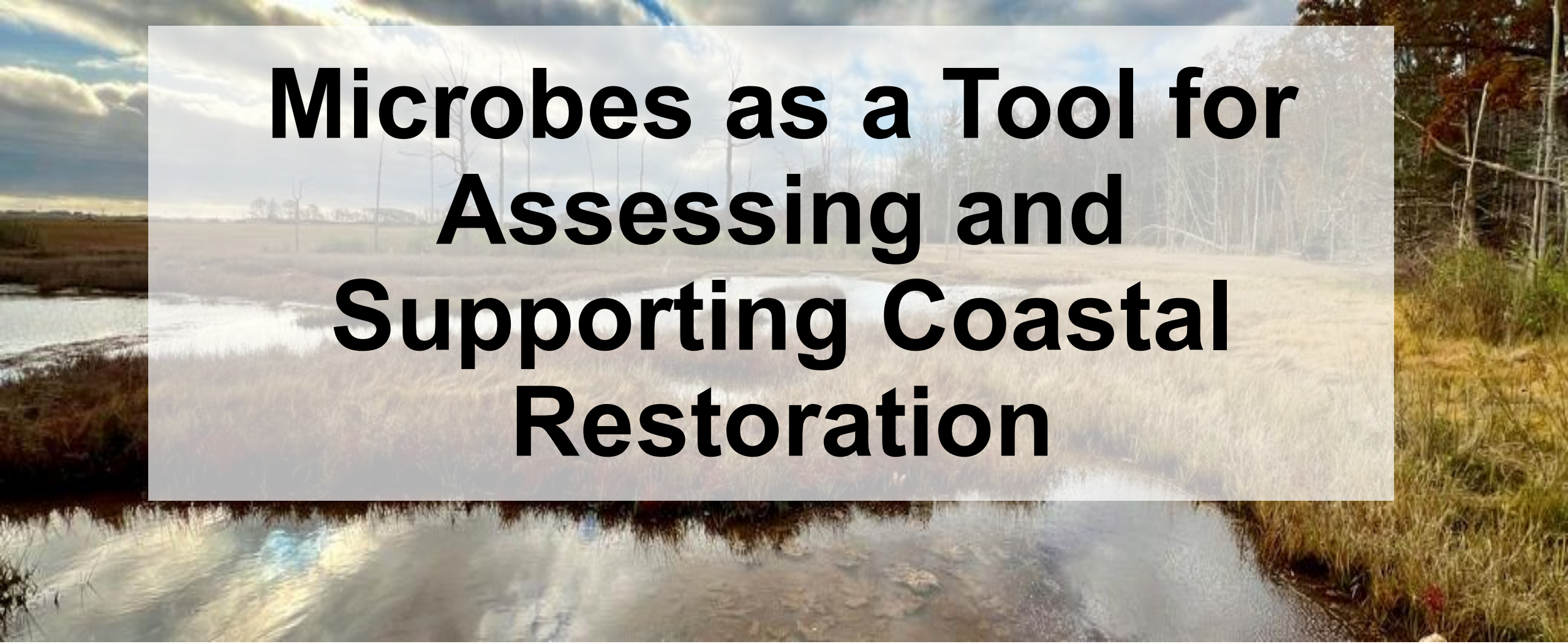


Microbes as a Tool for Assessing and Supporting Coastal Restoration

Ashley Bulseco

Wednesday, October 28, 2026

Hampton-Seabrook Estuary (HSE) Collaborative Meeting

revive & restore
GENETIC RESCUE OF ENDANGERED AND EXTINCT SPECIES

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JOINT GENOME INSTITUTE

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wellsreserve
at laudholm
Wells National Estuarine Research Reserve

NSF

Today’s outline

- Microbes: The **what** and **why**
- Ongoing projects



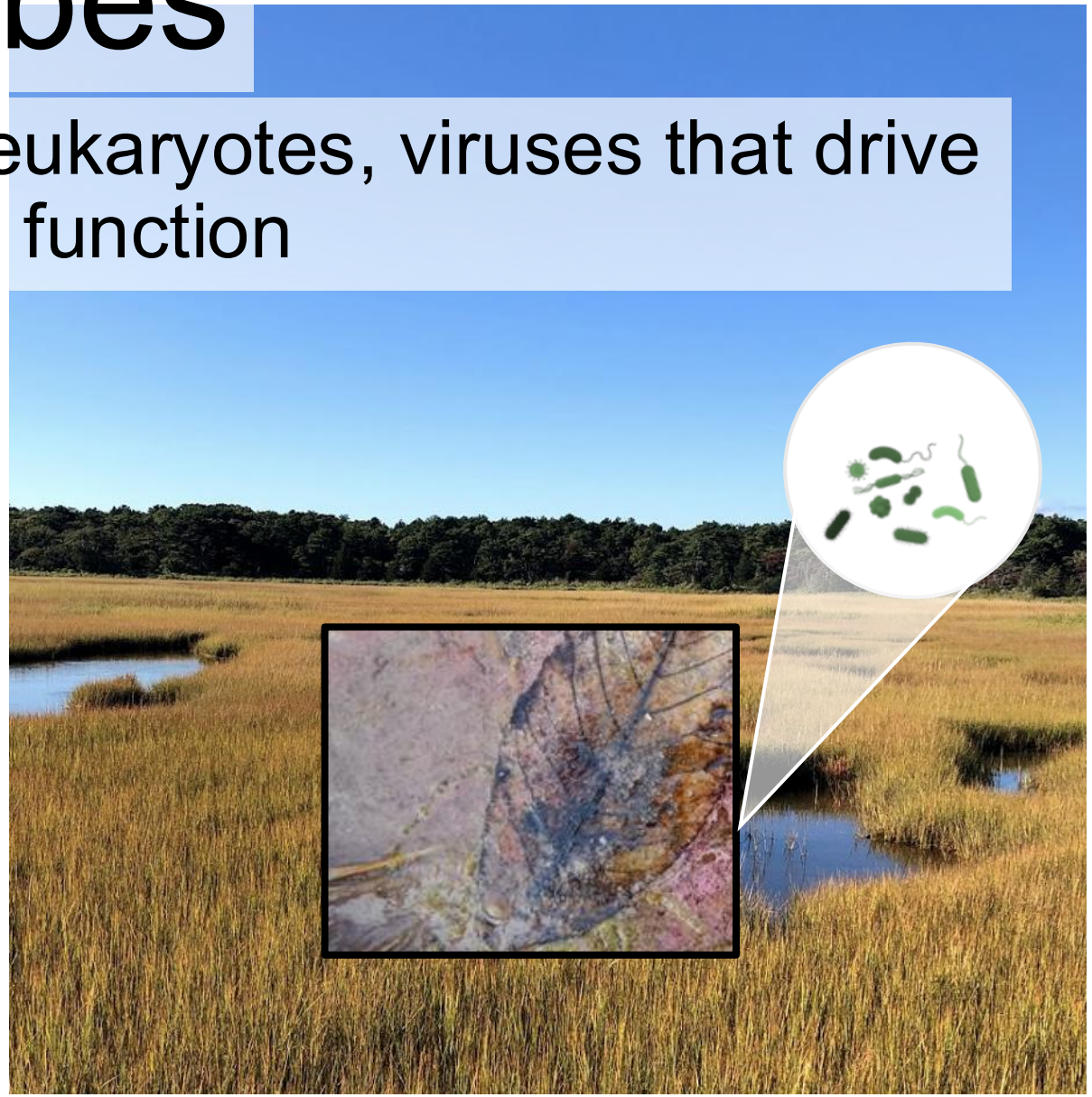




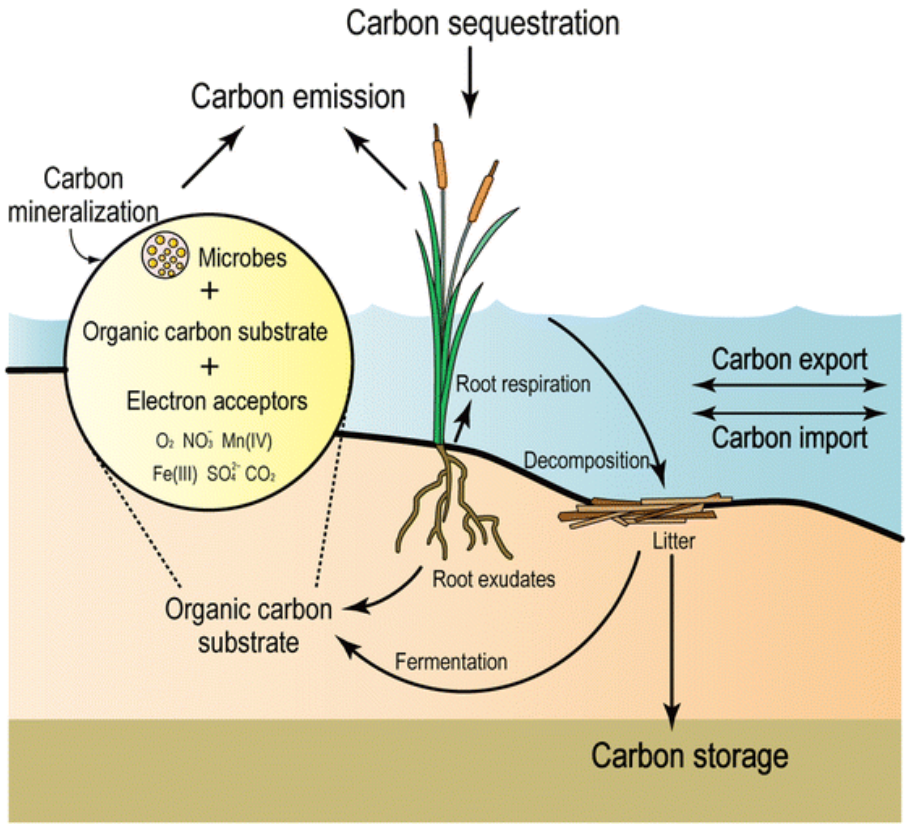
Microbes

bacteria, archaea, fungi, microeukaryotes, viruses that drive ecosystem function

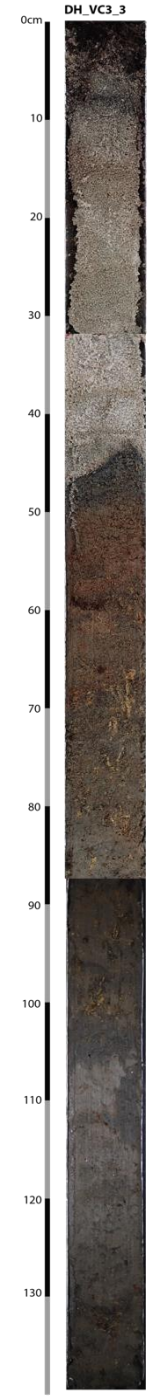




Microbes are critical for driving ecosystem function and plant health



- Microbes around roots and inside plant tissues help access nutrients
- Break down dead material and recycle nutrients
- Microbial activity determines how much carbon stays buried long term



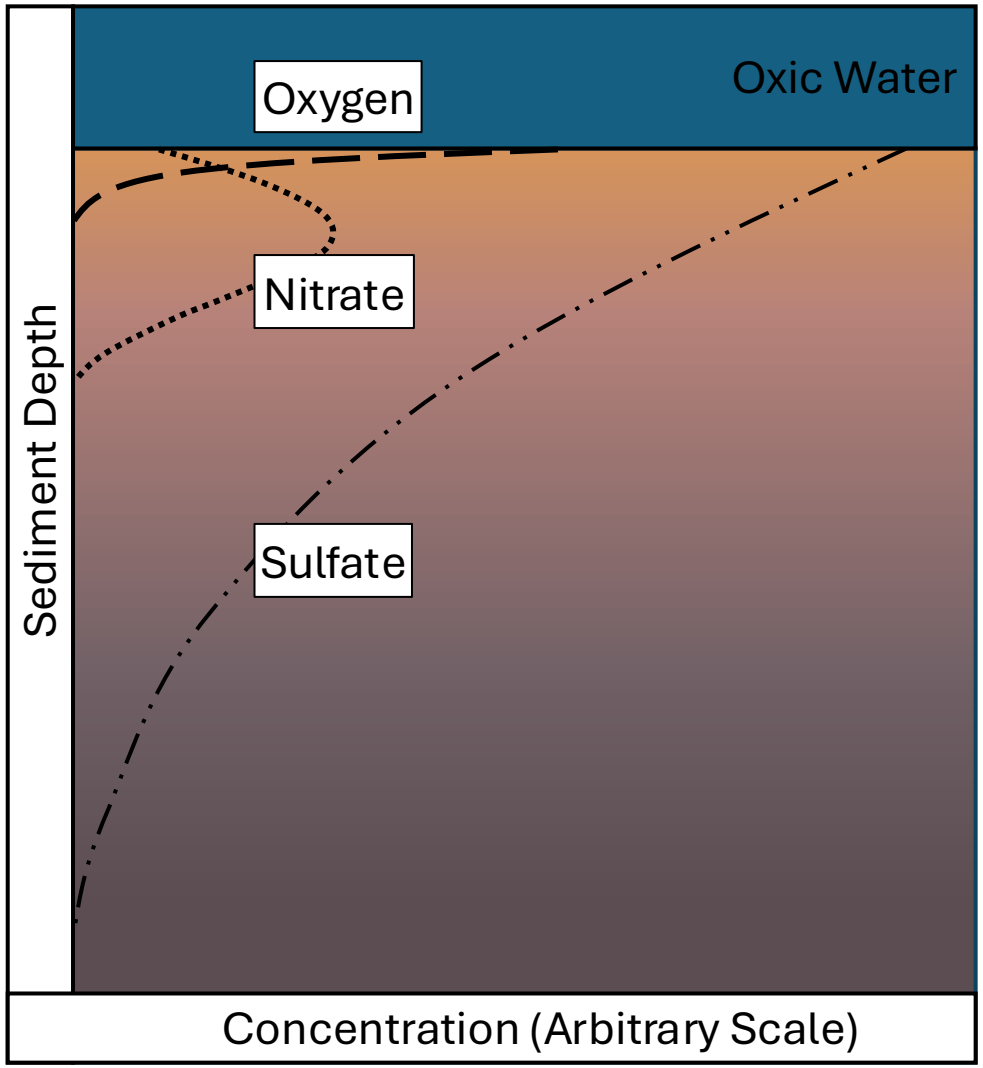
Luo et al. 2019; *Hydrobiologia*

e⁻ donor e⁻ acceptor

$$C_6H_{12}O_6 + SO_4^{2-} \rightarrow CO_2 + H_2O + ATP$$







Adapted from Canfield et al. 2005; Aquatic Geomicro.

Sometimes we can ***see*** microbial activity



Anoxygenic photosynthesizers





Chemolithoautotrophs

Sometimes we can ***see*** microbial activity



Iron bacteria with clumps and irregular edges



Oil discharge with smoothly swirling appearance



Chemolithoautotrophs

Sometimes we can ***see*** microbial activity

Chemolithoautotrophs

Heterotrophs

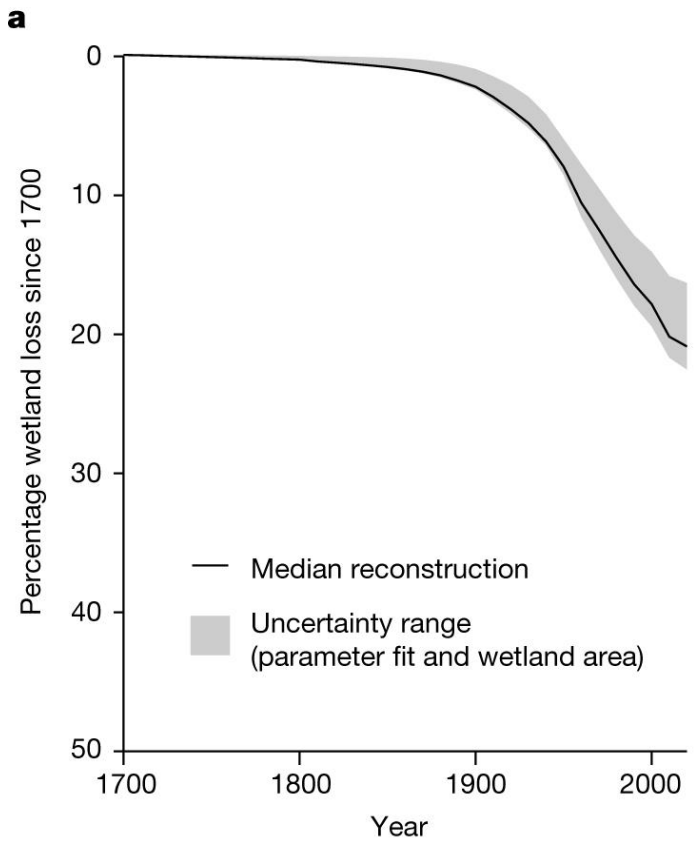
Photosynthesizers



Anoxygenic photosynthesizers

That's an oxygen bubble!

Decline in wetlands globally



Restoration to combat salt marsh loss



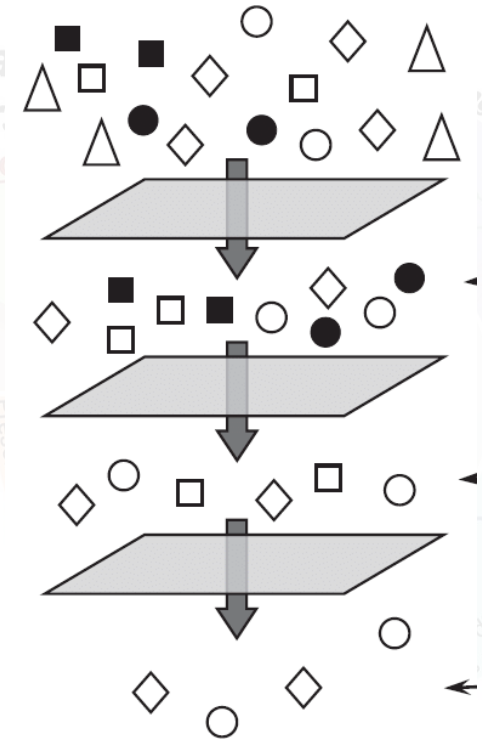


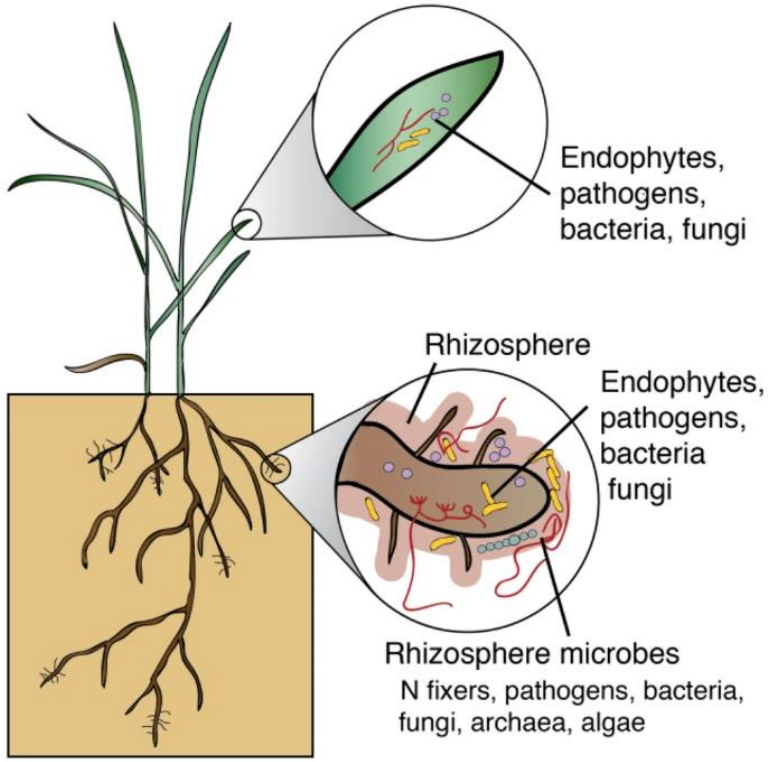


Fluet-Chouinard et al. 2023; *Nature*

Microbes in coastal restoration

1. Indicators of functional recovery through **monitoring**
2. Drivers of beneficial plant-microbe relationships through **microbial inoculation**





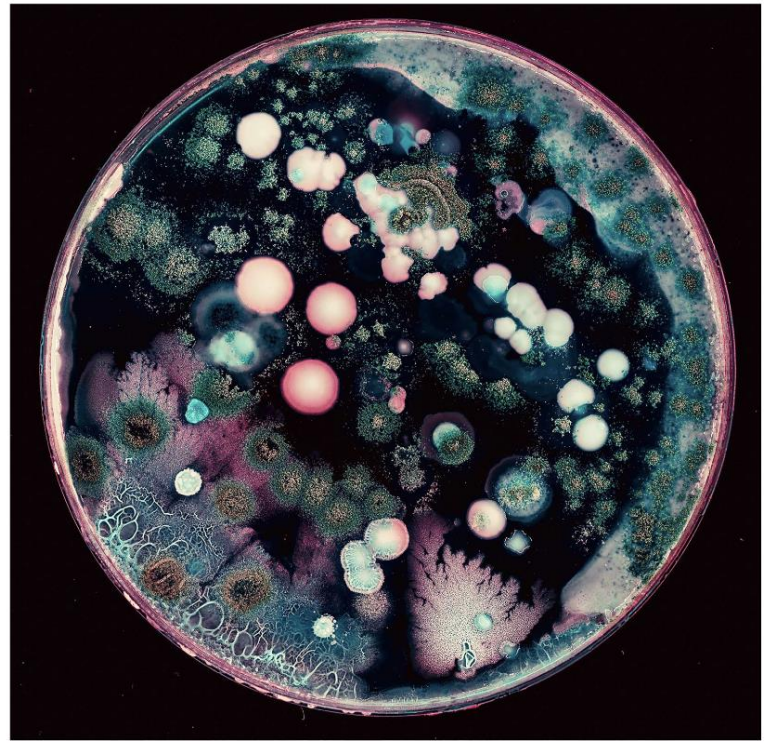
Panza et al. 2024

Farrer et al. 2022

PNAS OPINION

Microbial conservation is essential for sustaining ecosystem functions and services

Robert R. Junker[a,1] and Nina Farwig[b]



A world without microorganisms would lack essential life-supporting processes. Yet, despite being threatened by global change, microbes remain largely excluded from conservation efforts. Crucial steps are needed to establish microbial conservation. Image credit: Shutterstock/luchschenF.

Microorganisms are fundamental to life on earth, playing crucial and irreplaceable roles in biogeochemical cycles, climate, ecosystem services, and human health. Their diversity and functionality are increasingly threatened by human activities. Yet, microbes remain largely excluded from nature conservation efforts.

This challenge is gaining attention, and others have recommended to conserve microbes—most recently, with the establishment of a "Microbial Conservation Specialist Group" by the International Union for Conservation of Nature (IUCN). The IUCN suggests raising awareness of the need for microbial cexposed to the same threats as plants and animals. And the IUCN recommends extending conservation practice to microbes by highlighting their intrinsic and instrumental values for life on earth.

We support this call, as well as the adoption of microbial conservation as a coherent scientific discipline and a practical field of application. But we need to go further. Here, we propose a conceptual framework and a roadmap for microbial conservation that builds on and extends contemporary nature conservation efforts. Specifically, we outline how microbes can support traditional conservation goals and suggest adaptations to conserve microorganisms themselves.

Author affiliations: [a]Evolutionary Ecology of Plants, Department of Biology, Marburg University, Marburg 35043, Germany; and [b]Conservation Ecology, Department of Biology, Marburg University, Marburg 35043, Germany

Author contributions: R.R.J. conceptualization; R.R.J. and N.F. performed research; and R.R.J. and N.F. wrote the manuscript.

The authors declare no competing interest.

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Any opinions, findings, conclusions, or recommendations expressed in this work are those of the authors and have not been endorsed by the National Academy of Sciences.

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This article contains supporting information online at https://www.pnas.org/lookup/suppl/doi:10.1073/pnas.2503013122/-/DCSupplemental.

Published September 17, 2025.

Making tools reliable in the field remains a challenge

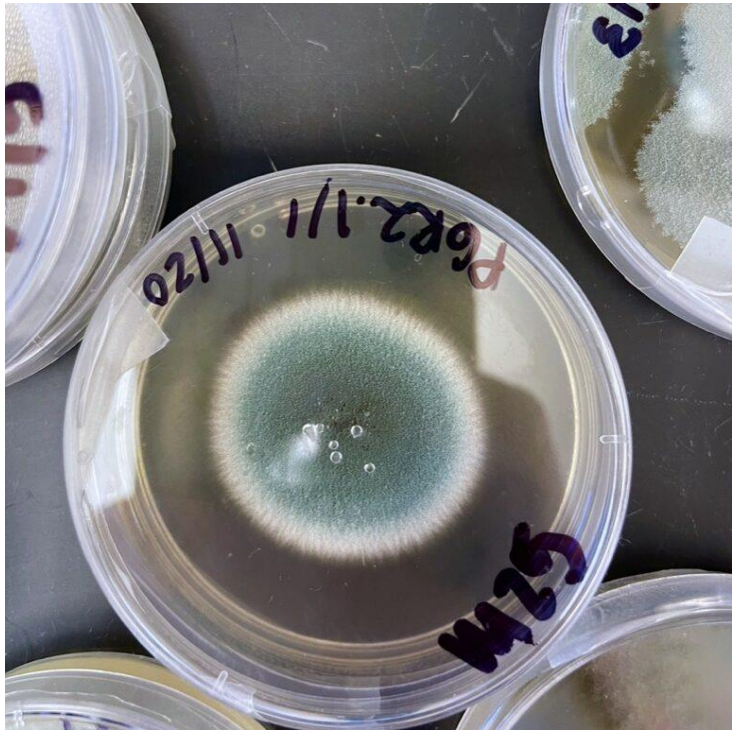
- Transferability: will it work somewhere else?
- Persistence: Will the benefits last?
- Scalability: Is it feasible to use over large areas?
- Predictability: Do we know what success looks like?

To make microbes useful restoration tools, we need to understand which microbes emerge, how environmental conditions shape their activity, and whether functions recover

How do we study microbes?

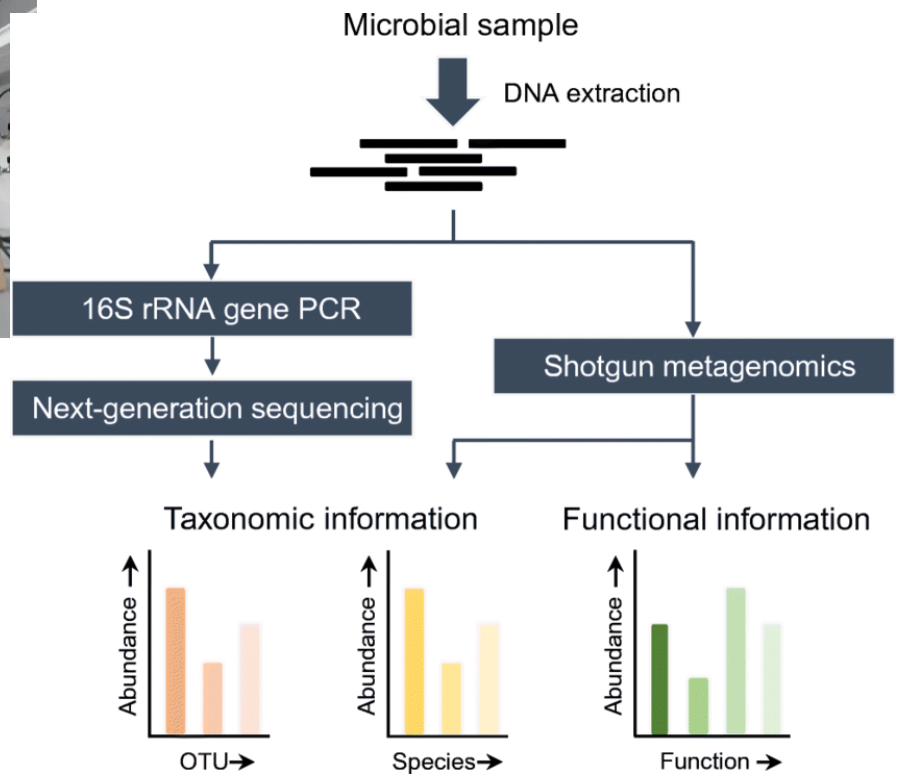
First, we have to collect samples (the easy part)…

Culture-**Dependent** Methods



Culture-**Independent** Methods



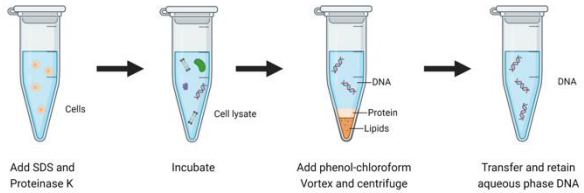


Credit: *Katie Sperry, CC BY-SA 4.0.*

Boers et al. 2019

What can we learn from a tube of sediment?





Who is there?	**Metabarcoding, amplicon sequencing, eDNA, 16S sequencing:** Identify the microbes that make up the community
What CAN they do?	**Metagenomics:** Quantify the genes involved in carbon and nutrient cycling, contaminant breakdown
Predict function?	**Link to function:** Measure processes of interest to determine if microbial communities reliably predict ecosystem function

Today’s outline

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Ongoing projects

- The Coastal MicroEco Lab is in the early stages of microbial monitoring and intervention research:
  - Tidal flow restoration
  - Runneling
  - Thin layer placement
  - Living Shoreline

  Salt marsh
  - Microbial inoculation

  Sea grass





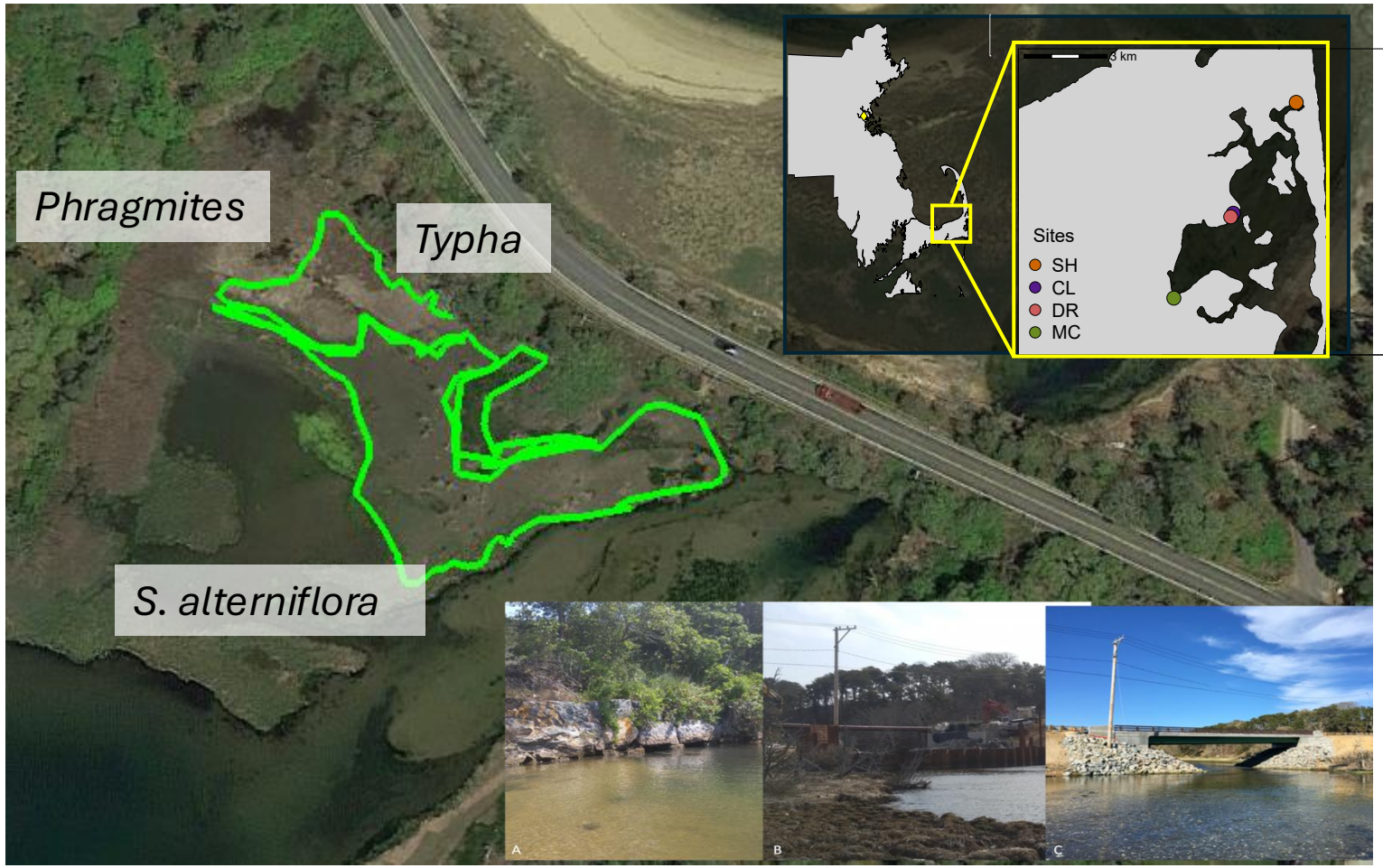




Tidal flow restoration – Muddy Creek, MA

Winter of 2015-2016



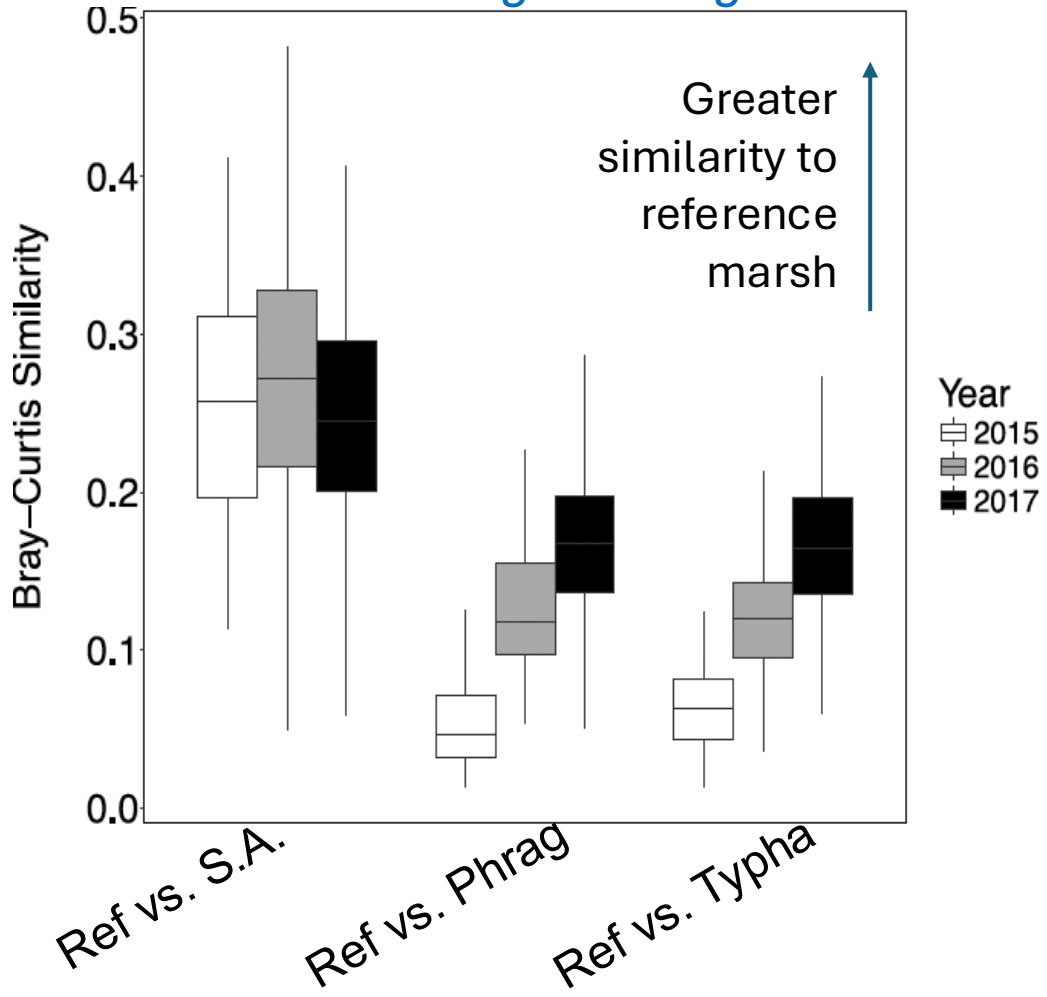


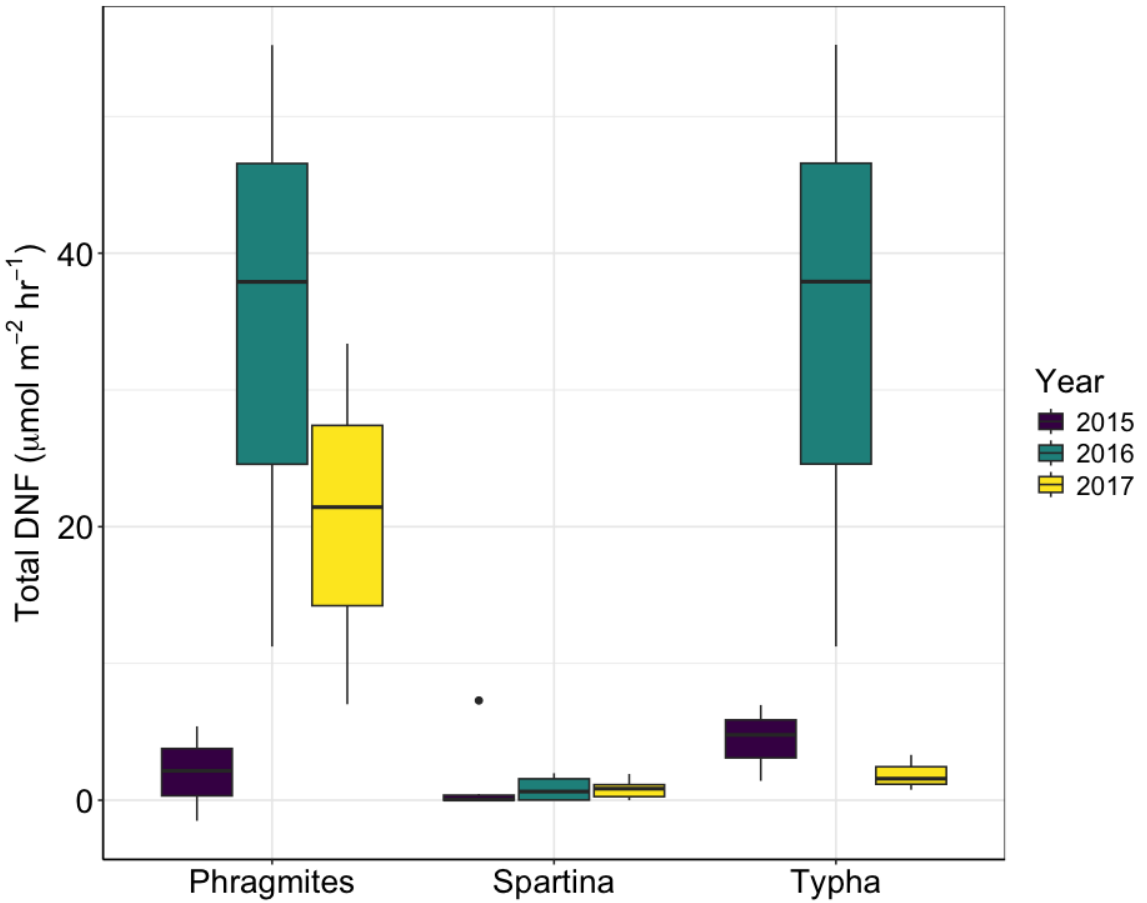


Lynum, Bulseco et al. 2020; *Estuaries & Coasts*

Microbial community structure more similar to reference marsh over time

Preceded changes in vegetation





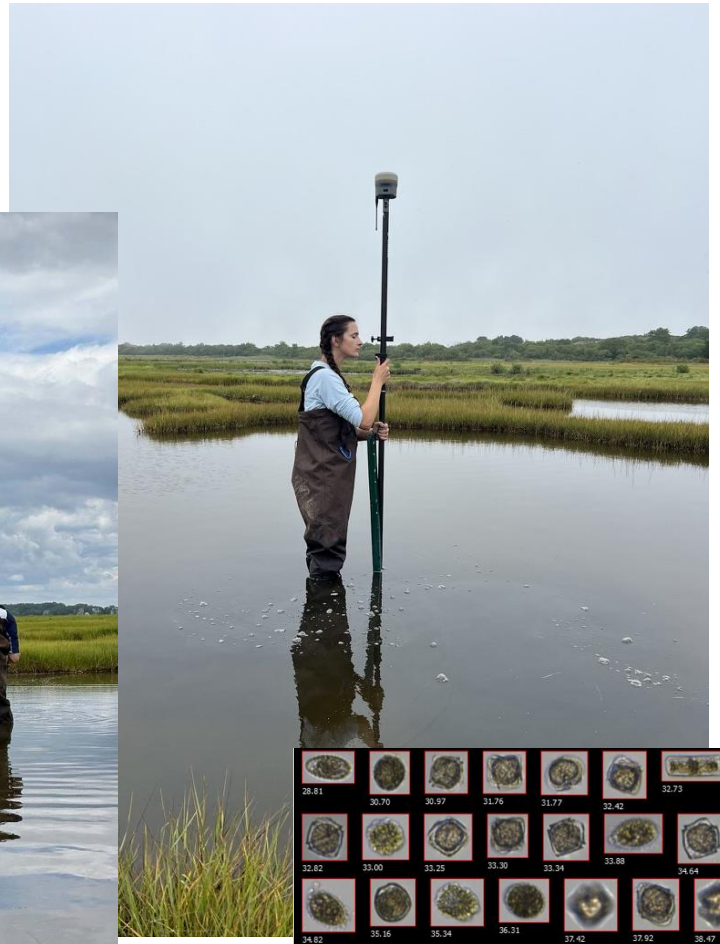
***Outstanding question**: Can we predict biogeochemistry from the microbial community?*

Lynum, Bulseco et al. 2020; *Estuaries & Coasts*

Runneling and its impact to salt marsh pond microbial communities

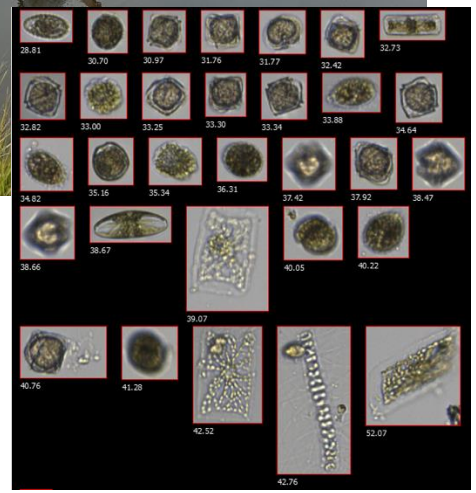
- Plum Island LTER in Rowley, MA
- Sampled three runneled and three “reference” ponds at low and high tide for 3 days (2x)
- Characterizing the aquatic bacterial, archaeal, phytoplankton communities







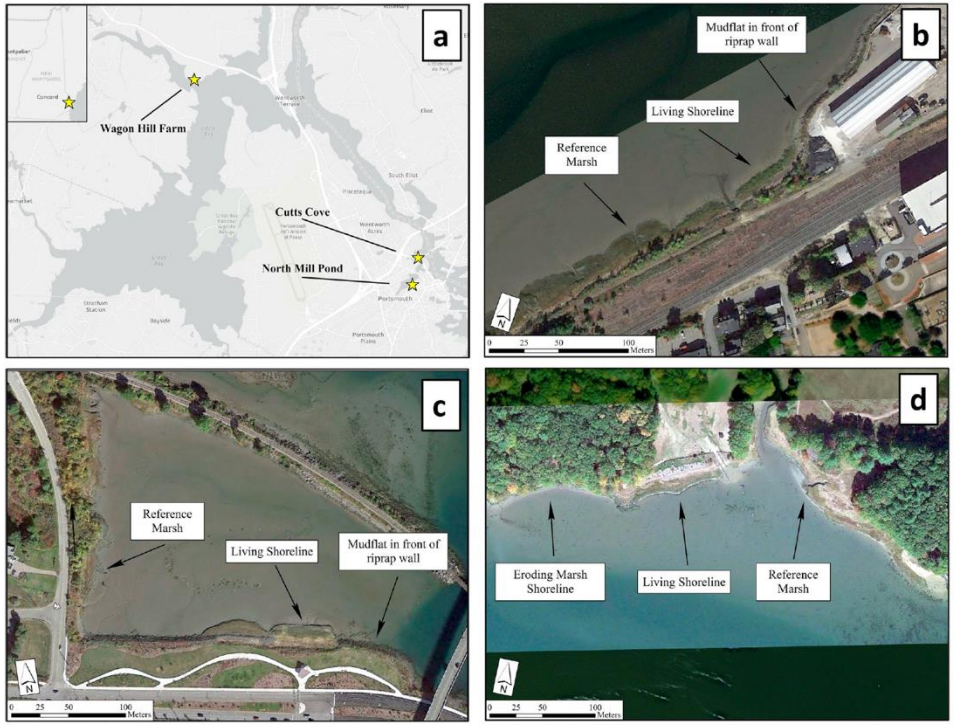
Ph.D. student Marley Gonsalves, M.S.

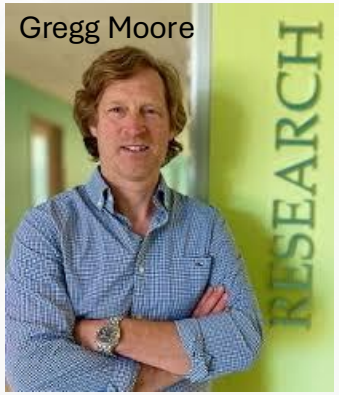


Thin Layer Placement & Living Shoreline

McKown et al. 2024; *Estuaries & Coasts*

- Characterizing the microbial community:
  - Living shoreline
  - Reference
  - No-action control
- Quantifying N-cycling
- Can we predict N-cycling from the microbial community?











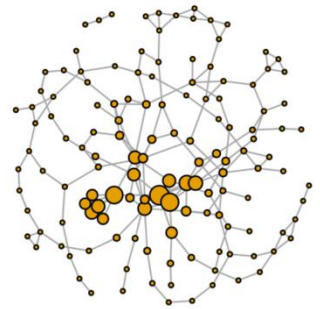


AI-guided microbiome tools for seagrass resilience

- Microbiome intervention has potential to enhance restoration and reduce disease, but results are inconsistent
- Microbial inoculation of seeds using NH and VA sediment assisted by AI
- Greenhouse/outplanting and measuring growth and success


Geoff Zahn

Talia Backman


Chris Patrick


Trevor Mattera



PREP
Piscataqua Region Estuaries Partnership

The Nature Conservancy

revive & restore
GENETIC RESCUE OF ENDANGERED AND EXTINCT SPECIES

How does the microbial community connect to ecosystem function?

- Collaborative team is sampling for:
  - Greenhouse gas fluxes
  - N-cycling
  - Carbon storage
  - Plant community
  - Porewater chemistry
  - Microbial community
- Can we predict any of these functions from the microbial community? Do they change in tandem?

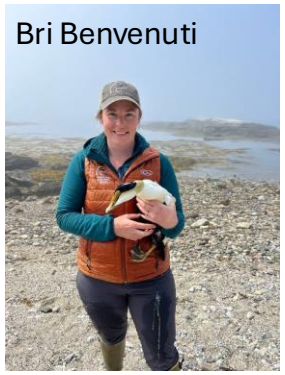


Claire Enterline



Erin Mansfield M.S. Student











Marjorie Mednikova



Gulf of Maine Research Institute
Science. Education. Community.

MAINE

Bates College

wellsreserve at laudholm
Wells National Estuarine Research Reserve

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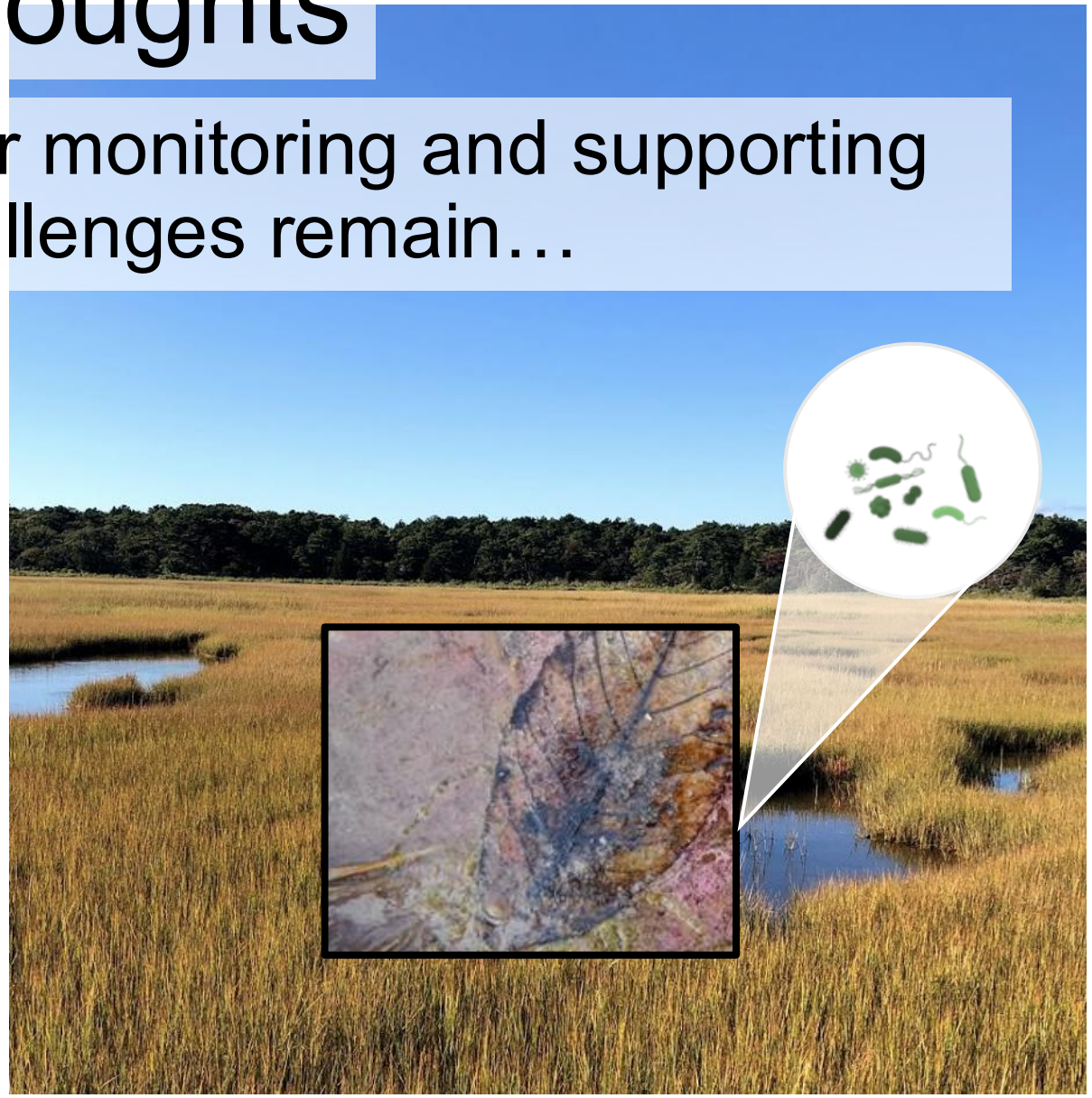
Making tools reliable in the field remains a challenge

- Transferability: We need to establish a baseline across sites
- Persistence: Track microbial communities over time, regularly
- Scalability: Identify metrics that allow for larger scale sampling
- Predictability: Measure microbes alongside other metrics to understand if we can predict restoration trajectories

Final thoughts

Microbes can be a key tool for monitoring and supporting restoration, but challenges remain…







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Website: https://the-coastal-microeco-lab.github.io/

Thoughts & Questions?