEB

Contact: Christopher.Janousek@oregonstate.edu

Scaling Regional Carbon Stock Data to Estuary-Level Mapping Tools and Carbon Calculators in Oregon

Lisa Beers and Mackenzie Taggart

Funding provided by The Pew Charitable Trusts

silvestrum CLIMATE ASSOCIATES

Application of PNW Data

2021 Coastal Wetlands GHG Inventory for Oregon – developed by a collaboration between Silvestrum, The Pew Charitable Trusts, and members of the Pacific Northwest Blue Carbon Working Group

- All coastal wetland types included *(except seagrass)*
- Carbon pools and fluxes – *biomass* , *soil*, *dead organic matter*, *methane*
- Area change – *NOAA's C-CAP landcover data*

Building on this work we:

Piloted an interactive blue carbon mapping tool for Coos Bay Estuary to visualize coastal wetland carbon stocks

Are developing a **blue carbon calculator** for Oregon

Current Conditions Layer

Emissions/removals data were applied to a modified CMECS biotic layer (Coastal and Marine Ecological Classification Standard) , refined in Coos Bay to better represent tidal forested and scrub-shrub wetlands.

Habitats Included

- Tidal emergent wetlands
- Tidal scrub-shrub wetlands
- Tidal forested wetlands
- Seagrass beds *(max known extent)*
- Tidal mud flats
- Former tidal wetlands/pasture

Carbon Data Included

- Soil C accumulation → *vegetated tidal wetlands*
- Soil C stocks to 1 m depth
- Total biomass → *seagrass, emergent, scrub-shrub, forest*
- Biomass accumulation → *forest*
- Dead organic matter → *forest*
- CH_4 emissions

Soil Carbon Stock Data

Soil carbon accumulation rates (t C $acre^{-1}$ yr^{-1}) and soil carbon stock to 1m from the Pacific Northwest Blue Carbon Database were utilized.

Soil carbon accumulation rates

Stratified by wetland type

Soil carbon stock to 1m

Stratified by wetland type, and included tidal flats and former tidal wetlands/pasturelands

Wetland Type	soil C accum. (t C $acre^{-1}$ yr^{-1})			soil C to 1 m (t C $acre^{-1}$)		
	min	mean	max	min	mean	max
Tidal Forested Wetland	0.05	0.41	0.76	147.2	154.7	162.2
Tidal Scrub/Shrub Wetland	0.29	0.36	0.44	203.4	215.1	226.7
Tidal Emergent Wetland	0.19	0.49	0.78	113.6	116.3	118.9
Seagrass	0.06	0.11	0.16	46.6	48.8	50.9
Tidal Flat				42.7	45.9	49.0
Former wetland/pasture				99.6	105.4	111.2

Biomass Data

Biomass data (AGB, BGB, DOM) from Kauffman et al. (2020) was utilized. Belowground biomass was calculated using IPCC Tier 1 Root:Shoot ratios.

- No biomass data available for scrub-shrub wetlands → emergent wetland values were used
- For forested wetlands – utilized biomass accumulation curve (capped at mean value) and the annual growth rate (2.2 t C $acre^{-1}$ yr^{-1}) of upland Sitka spruce forests from Smith et al. (2006)

Wetland Type	total biomass (t C $acre^{-1}$)		
	min	mean	max
Palustrine Forested Wetland	64.21	122.40	180.59
Palustrine Scrub-Shrub Wetland	4.76	5.43	6.10
Palustrine Emergent Wetland	4.76	5.43	6.10
Estuarine Scrub-Shrub Wetland	7.16	7.86	8.55
Estuarine Emergent Wetland	7.16	7.86	8.55
Seagrass	0.49	0.75	1.00

Methane Data

Utilized the IPCC Tier 1 emission value for methane of 2.195 t CO2e acre-1 yr-1 (1.131 - 4.057), and a global warming potential of 28.

- IPCC Tier 1 rate does not apply to seagrass or tidal flats – no rate currently applied
- Former wetlands/pasturelands are assumed to emit methane at the IPCC Tier 1 rate

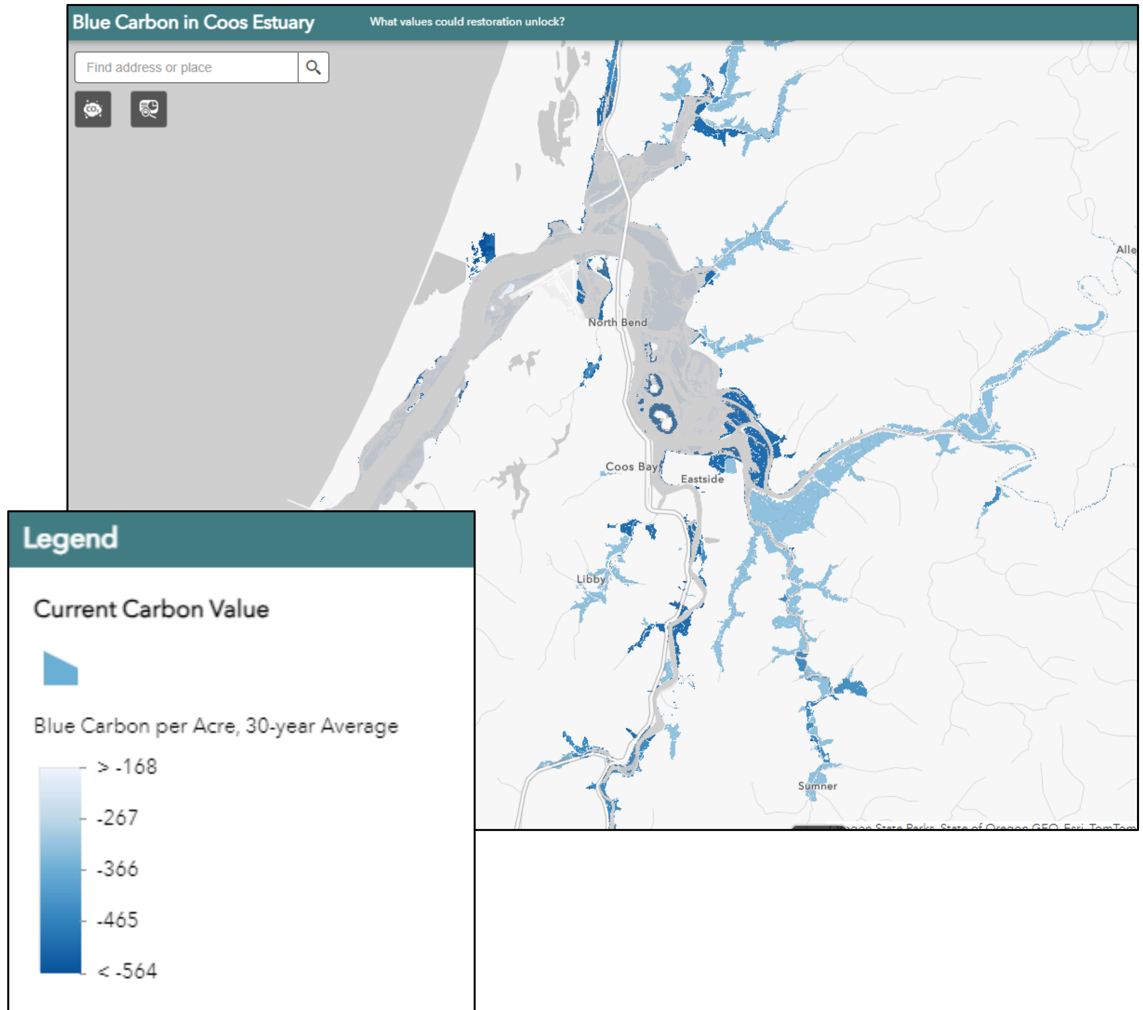
Methane emissions were calculated for tidal emergent, scrub-shrub, and tidal forested wetlands **with salinity < 18 PSU**.

- Site salinity was determined using average surface salinity values from October (highest salinity month)

Blue Carbon in Coos Estuary

The final product is an interactive mapping tool that provides estimated carbon values per acre after 30 years.

Carbon values reflect:
total carbon stocks *(soil C 1m, biomass, DOM)*
+
30 years of fluxes *(soil C accum., CH_4)*



Restoration Opportunity Layer (ROI)

The ROI layer includes sites that have been recently restored and sites with restoration potential.

Pre-restoration site data is based on the current conditions layer

Post-restoration wetland type was based on current tidal elevations ➡

Sites could restore to:

- Emergent tidal wetland
- Scrub-shrub wetland
- Forested tidal wetland

If 50% of site area is:

At or below mean tide level (MTL) → *emergent tidal wetland*

Between MTL and mean higher high water (MHHW) → *emergent tidal wetland*

At or above MHHW → *emergent, scrub-shrub or forested tidal wetland*

Restoration Opportunity Layer (ROI)

The carbon potential (CO_2e acre^{-1}) of a restored site is provided for 15, 30, and 50-years post restoration.

Assumptions:

- Sites are considered *non-tidal* prior to restoration → have methane emissions
- Post restoration – if a site has salinity >18 PSU, avoided emissions are calculated
- Soil carbon accumulation begins 5 years after restoration
- Biomass for emergent wetlands and seagrass is assumed to cover entire site, and is only counted once
- For forested wetlands - tree biomass follows upland Sitka spruce growth curve is are capped at the mean value provided in Kaufmann et al. (2020)

15 years	**30 years**	**50 years**
0.2 to 260.4 CO_2e acre^{-1}	-12.9 to 315.9 CO_2e acre^{-1}	-30.4 to 389.9 CO_2e acre^{-1}

Oregon Blue Carbon Calculator

Currently In development

Funded through the Oregon Watershed Enhancement Board (OWEB), the **calculator will enable users to calculate estimated GHG emissions/removals** resulting from specific land management actions, including:

- restoration and conservation
- changes in wetland type
- disturbance – excavation, draining, filling

It will be released as a spreadsheet and a publicly accessible online interface, providing estimated emissions/removals over a 50-year timeframe.

Once completed, it will:

- Enable coastal planners to account for and consider GHG emissions with regards to land use and restoration
- Allow wetland regulators to add GHG emissions and impacts to their evaluations of development projects
- Provide valuable data for carbon finance project planners

Questions?

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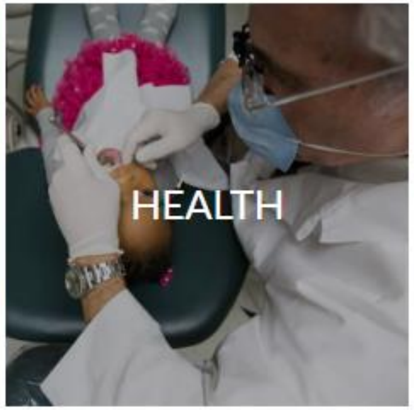
Oregon Blue Carbon Project Team, "Incorporating Coastal Blue Carbon Data and Approaches in Oregon's First-Generation Natural and Working Lands Proposal" (2021), https://www.keeporegoncool.org/s/OR-NWL-bc-data-and-approaches-white-paper.pdf.

Blue Carbon in Coos Bay Mapping Tool:
https://geo-community.maps.arcgis.com/apps/webappviewer/index.html?id=46784b2693004bf295f855513ffb1edf

Making Blue Carbon Count

Incorporating coastal wetlands into state climate planning

Pew

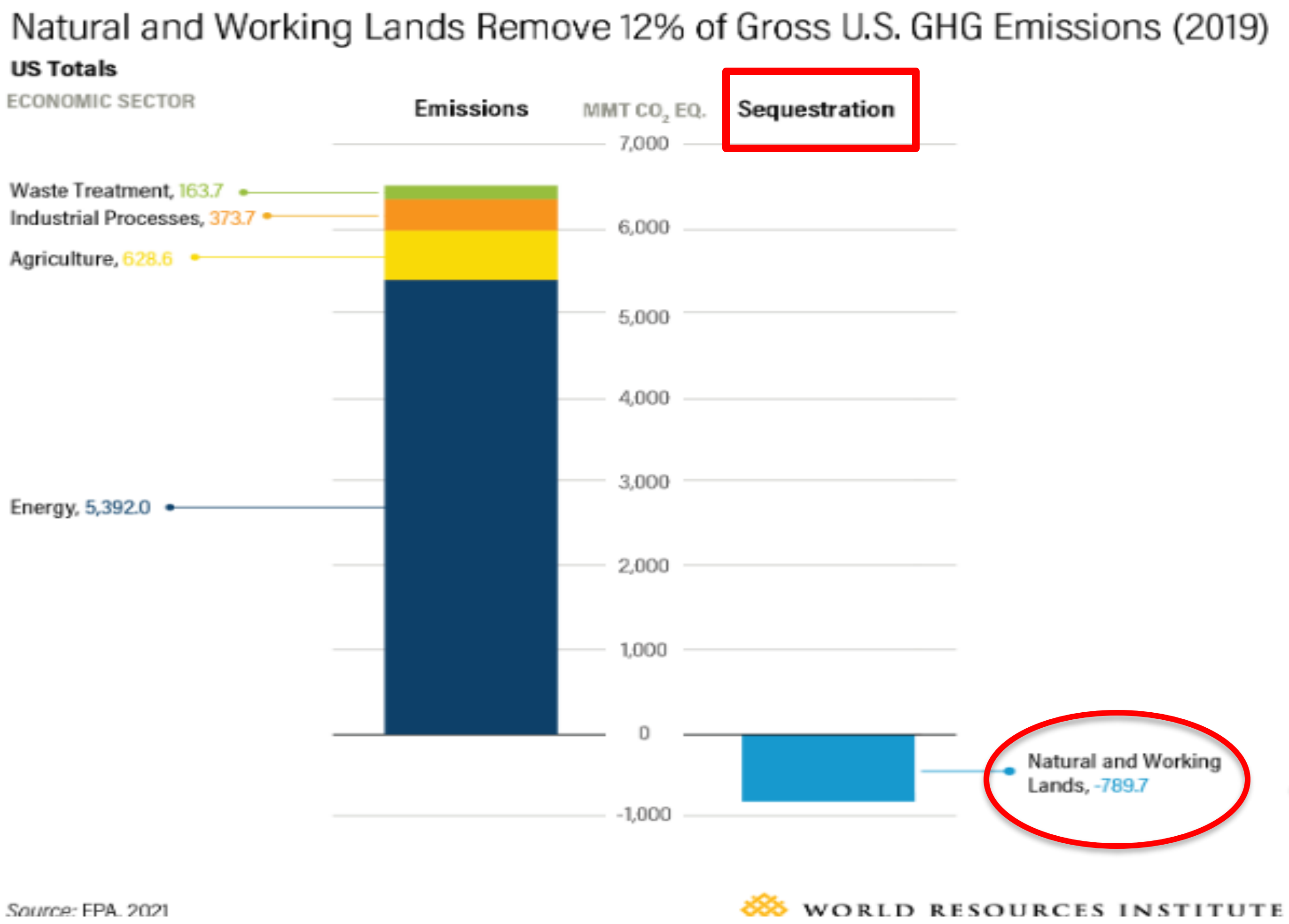


Introduction to Pew

- Founded 1948 by Pew family as grantmaking foundation, a public charity since 2002
- Nonpartisan, evidence-based approach to advancing sound public policy
- US environmental work:
  - Energy Modernization: Grid / Renewables / EV
  - U.S. Conservation: Building resilience of ecosystems and communities

- Blue carbon work
  - **International:** help countries incorporate blue carbon into Paris treaty goals
  - **U.S. Conservation:** help states incorporate blue carbon into climate planning and policies that leverage “natural and working lands”

“Natural and Working Lands” and climate change



Natural and Working Lands Plans

Land management: farms, ranches, grasslands, forests, wetlands

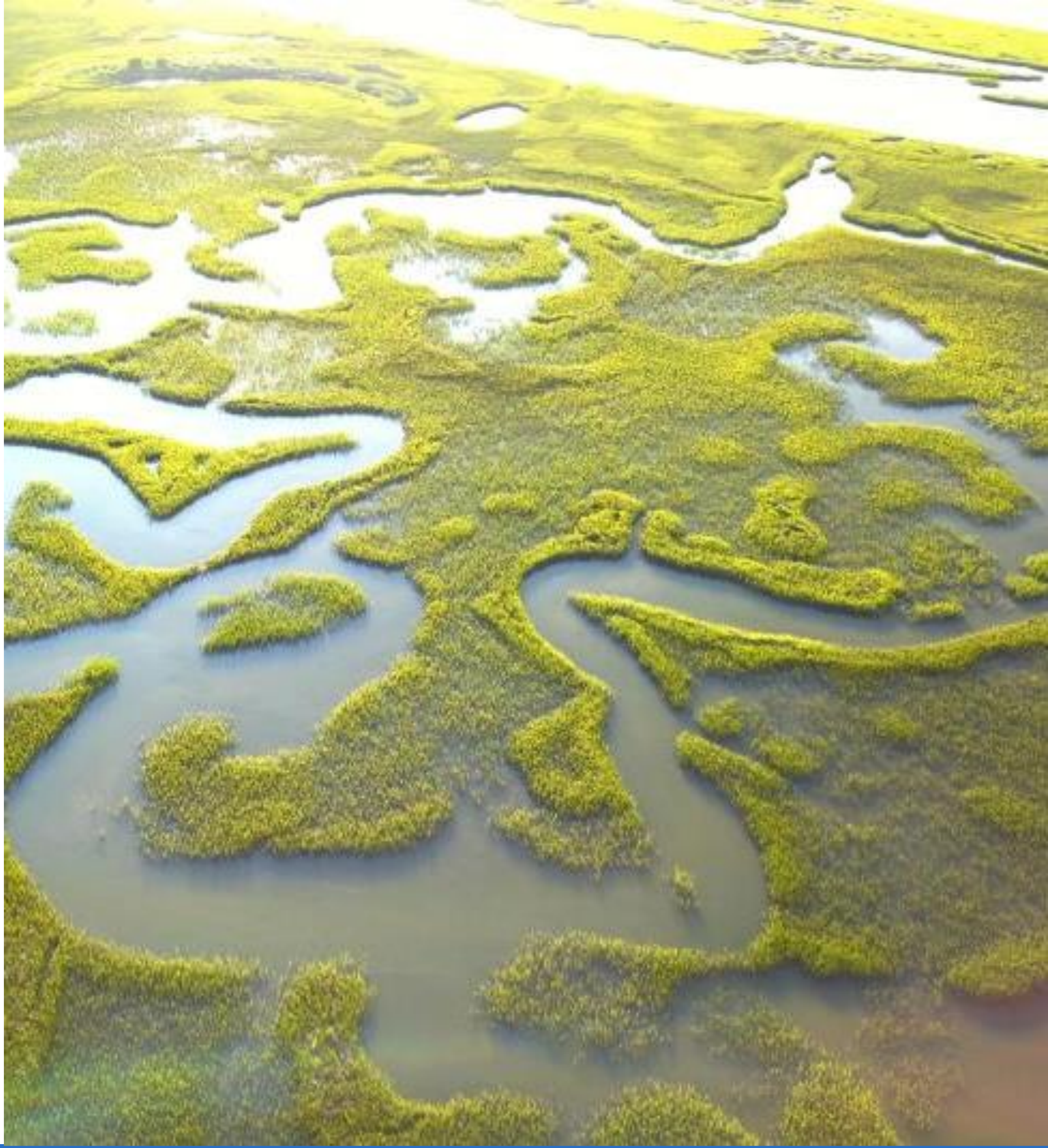
Reduce emissions (e.g., restore degraded landscapes, improve ag & forestry practices)

Avoid emissions (protect existing carbon sinks from current and future threats)

Expand carbon sinks (restoration)

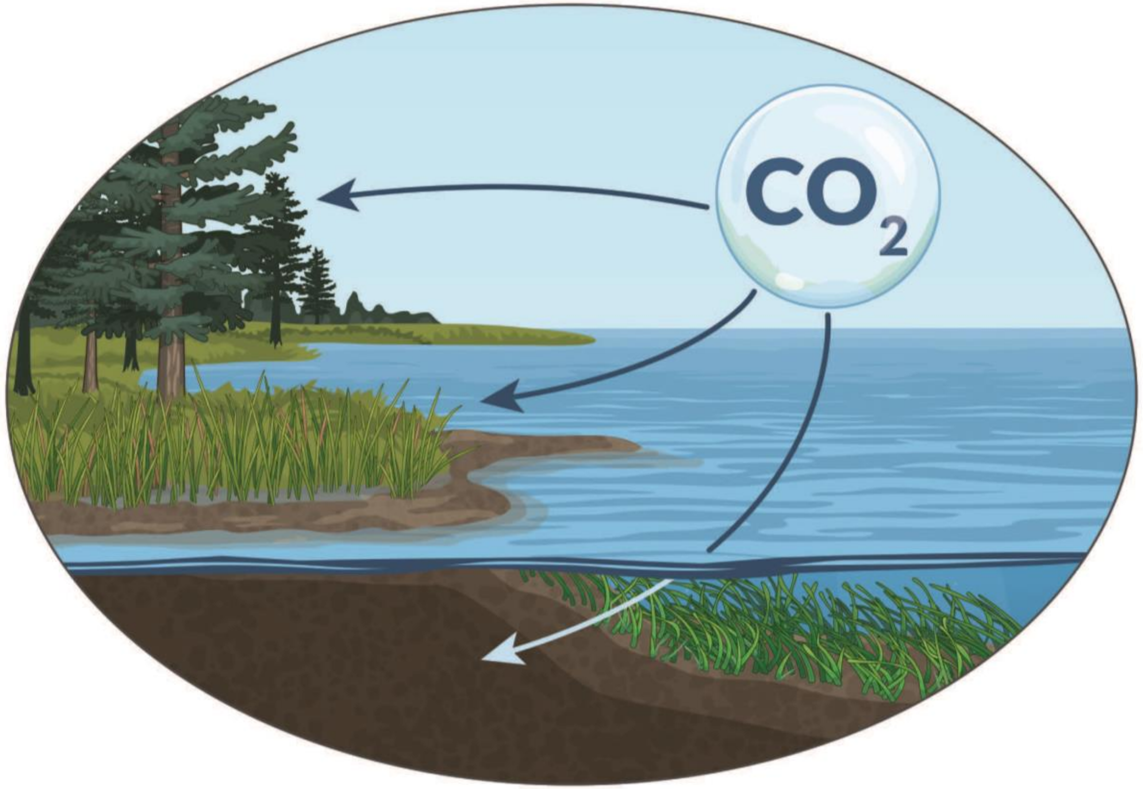
NWL Plan - Typical Elements

- **Carbon assessment**
  - Basic estimates of existing carbon stocks
  - More sophisticated - GHG inventory of emissions and removals
  - Inventories help inform management strategies to reduce and avoid emissions & enhance removals
- Specific targets and pathways beyond BAU
- Progress tracked over time



Blue carbon as a NWL strategy

- Climate mitigation benefits of **vegetated coastal blue carbon habitats** recognized by the IPCC
  - Per acre on par/exceeding tropical forests
  - Most carbon stored in sediments
  - If left undisturbed, can accumulate for millennia
- IPCC accounting methodologies
  - EPA now including coastal wetlands in national GHG inventory
- States increasingly interested but need help
- Action needed to stop degradation and loss, bring about recovery (“additionality”)
- **Co-benefits!**

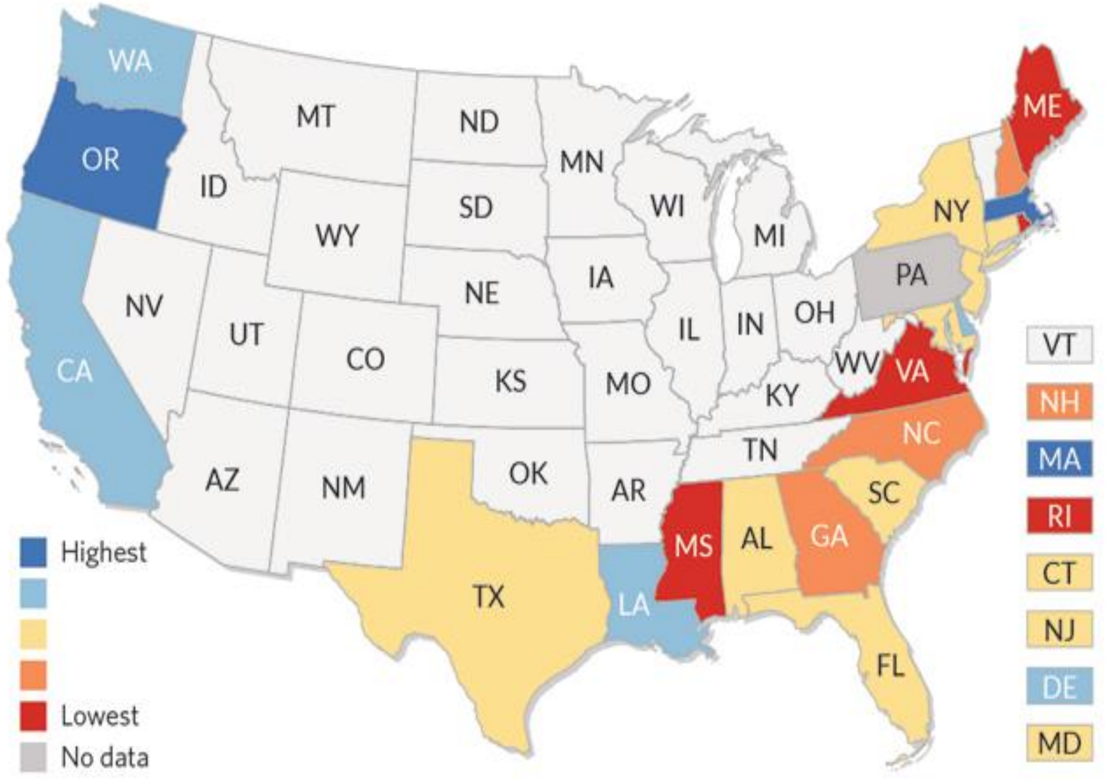


How does Pew engage?

- Convener: connects coastal wetlands researchers & managers with climate planners
- Data/science: inventories, scenarios, targets
- Communications: elevate & educate
- Policy advocacy: focus on states, though growing opportunities at the fed level

How States Rate on Blue Carbon

West Coast has more—and better—data on areas that can help fight climate change



Note: Rankings reflect composite averages derived from quantity, quality, and spatial and habitat coverage of soil carbon data from the Smithsonian Environmental Research Center's "Coastal Carbon Atlas" as of March 2021.

Source: J. Wolfe, Smithsonian Environmental Research Center, "Coastal Carbon Research Network Blue Carbon Inventory" (2021)

State Work

Oregon: NWL proposal, bill, action plan

California: Climate Change Scoping Plan, AB 1757, Climate Smart Strategy

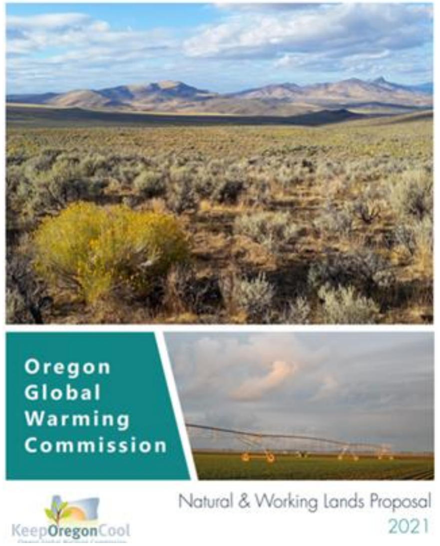
North Carolina: blue carbon inventory inclusive of seagrasses

New Jersey: NWL plan

Maine, MD & LA also integrating blue carbon into climate plans

Oregon: policy landscape/timeline

- Oregon Executive Order 20-04 — Spring 2020
- Oregon Climate Action Commission Natural and Working Lands Proposal — August 2022
- Natural and Working Lands Project — 2022 -2023
- Natural Climate Solutions Legislation — June 2023
- Implementation — Now



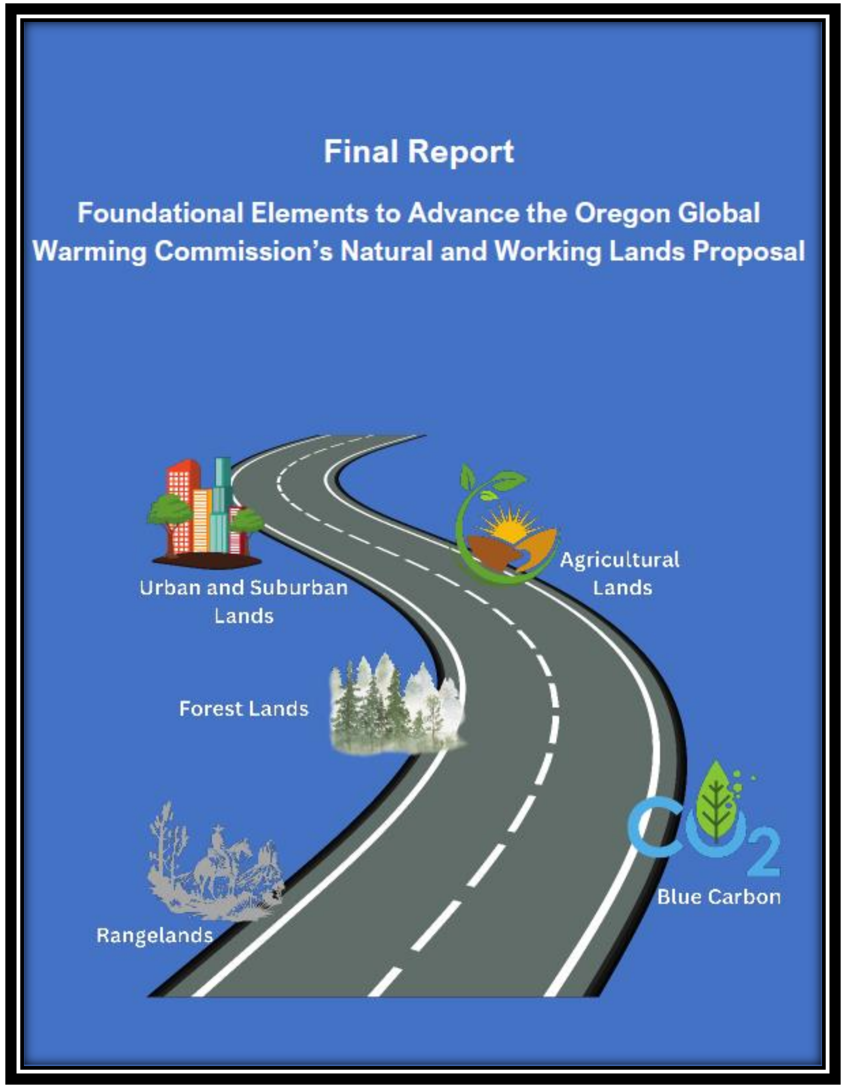
Phase 1

Phase 2

Phase 3

Recommended Practices for OR NWL

- Global Warming | Natural And Working Lands Project (ogwcnaturalandworkinglands.org) – recommended practices across landscape types including coastal wetlands and seaweeds/kelp
- **Recommended practices** (can start now) **for blue carbon**
  - Tidal wetland conservation
  - Tidal wetland restoration
  - Seagrass conservation
- **Emerging practices** (need more data & policy work) **for blue carbon**
  - Seagrass Restoration
  - Kelp and Seaweed Protection and Restoration
  - Enhance Tidal Wetland Resilience to Sea Level Rise
- **Tools to guide implementation**
  - Prioritization tool - Blue Carbon in Coos Estuary | oregonexplorer | Oregon State University
  - Blue carbon calculator



California Natural Climate Solutions

- **New mandate to establish ambitious targets that reduce emissions, enhance carbon sequestration, build resilience – *encompasses blue carbon habitats!***
- California Natural Resources Agency (with the California Air Resources Board and Dept of Food & Ag) will **set targets by 2024**
  - Incorporate into upcoming 5-year climate change scoping plan
- **Natural & Working Lands Expert Advisory Committee recommended 2045 targets for wetlands/blue carbon**
  - *Set restoration targets for freshwater wetlands in the Delta, saline & brackish tidal wetlands & eelgrass*
    - *147,500 acres for Delta/Suisun marsh*
    - *20,000 acres for SF Bay*
    - *3,000 acres for eelgrass*
  - *Prioritize conservation and restoration approaches that preserve & maximize existing carbon sinks*
  - *Complete statewide mapping of wetland/eelgrass/kelp ecosystems at least once every 5 years*

North Carolina

North Carolina has ~ 100,000 acres of seagrass and ~ 390,000 acres of intertidal wetlands

Coastal habitats NWL stakeholder group developed GHG inventory

Emergent wetlands ~ 307,000 MT CO2E in 2021 (low salinity wetlands & loss due to SLR)

Seagrasses ~ (55,000) MT CO2E in 2021

Total BC stocks ~ 38.7 million metrics tons C

Among the first to include seagrass in GHG inventory – Forests, natural lands, and agricultural lands sequestered an estimated 34% of the state's gross GHG emissions in 2020, a much higher amount that reported previously

Inventory used to measure GHG impact of coastal habitat protection plan goals, incorporation of coastal wetlands in EPA Priority Climate Action Plans

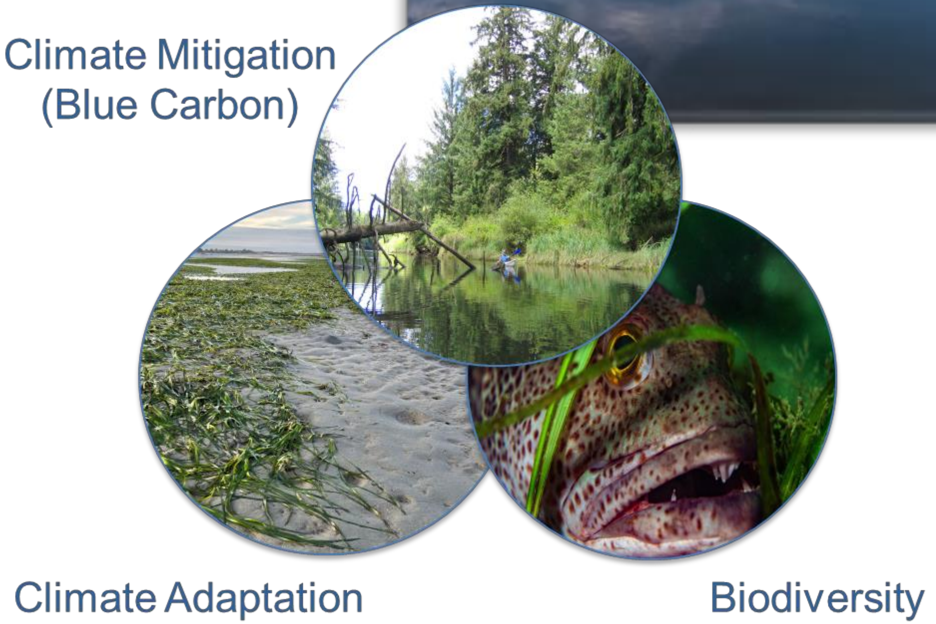
National

- Blue Carbon Network – facilitates information sharing among states
- **Federal opportunities:**
  - BIL and IRA
  - America the Beautiful
  - Nature-based Solutions Roadmap
  - Ocean Climate Action Plan

Ocean Climate Action

Hot topics across states

- Need for mapping & change over time data
- How to understand and manage sea level rise impacts on coastal landscapes
  - Fate of carbon
  - "Good adaptation strategy is a good carbon strategy"
- Accounting for multiple benefits: carbon, flood mitigation, biodiversity, water quality
- Other carbon sinks - oceanic carbon, peatlands



Pew

Thank You

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Extra Slides *****************

Pew

Elevating blue carbon in the climate policy arena

Challenges –

- Blue carbon habitats overlooked in state NWL strategies despite GHG mitigation benefits
- Lack of connections between coastal and climate practitioners

Opportunities –

- States eager to assess and incorporate coastal wetlands in GHG mitigation plans
- Venue to secure new conservation and restoration goals for blue carbon habitats & leverage state (and fed, private) climate funding

Effectively Crafting Decision Support Tools to Maximize the Application of Blue Carbon Data

Adrian Laufer

Sea&Shore SOLUTIONS

ACKNOLWEDGMENTS

OREGON EXPLORER

OCMP

Oregon Coastal Management Program

THE PEW CHARITABLE TRUSTS

BUILDING A MAP TOOL THAT....

1. Serves varying levels of familiarity with map tools
2. Illustrates multiple possible restoration outcomes
3. Manages data uncertainty and misuse

TOOL USERS

BEGINNER

Very little to no experience with GIS or online tools

MODERATE

Has used online tools before, but no GIS expertise

EXPERT

GIS professional

TOOL USERS

BEGINNER	MODERATE	EXPERT
Very little to no experience with GIS or online tools	Has used online tools before, but no GIS expertise	GIS professional
PRE-MADE OPERATIONS	**ADVANCED TOOL FUNCTIONLITY**	**DOWNLOADABLE DATA**

ILLUSTRATE MULTIPLE OUTCOMES

- Restored habitat is uncertain
- No single restoration outcome layer forces users to explore different habitat options

MANAGING UNCERTAINTY AND MISUSE

- Splash screen
- Always illustrate multiple possible scenarios
- Assumptions

Sea&Shore SOLUTIONS

Oregon GeoHub
GIS software and hosting

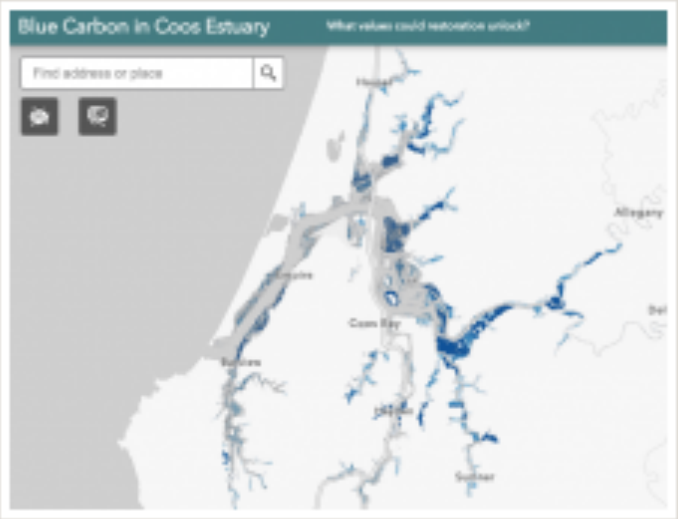
Oregon Explorer
Tool publishing and sharing

TECHNOLOGY

oregonexplorer.info/content/blue-carbon-coos-estuary

OREGON EXPLORER Natural Resources Digital Library

Topics Places Tools Data



Blue Carbon in Coos Estuary

This tool was created to help prioritize areas in Oregon estuaries where tidal wetland conservation and restoration would be particularly effective for maintaining and/or expanding blue carbon sequestration and storage, and for reducing GHG emissions. The data shown in this map is based on completed and ongoing work to quantify the blue carbon value of Oregon's estuaries.

Shapefile Download: here For users that want to download the data layers and use them in their own GIS space.

Methods Manual: here. Report on exactly how the data was developed in the tool.

Acknowledgments: The Pew Charitable Trusts, Institute for Applied Ecology, Silvestrum Climate Associates, Sea & Shore Solutions

TOPIC TAG(S): Coastal Research

Resource Date:
2023

Open

Sea & Shore SOLUTIONS

THANK YOU

Questions?

adrian@sea-shoresolutions.com

Sea & Shore SOLUTIONS

Q&A

Q: How did the sampling strategy account for patchiness?

- **A (Chris):** We had six chambers per site in the study, and we accounted for some of that patchiness in plant communities. We had a site, for example, dominated by Carex lyngbyei, but we had a few open areas and we had one or two chambers that fell into those areas.
- **A (Scott):** We did transects away from the major waterway to intentionally sort of measure the hydrologic variability within the site and then after that it was basically random along a transect. I think with a regional approach like this we don't capture variability greater than any single site, but the intention was to capture regional variability and hopefully we've done a reasonably good job with the sampling scheme across all the different sites. You have 36 sites times six chambers per site, so we had lots of chambers in very different types of vegetation communities across the whole study. In the paper we look a little bit at plants but not too extensively because the study was not designed to look at plant effects on methane per se.

Q: What is the restoration age range for the polyhaline and oligohaline restored sites included here?

- **A (Scott):** They varied from about a year to about 25 years. It'd be the early 1990's I think were the older sites.

Q: Given the results of the radiative balance, how would you respond to the possible criticism that, over a 100 year timeframe, restoration of these ecosystems for climate benefits alone does not appear to be worth the effort and resources would be better used on protection of reference sites or on other methods to draw down carbon?

- **A (Scott):** In general, I would say that protection of existing sites is always really important, particularly if they have high soil carbon because if you lose that soil carbon it's a really major CO_2 emission to the atmosphere. So I would always prioritize protection. In terms of these fresh and oligohaline storage sites, I do think there are management activities that you could try to do to reduce the methane emissions and I discussed some of them. Either initially or overtime you would expect that they would rapidly rise in tidal elevation and eventually their methane emissions should decrease. On the other hand, there are lots of ecosystem benefits from these oligohaline marshes and I think we're often these days focused on carbon balances and climate forcing, but certainly, locally, the other ecological benefits of these sites are doing way more, in my personal opinion. But if you are doing it intentionally for carbon credits or something like that, then these results are really highly pertinent.

Q&A

Q: What take-home messages do you think most stakeholders need to know, and what parameters are the most significant as my organization collects data on Blue Carbon Systems?

- **A (Katrina):** There are many take-home messages but one is that we could get very different conclusions on management implications if we just focused on stocks vs carbon accumulation rates vs greenhouse gas emissions and so we're finding that it's important to measure all of them to understand the different considerations in managing for carbon. I would also reiterate what Scott said that we could get really into the details about carbon but we still want to be restoring these ecosystems because they are so important for other reasons too. So, if we're restoring maybe there are ways we can accelerate that trajectory towards lowering carbon emissions by adding sediment or increasing channel networks but I think we should still be focusing on restoration for other reasons.
- **A (Craig):** It's tough to say what parameters are most significant without knowing what other data might be available in this person's region. figuring out what's missing might be one place to start and start filling some data gaps.

Q: Charting restoration effects is difficult because of the extended recovery times. Do you have a sense of recovery age that is necessary to yield stable results?

- **A (Scott):** No, not yet. We're in the process of modeling, where we're beginning to think about these things and also sea level rise within those. Many of these restored sites. as Katrina showed, accrete sediments very rapidly, so I think up to a centimeter or more per year. It doesn't take 100 years to accumulate a whole lot of elevation in some of these sites. They are accumulating an inch in several years at some of them. It's more rapid that moving up in the tidal frame than the question presented, in many of our sites.
- **A (Katrina):** At the restored sites 1-3 cm per year, initially
- **A (Chris):** What we don't really know is how rapidly soil and groundwater conditions change. We've only within the last decade or 15 years been starting to monitor groundwater in tidal wetland in the PNW, so we don't yet have a good sense of how that water table is changing over time. Presumably as the wetland gains elevation it's water table will be more similar to a reference site, which trevor showed had pretty low methane emissions, but we don't java good empirical data on that yet.