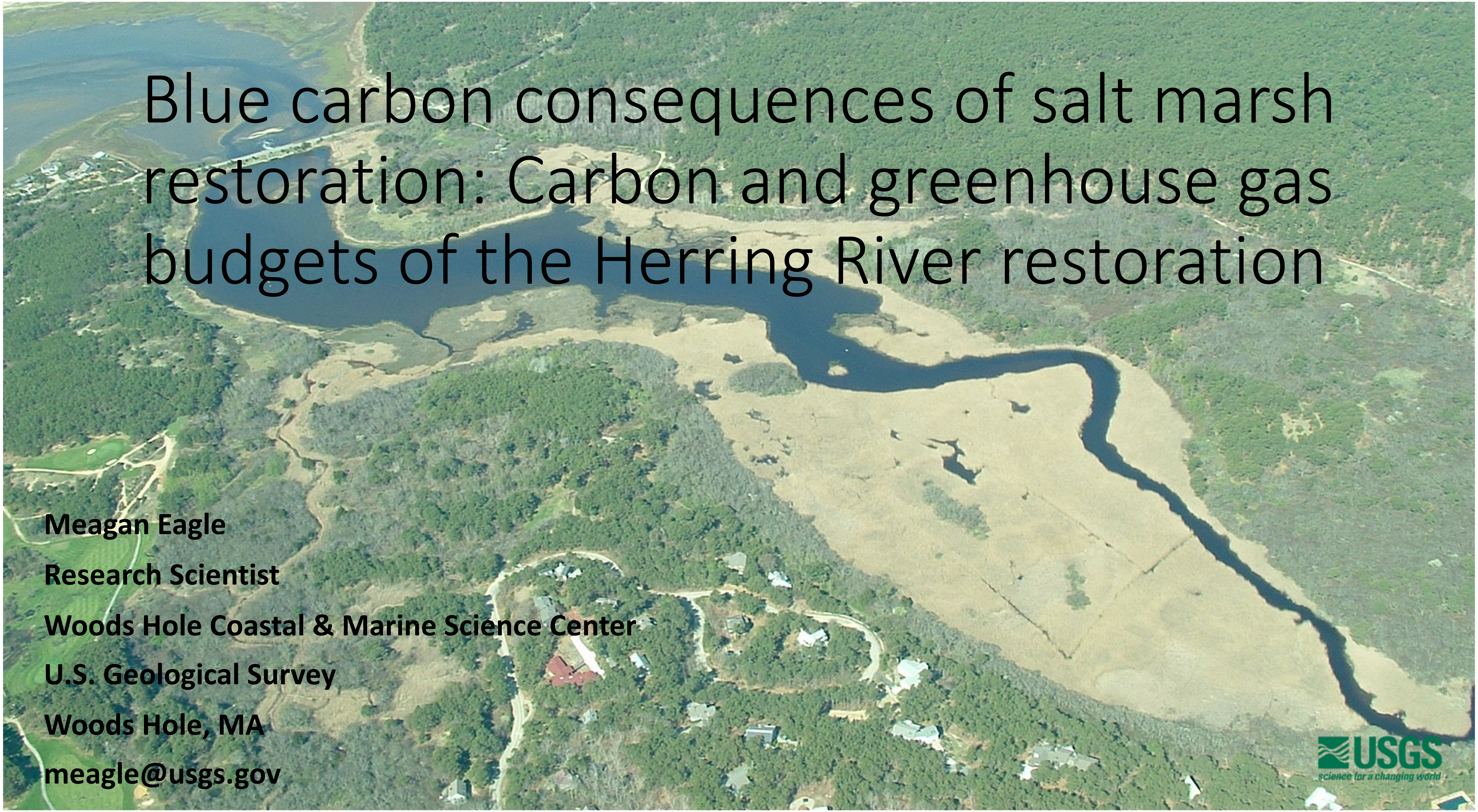
Blue carbon consequences of salt marsh restoration: Carbon and greenhouse gas budgets of the Herring River restoration



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Funding: NOAA NERRS Collaborative, United States Geological Survey-Land Carbon and Coastal & Marine Hazards, NOAA Sea Grant, NSF

*Photo credit Sandy Brosnahan

What are coastal wetlands?

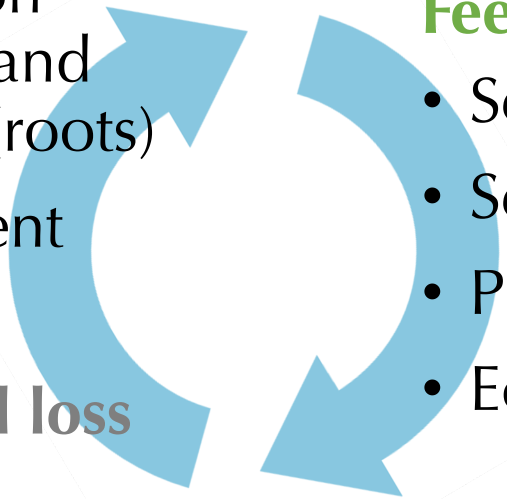
- Habitat for birds, fish and animals
- Recreation
- Coastal storm/flood protection
- Carbon Storage or Blue Carbon

Marsh growth

- Plant production above (leaves) and below ground (roots)
- Mineral sediment deposition

Marsh decay and loss

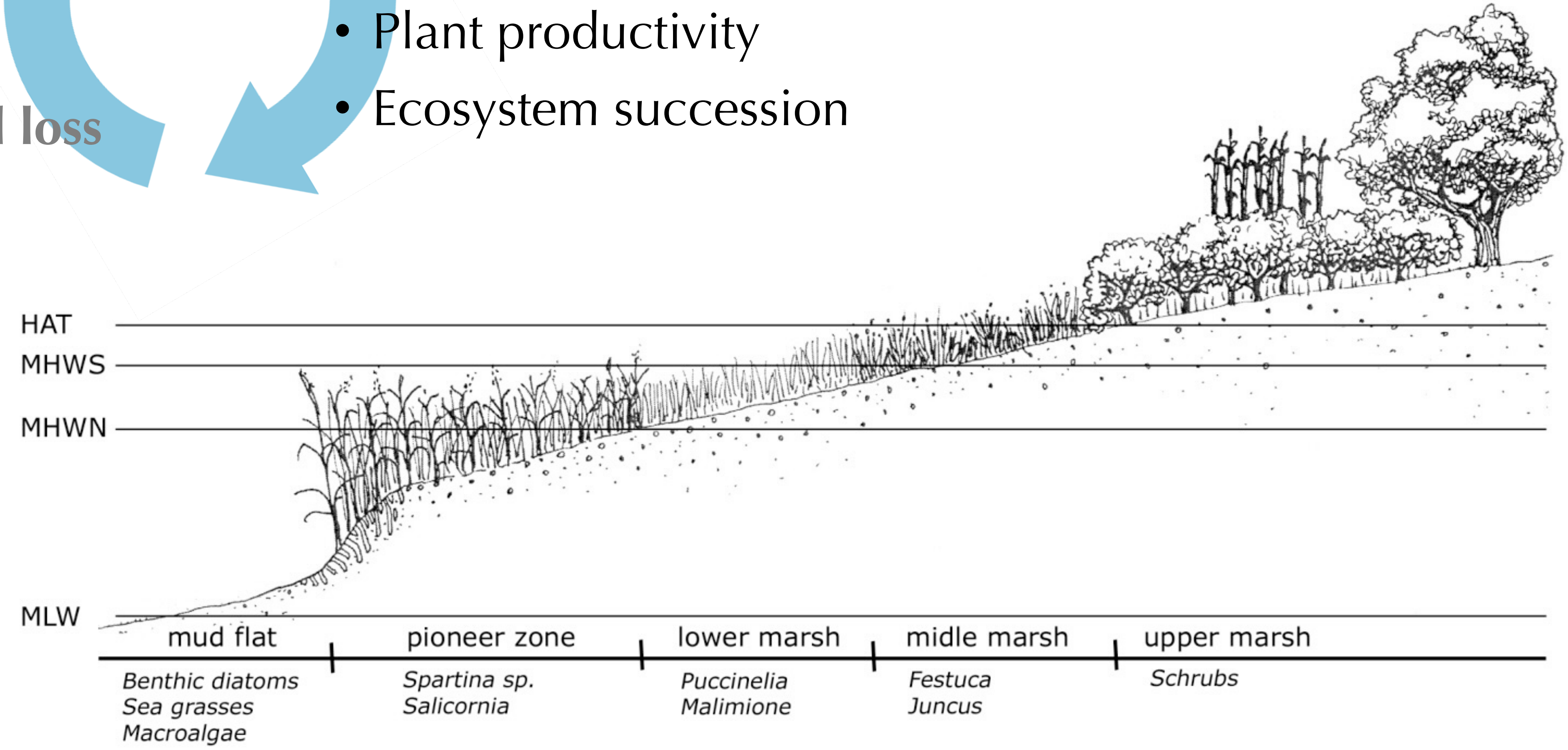
- Decomposition
- Erosion

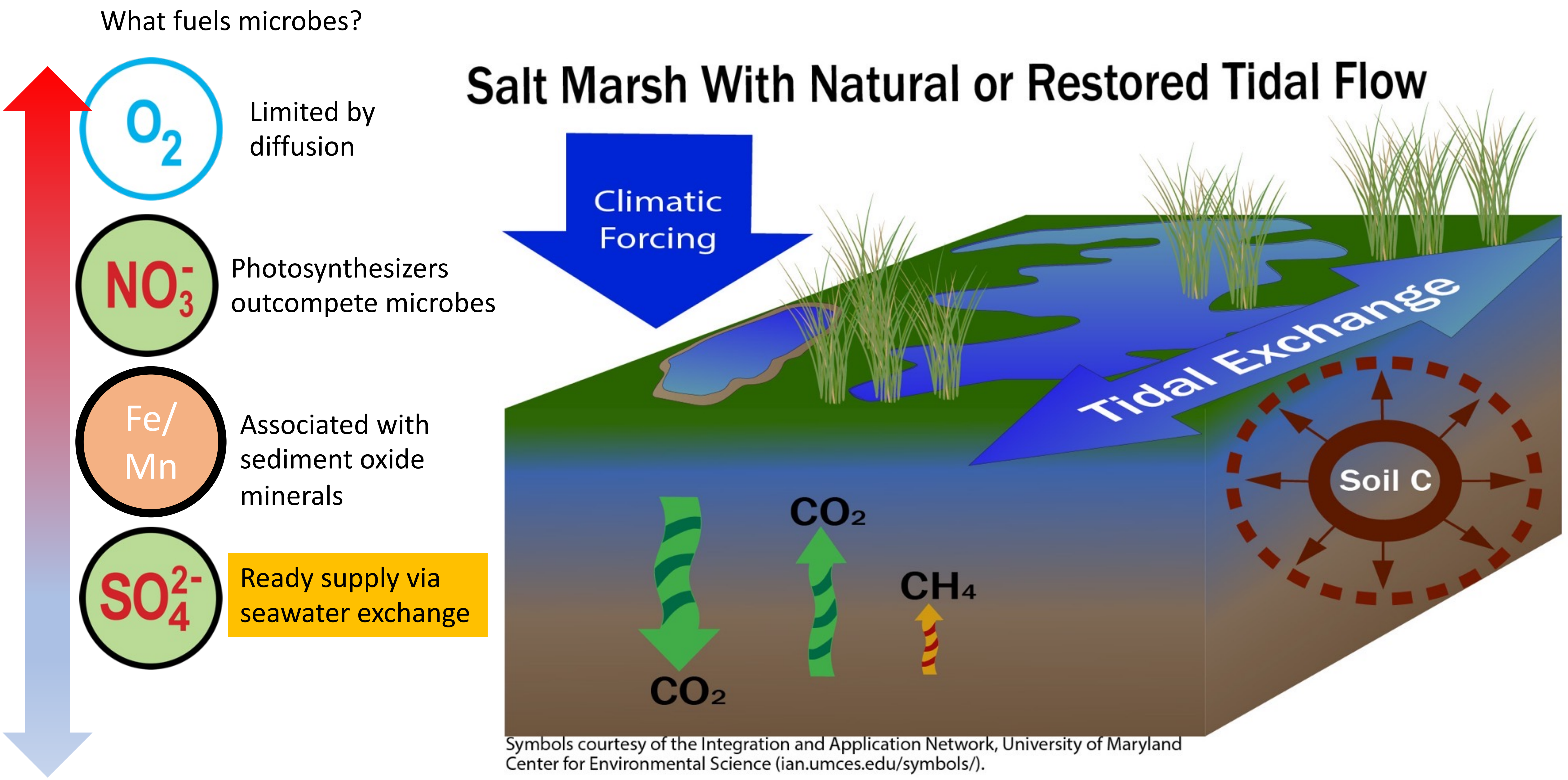


Ecogeomorphic Feedbacks

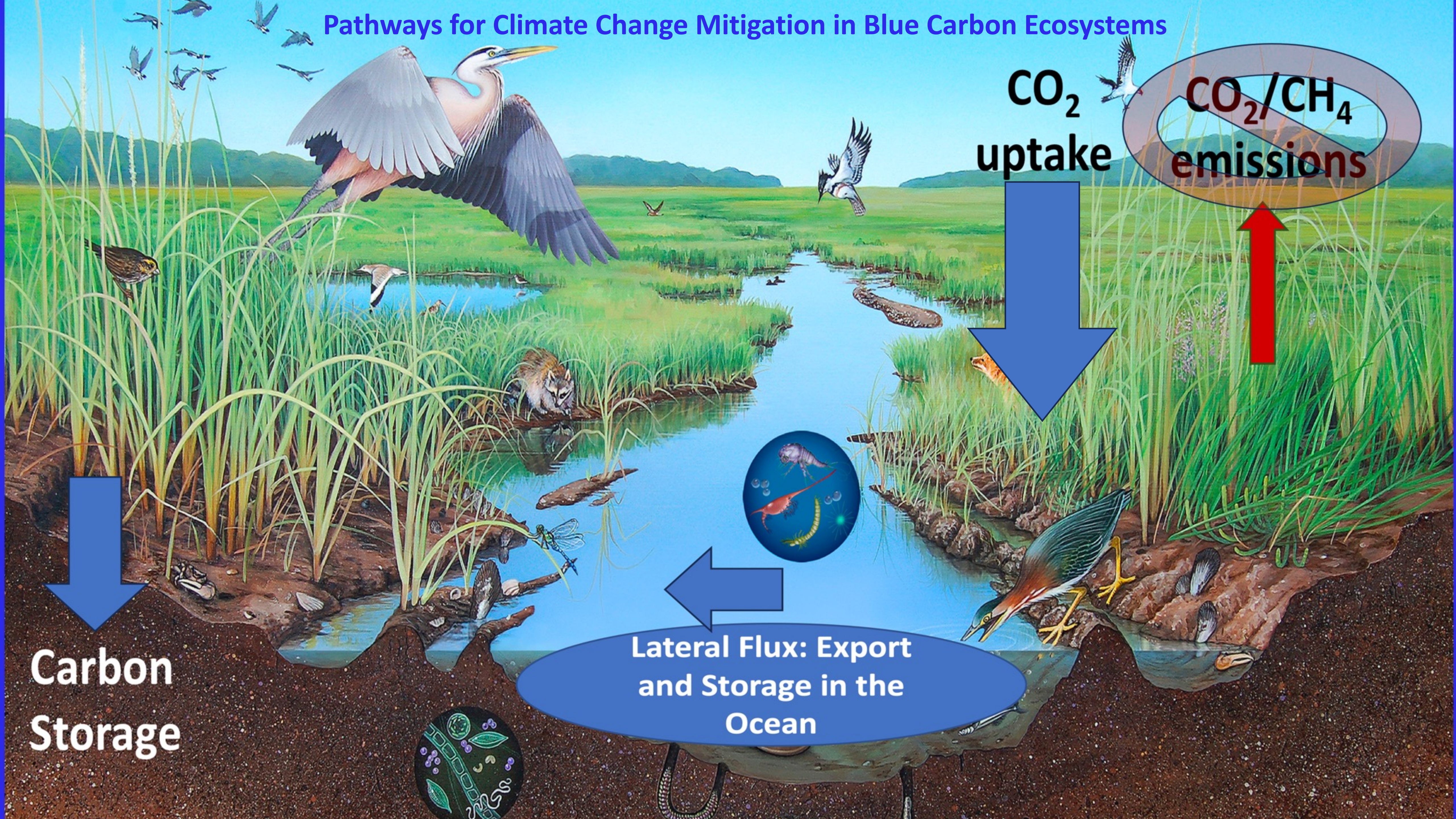
- Sediment supply
- Sea-level rise
- Plant productivity
- Ecosystem succession

Marshes occur where land and ocean meet. They are a dynamic landscape that can grow and expand if conditions are favorable.



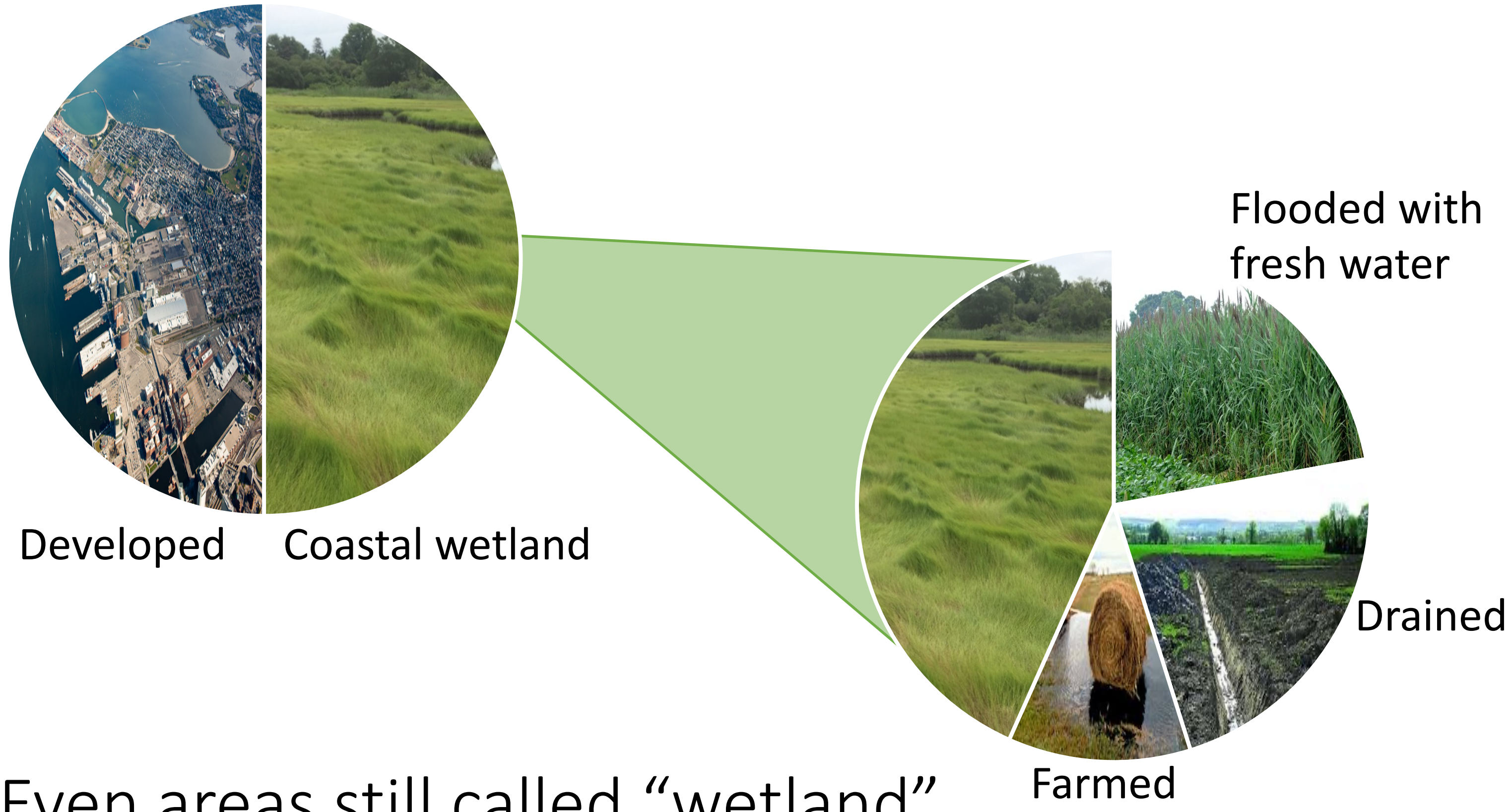


Kroeger et al. 2017; Graphics, Jennifer O'Keefe Suttles



Pathways for Climate Change Mitigation in Blue Carbon Ecosystems
CO_2 uptake
CO_2/CH_4 emissions
Carbon Storage
Lateral Flux: Export and Storage in the Ocean

Since New England was colonized by Europeans, **50%** of coastal wetland area has been lost to development.



Even areas still called "wetland" may not look like they did hundreds of years ago—or provide the same benefits to animals and people.

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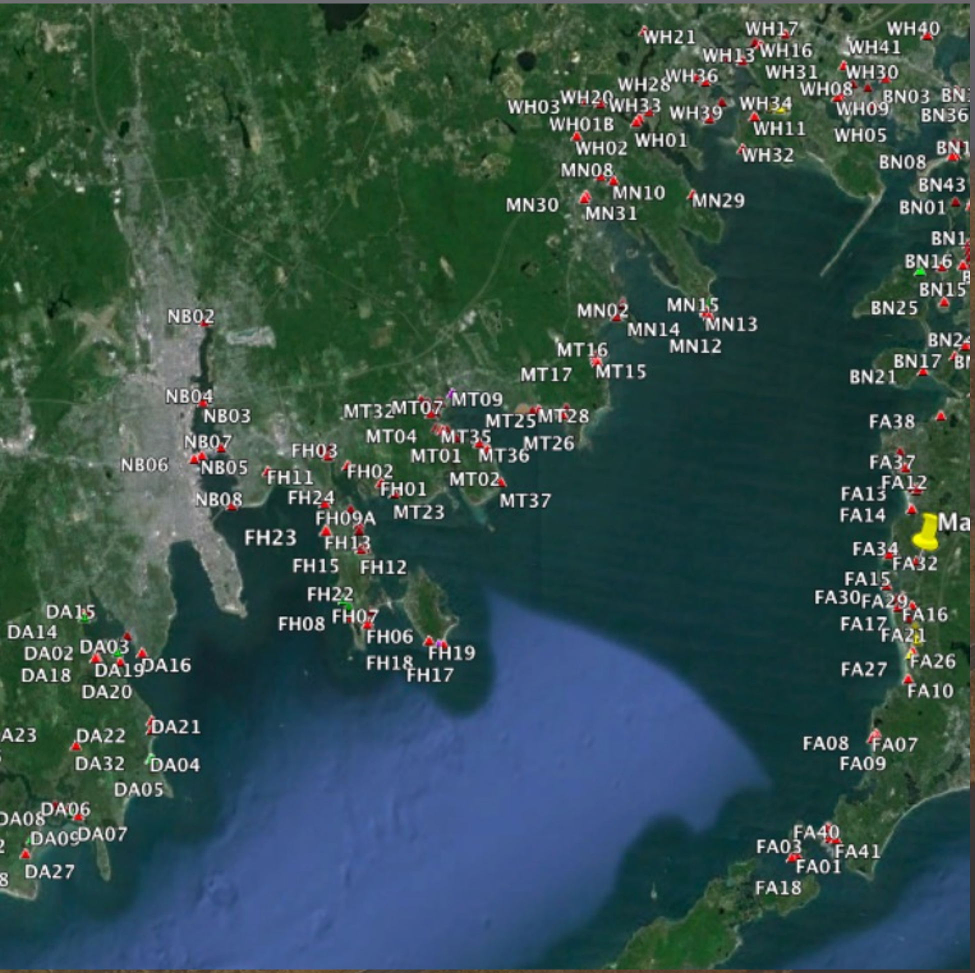


Impounded and tidally restricted wetlands

- Nearly 600 tidal restrictions in the state of Massachusetts alone
- Estimated ~1.2 million acres across the continental U.S. (Kroeger et al. 2017, Fargione et al. 2018)

Buzzards Bay tidal restrictions mapped by Buzzards Bay NEP & Buzzards Bay Coalition

https://buzzardsbay.org/living-resources/salt-marshes/salt-marsh-atlas/

Diked and drained wetlands

- ~0.6 million acres of drained, formerly tidal wetland within US (Crooks et al. 2018)
- Commonly for farming or development
- Increased and enhanced deployment in response to sea level rise is likely
- Result in non-resilient landscapes:
  - Elevation loss
  - Diminished SLR-induced accretion
  - Enhanced fire risk

Marsh growth

- Plant production above (leaves) and below ground (roots)
- Mineral sediment deposition

Marsh decay and loss

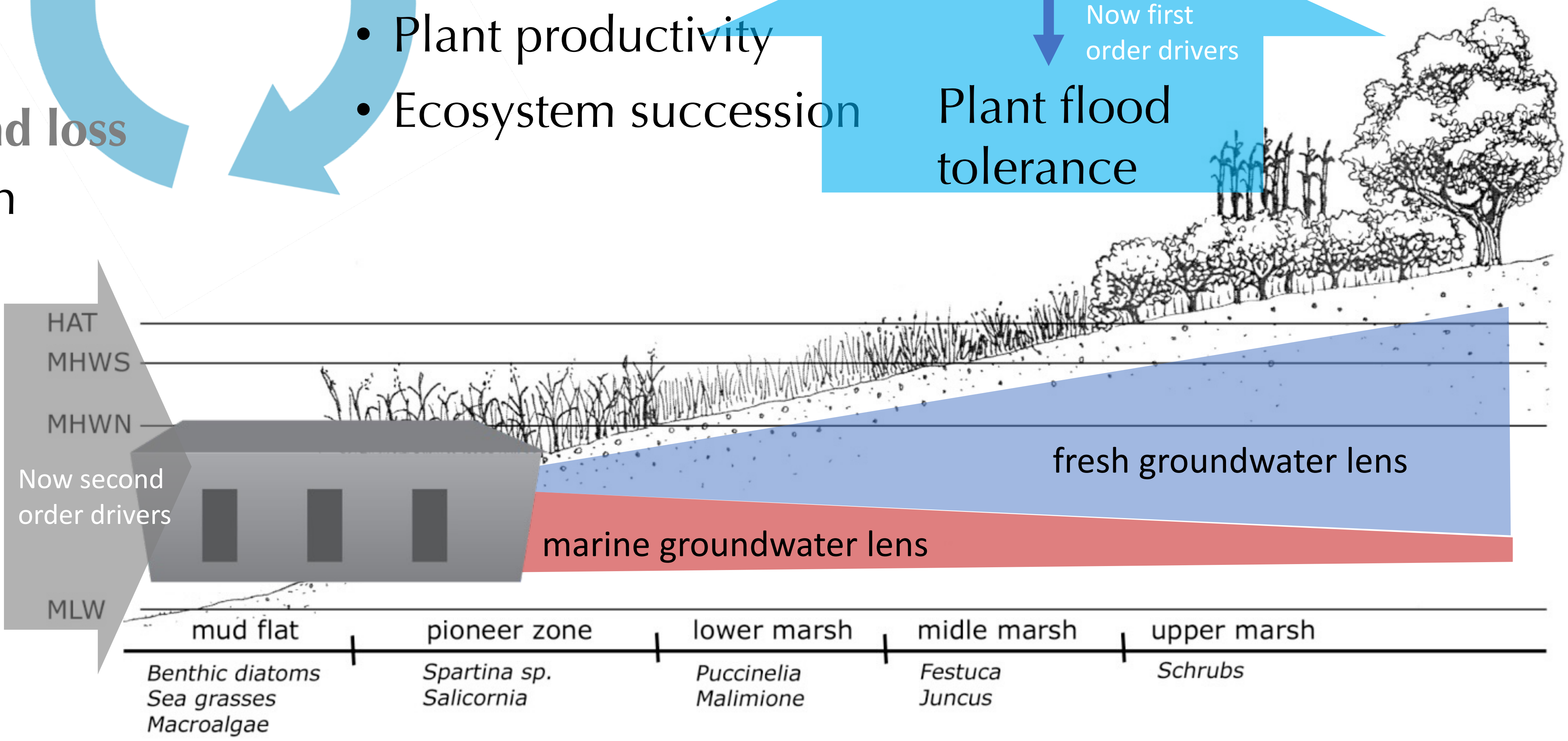
- Decomposition
- Erosion

Ecogeomorphic Feedbacks

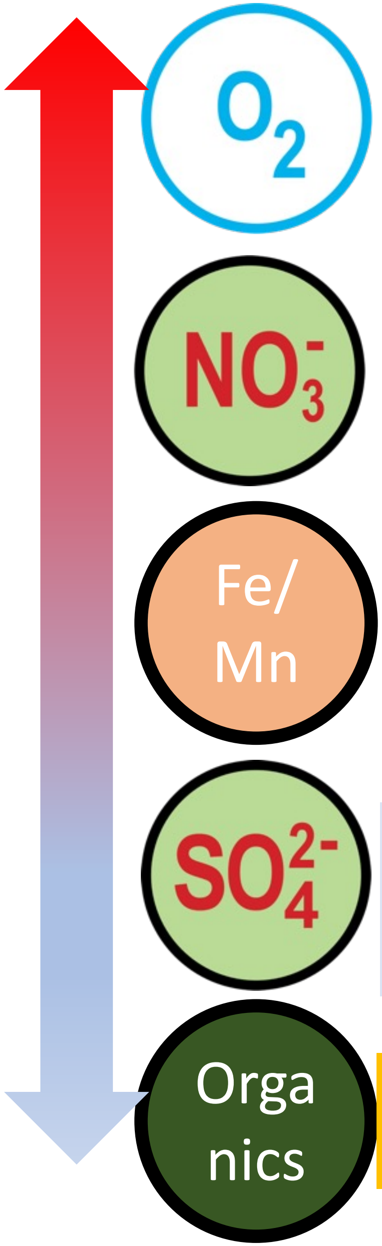
- Sediment supply ↓ Greatly reduced
- Sea-level rise → Groundwater rise
- Plant productivity
- Ecosystem succession

Now first order drivers

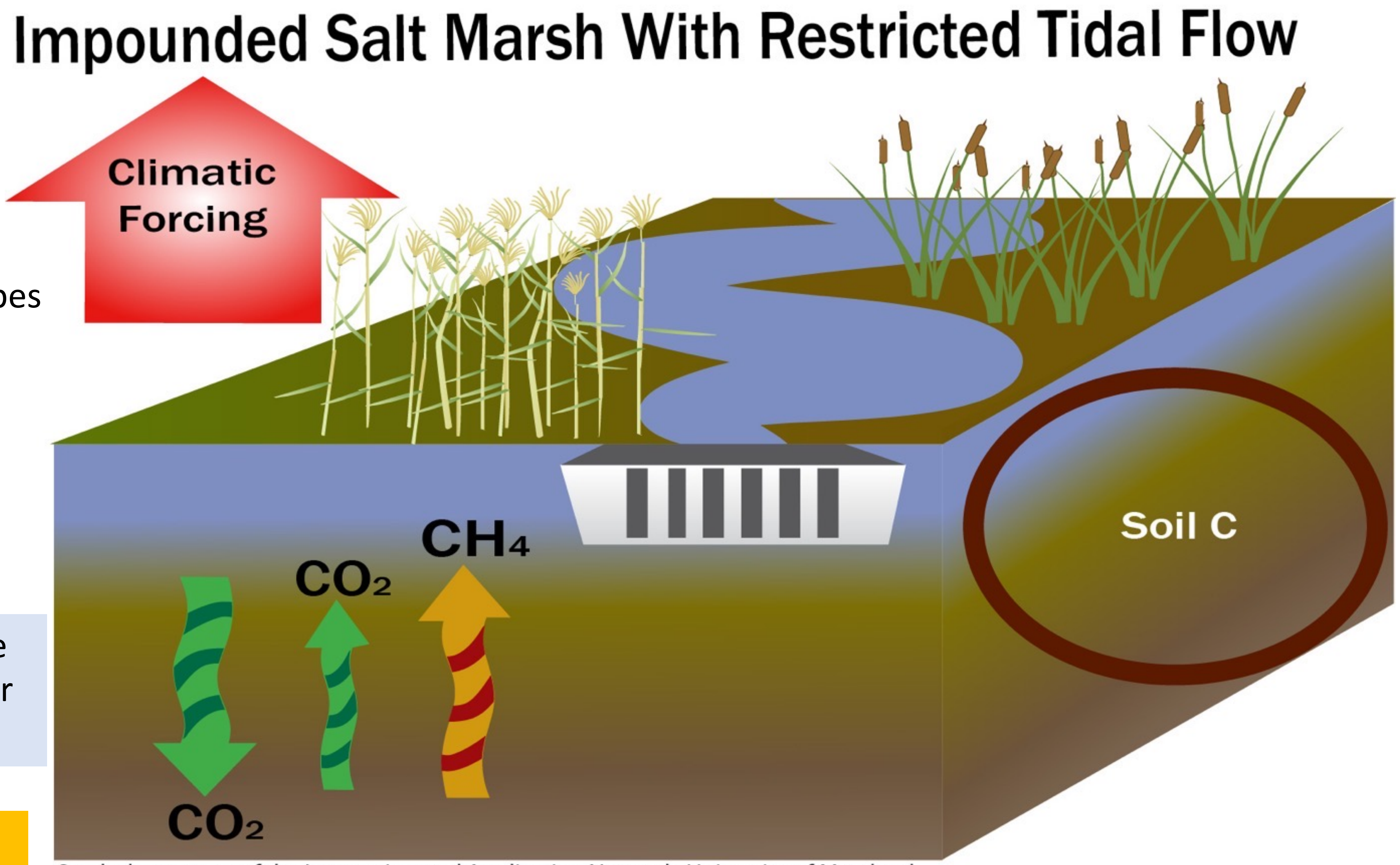
Plant flood tolerance



What fuels microbes?



- O_2: Limited by diffusion
- NO_3^-: Photosynthesizers outcompete microbes
- Fe/Mn: Associated with sediment oxide minerals
- SO_4^{2-}: Limited supply due to limited seawater exchange
- Organics: Ready supply from organic matter

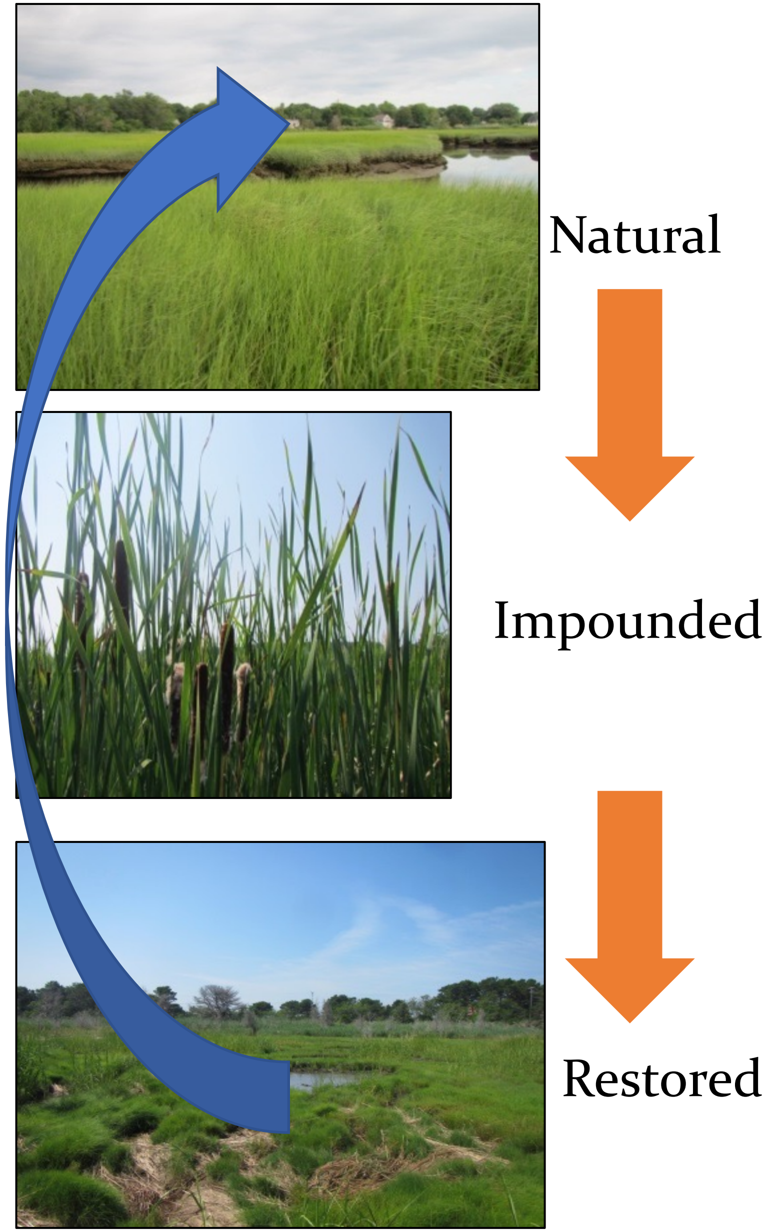


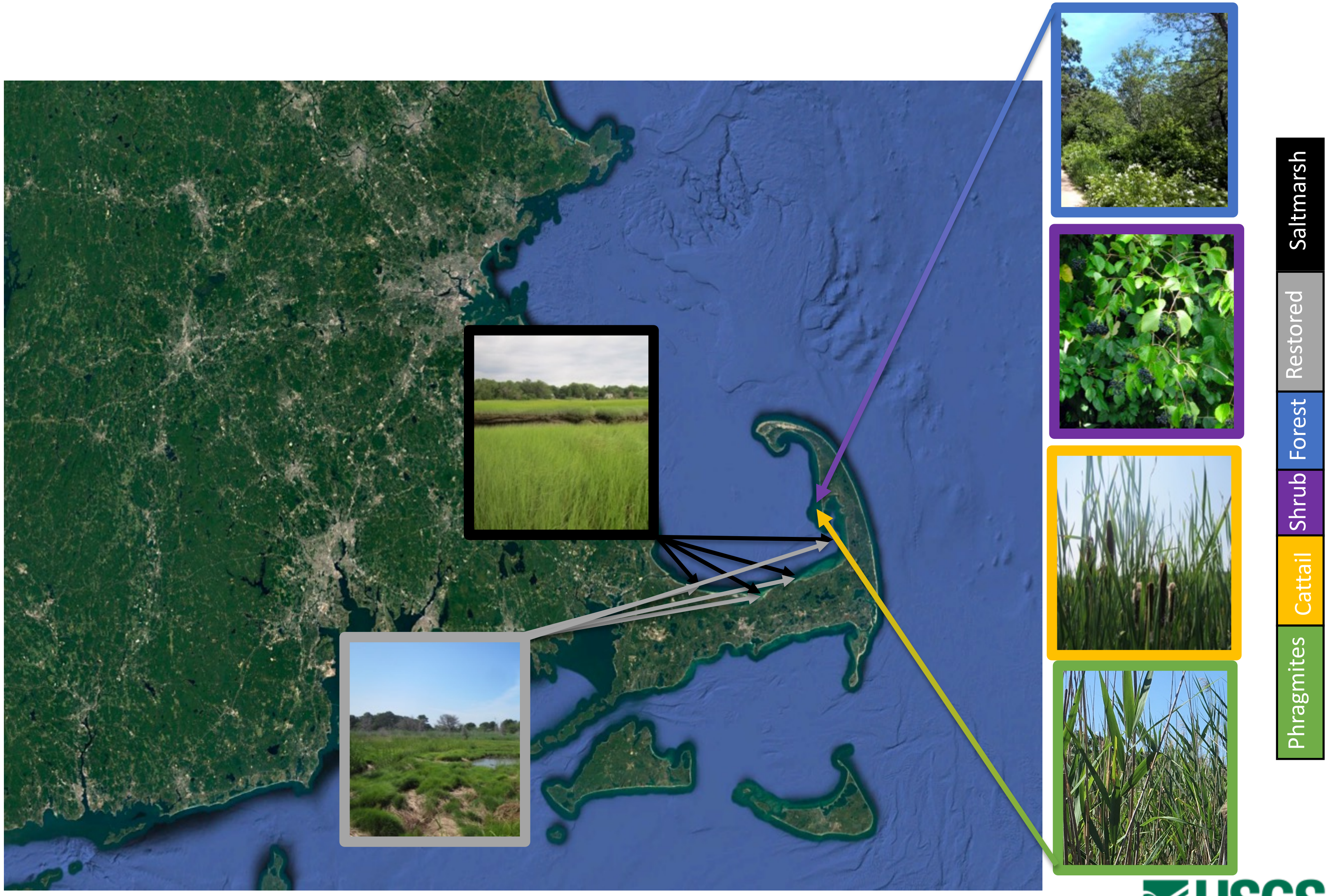
Symbols courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/).

Kroeger et al. 2017; Graphics, Jennifer O'Keefe Suttles

The Herring River in Cape Cod National Seashore has ~1000 acres of tidally restricted wetland, that is proposed for restoration, and contains both drained and freshened/impounded former salt marsh.

Herring River (Impounded) and Restored Marshes Sampling Sites





There is a large variety of impounded and drained wetlands behind the Herring River impoundment.


Natural salt marsh


Forrest and shrub in drained acid sulfate soil


Typha in saturated soil


Phragmites in saturated soil

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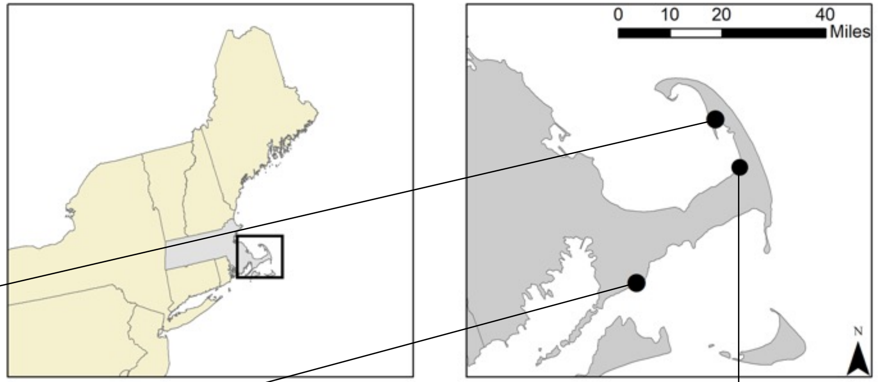
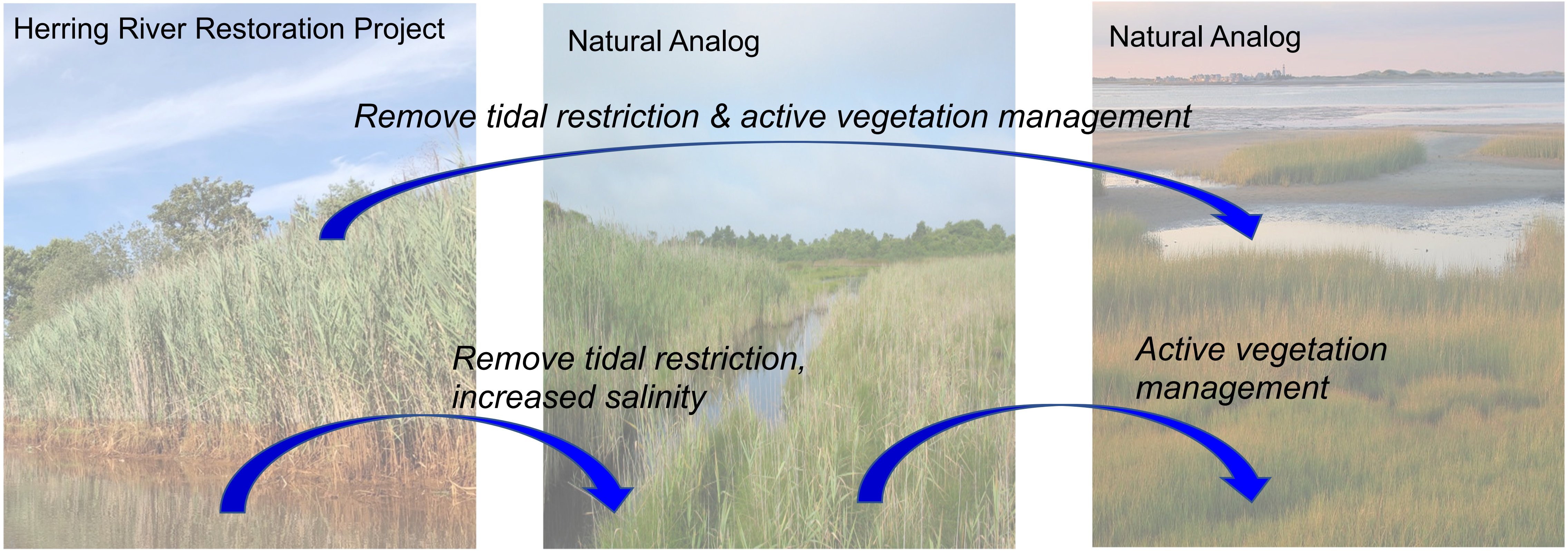
Methane, CO_2 fluxes & C accumulation measured at Herring River and across different end points of restoration

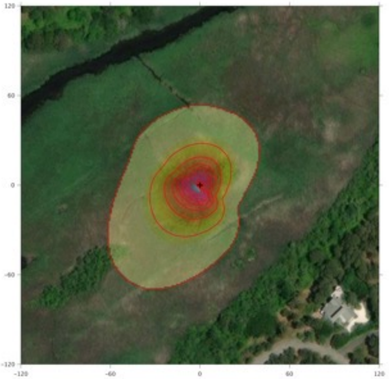


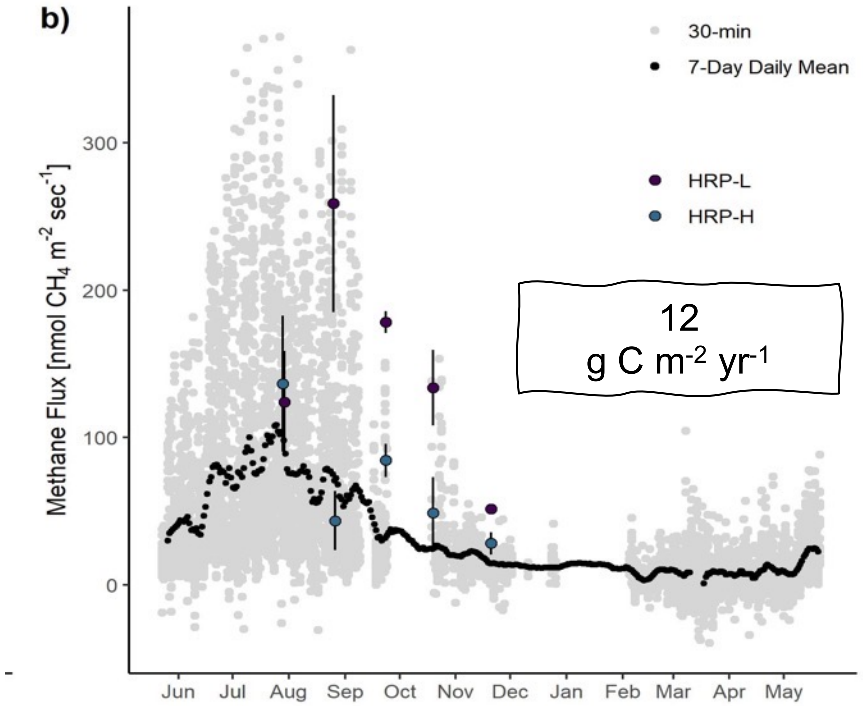
Impounded *Phragmites* wetland **Tidal *Phragmites* wetland** **Tidal *Spartina* wetland**



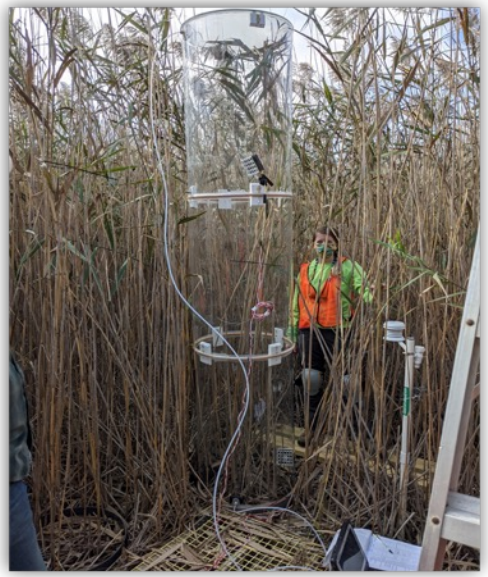
Comprehensive measurements of methane and C accumulation

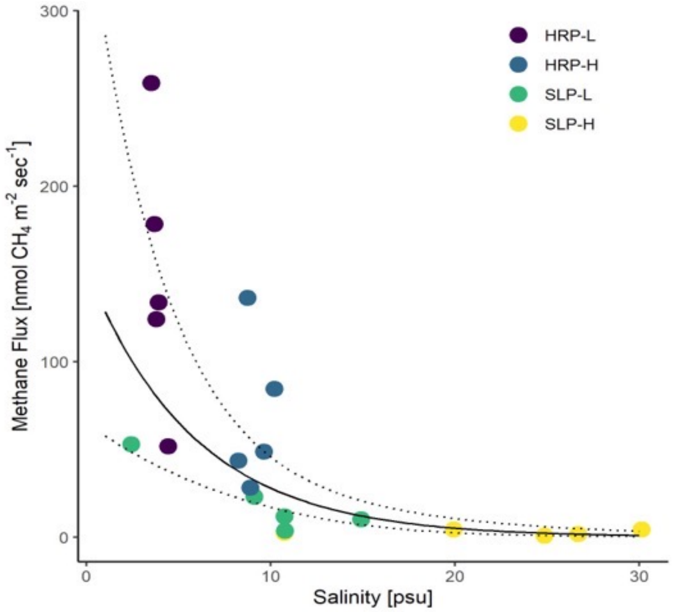
Eddy covariance at Herring River





Static chamber fluxes across *Phragmites* salinity gradient

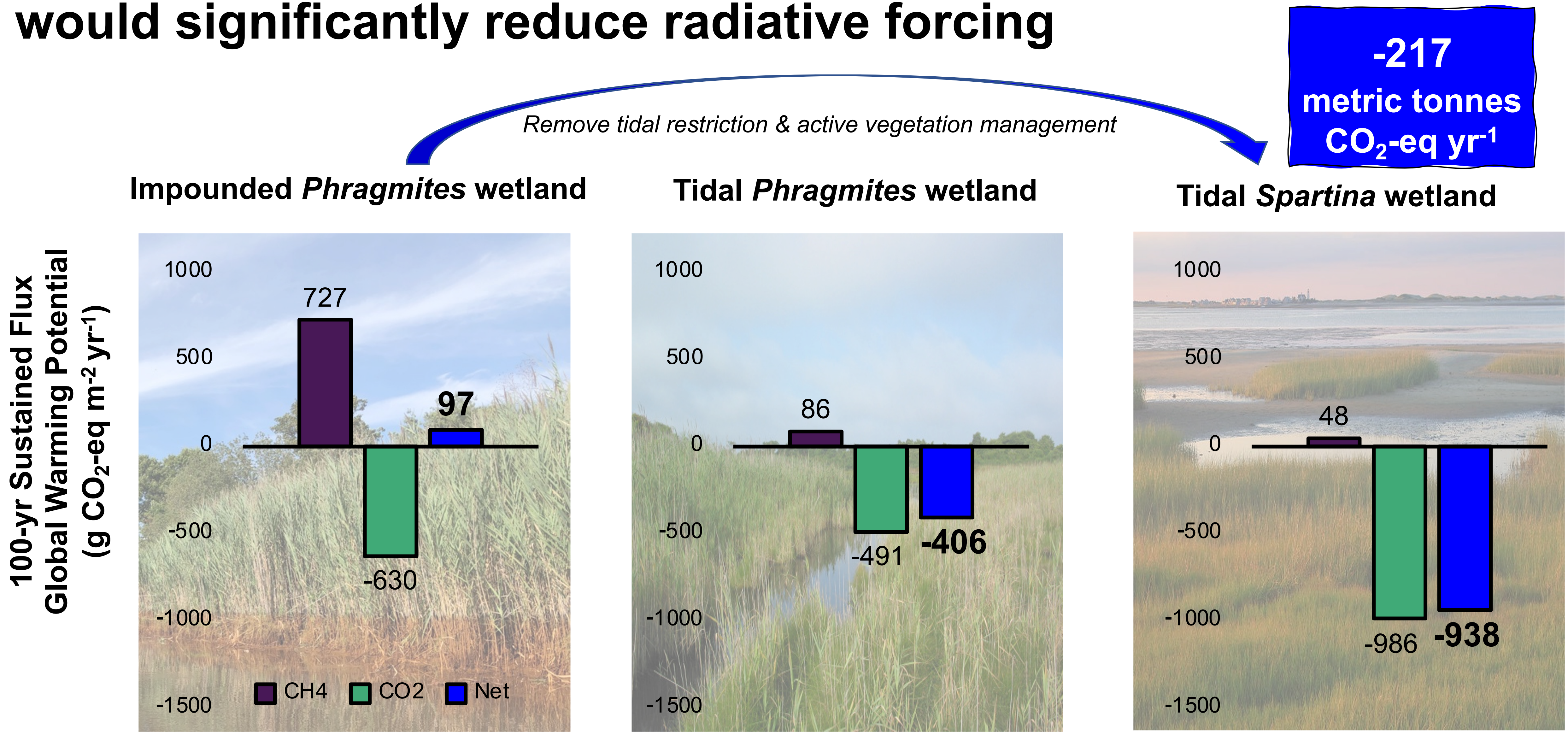




C accumulation from sediment coring

Sanders-DeMott et al., Eagle et al.

Resalinization with tidal restoration and *Phragmites* management would significantly reduce radiative forcing



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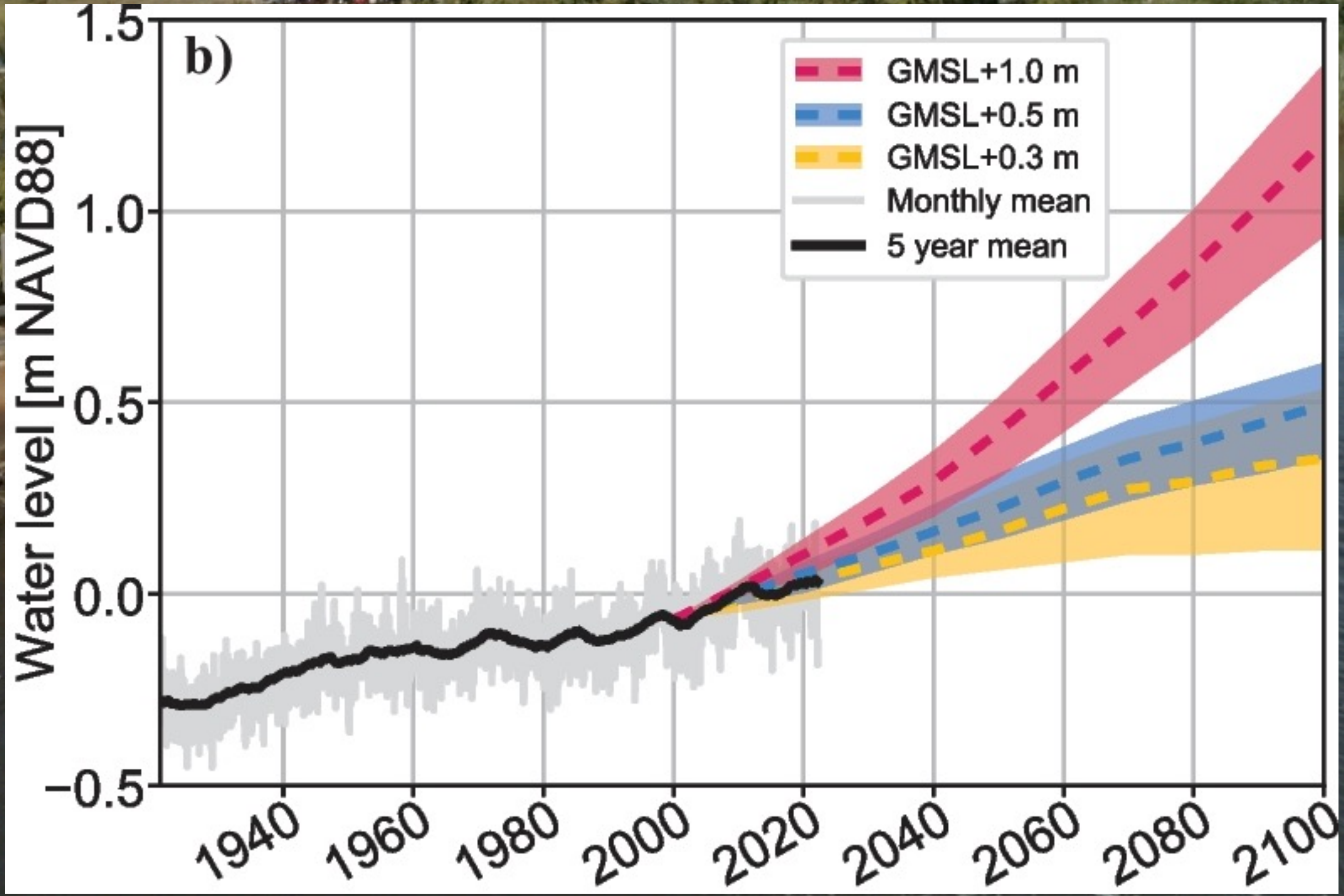
Sanders-DeMott et al., Eagle et al., O'Keefe-Suttles et al, 2020a,b, Knox et al. 2019

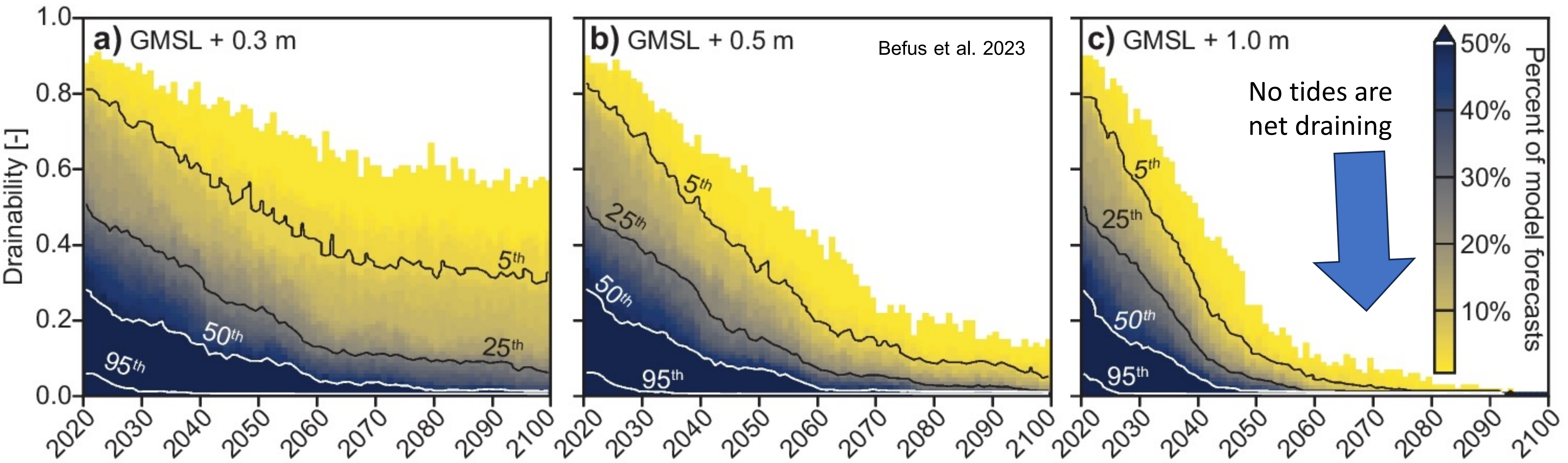
What would happen without restoration?

Sea level rise is set to accelerate into the next century.



Befus et al. 2023

Without intentional hydrologic restoration, impounded regions are expected to transition rapidly as sea level rises.



Drainability = Proportion of tides that are net draining

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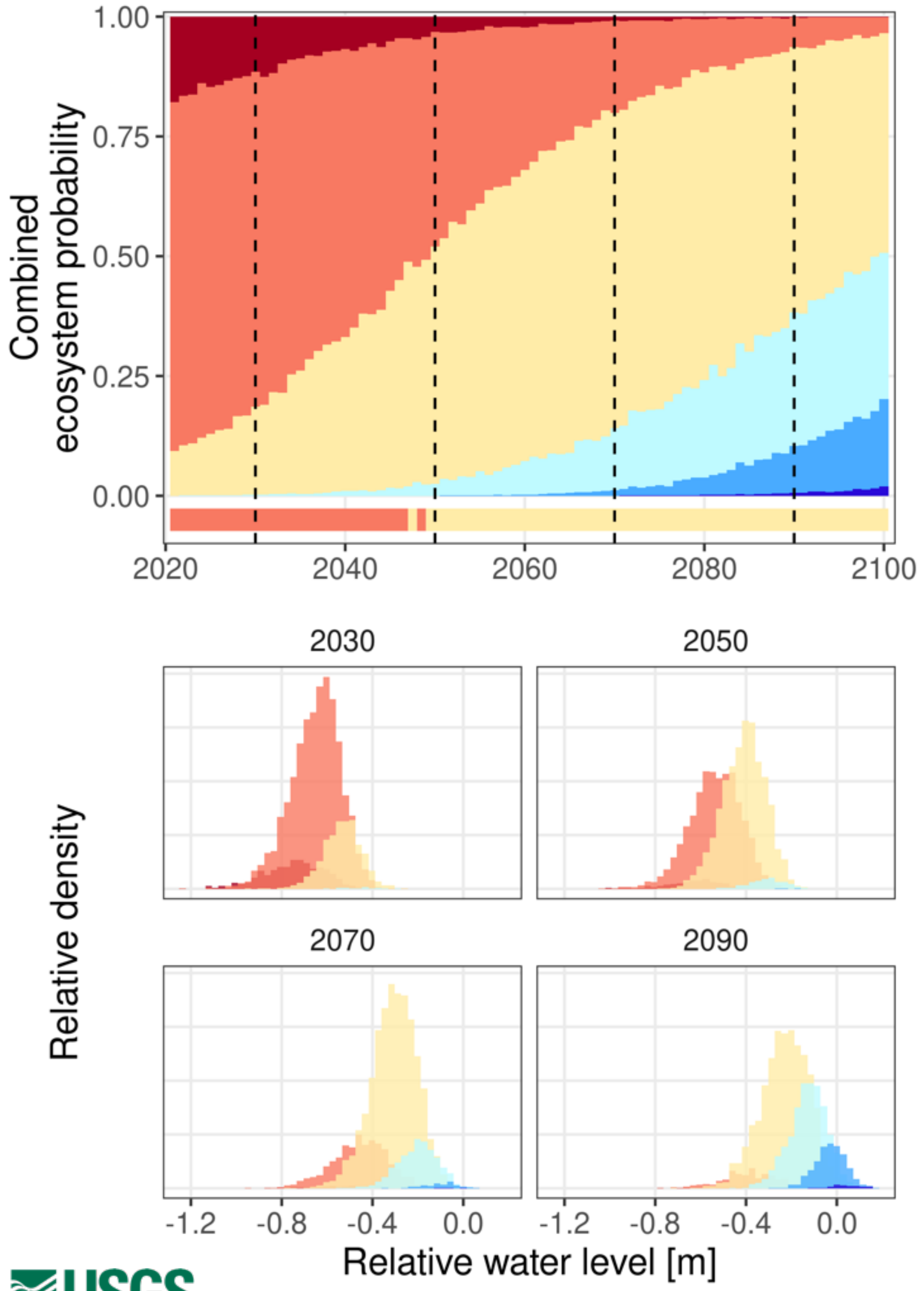

Ecosystem transitions will potentially occur rapidly…

Expected ecosystem

- Upland
- Dry Forest
- Wet Shrub
- Typha Wetland
- Phragmites Wetland
- Open Water

…and are already being observed.

Forrest/shrub

Shrub/wetland

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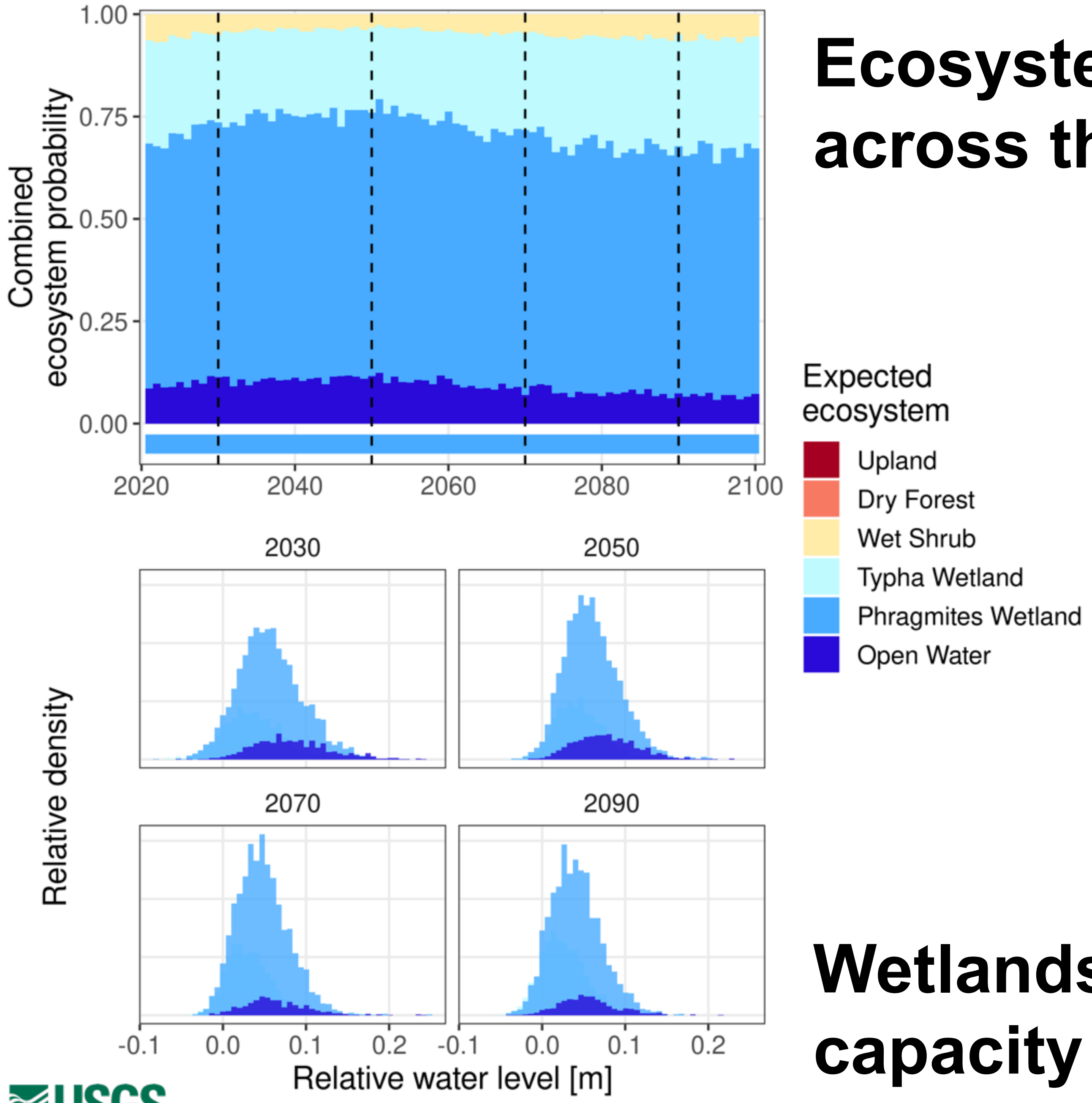
Mercer et al., in prep

Ecosystem transitions will vary across the Herring river.



Mercer et al., in prep

Phragmites

Wetlands with greater accretion capacity will resist change.

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Take home messages:

1. **Tidal impoundment and drainage** result in ecosystems with diminished carbon storage potential and enhanced methane emissions.

2. **Hydrology** is the master driver of **wetland structure**—groundwater is key in impounded systems, and sea level in natural.

3. **Tidal Restoration** can have a large impact on radiative balance of a coastal wetland.

4. **Future ecosystem resilience** is important to consider, especially for systems not captured in current models and/or data.

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Where is Woods Hole?

Seaside village in Massachusetts that is home to many research and academic institutions:

1) Marine Biological Laboratory
2) NOAA (Fisheries)
3) USGS
4) Woods Hole Oceanographic Institution
5) SEA Education
6) Woods Hole Research Center

Working at Coastal & Marine Science Center, USGS:

- We provide science products, knowledge, and guidance to local, state and federal partners. They use these tools and information to manage coastal lands and resources.
  - *I like how my science directly feeds into management questions.*
- Staff have science backgrounds ranging across biology, ecology, geology, chemistry and ocean engineering.
  - *Most staff have an MS in an above field with research scientists having PhDs.*
- Look for jobs at usajobs.gov
  - *Make an account and set up a search to alert you when positions you are interested open.*
  - *Positions are usually only open a few weeks.*
- Student opportunities at USGS
  - *Undergraduate NAGT internships*
  - *Graduate USGS-NSF GRIP and INTERN programs*
  - *Postdoc Mendenhall program*

Key websites:

Undergraduate NAGT internship: https://nagt.org/nagt/students/usgs_field.html
Graduate internships: https://www.usgs.gov/science-support/osqi/nsf-usgs-internship/science
Postdoc Fellowship: https://www.usgs.gov/centers/mendenhall

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Woods Hole Science Community Undergrad Internship Programs (that I've been involved with):

1

USGS-YES internship: 10-12 week with potential for extension (dependent on funding and project availability). Usually only one per Center (so not a group of interns together), but can happen any time during the year (not just summer). Matches project and intern, available with focus on ecology (ESA), GIS, and geology nagt.org/nagt/students/usgs_field.html **Must be nominated by faculty member.**

2

Partnership Education Program (PEP): 10 week (Course 4/Research 6) program housed at SEA, matched with scientists from all six research institutions across wide range of science backgrounds. https://www.woodsholediversity.org/pep/

3

WHOI SSF: 10-12 week program across all Oceanography disciplines (Biology, Geology, Chemistry, Engineering, Policy). **For rising seniors ONLY**. https://www.whoi.edu/what-we-do/educate/undergraduate-programs/summer-student-fellowship/

Graduate students: NSF/USGS INTERN program

1a. Find a project by [Field of Study], by [NSF Division], that is what you want to do, and work with the project lead to develop a proposal together

1b. Find a USGS researcher who is doing interesting things, and develop a proposal together

2. Talk to your advisor about USGS research of interest
3. Develop proposal with advisor and NSF program manager

*Either You (NSF-GRFP) or your advisor have NSF funding (of any kind)

Walter C. Mendenhall

Walter C. Mendenhall joined the USGS in 1894 where he mapped Appalachian coal fields, did pioneering work on the geology of Alaska, and became one of the first ground water specialists in the Water Resources Branch in 1903.

Research Opportunities

Currently available research opportunities.

How to Apply

Documents that must be included in the application and submission information.

Postdoctoral fellowship: Mendenhall

1. 2 years of full support at GS 12 level
2. Fields range across geoscience
3. Develop relationships with USGS scientists early and work with them through the process