

Nature-based Climate Solutions: Opportunities and Limits in Blue, Green, and Grey Solutions

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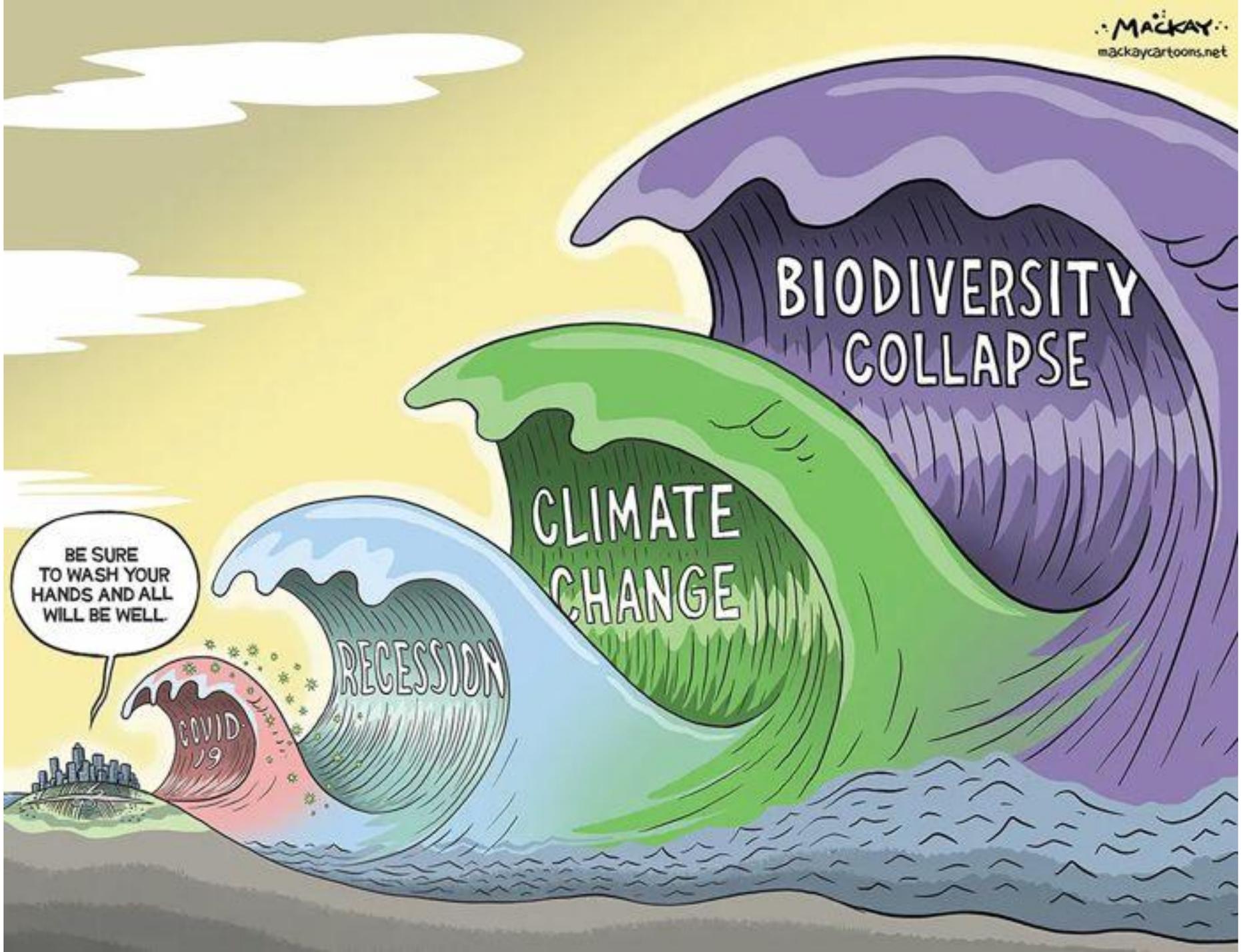
Boston College, Department of Earth and Environmental Sciences

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- 5th Year PhD Candidate at Boston College
- Hometown: Fresno, California
- Previously:
 - MSc, Geology from CUNY The City College of New York
 - NASA GISS Graduate Research Intern
 - Undergrad at New York University
- Research Interests:
 - Autonomous Sensors
 - Ecosystem Metabolism
 - Ocean biological pump
 - Controls on carbon cycling (e.g., nutrients, physics)
 - mCDR and Nature-Based Climate Solutions (obviously)





BE SURE
TO WASH YOUR
HANDS AND ALL
WILL BE WELL.

COVID
19

RECESSION

CLIMATE
CHANGE

BIODIVERSITY
COLLAPSE

CLIMATE CHANGE 2023 Synthesis Report

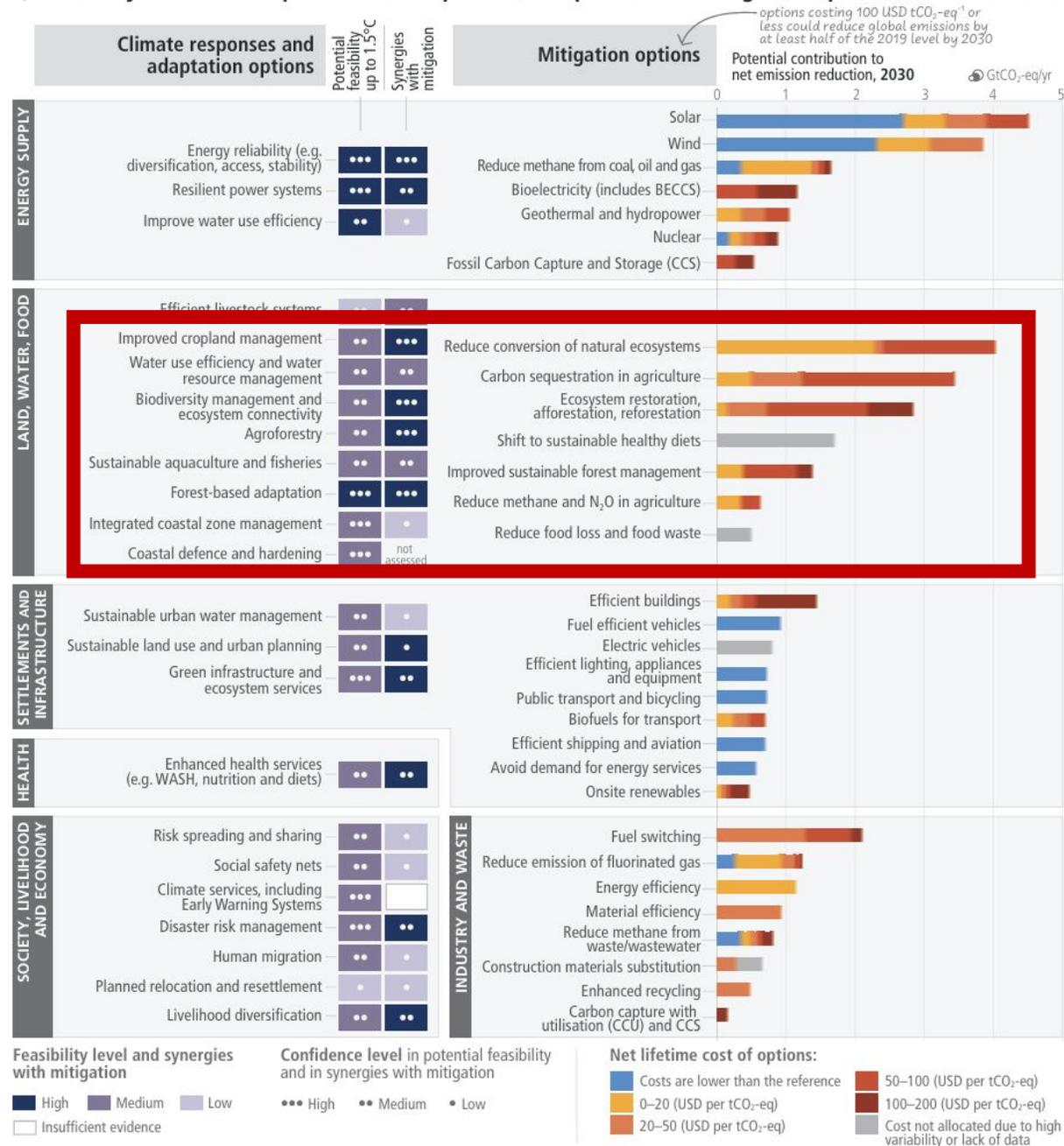
Summary for Policymakers

A Report of the Intergovernmental Panel on Climate Change

NbS could provide ~30% of needed climate mitigation, but investments in infrastructure and more science is necessary.

There are multiple opportunities for scaling up climate action

a) Feasibility of climate responses and adaptation, and potential of mitigation options in the near term



What is a nature-based solution?

- Actions to **protect, restore, or sustainably manage ecosystems to address societal challenges** (climate change, disaster risk, biodiversity loss).
- NbS exist on a spectrum:
 - *green* (land/vegetation),
 - *blue* (water/ocean),
 - *and grey* (engineered) approaches.



Green Approaches

USA

Germany



Blue Approaches

USA

Germany



Oyster reef restoration



Salt marsh restoration



Peatland (moorland)
rewetting

Grey Approaches

USA

Germany

Beneficial use of dredged sediment



US Army Corps of Engineers®



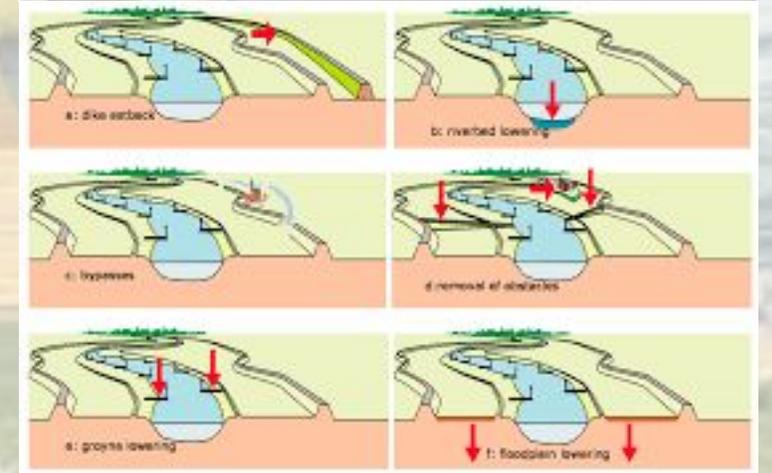
Beach sand nourishment



Seawalls and levees



Setting back dikes (Rhine River)



Approach Comparison

USA

Larger scale projects, often tied to disaster resilience and federal/state programs.

Army Corps strong in hybrid NbS + grey solutions.

Market mechanisms (carbon credits, voluntary offsets) play bigger role.

Germany

Strong policy integration via EU Green Deal & national climate law.

Focus on peatland rewetting and forest management.

Higher public acceptance of green/blue NbS but challenges with agricultural lobby.



Species +
Protection



CO₂

Climate Mitigation Potential

NbS is not a substitute for decarbonization.

Additional sequestration pathways are needed.

Trade-offs & Conflicts

Land competition: afforestation vs. agriculture.

Permanence & Risk

Wildfire, drought, or sea level rise can reduce carbon storage.

But how do we quantify impacts and evaluate success?

Land ownership conflicts in U.S. and Germany.

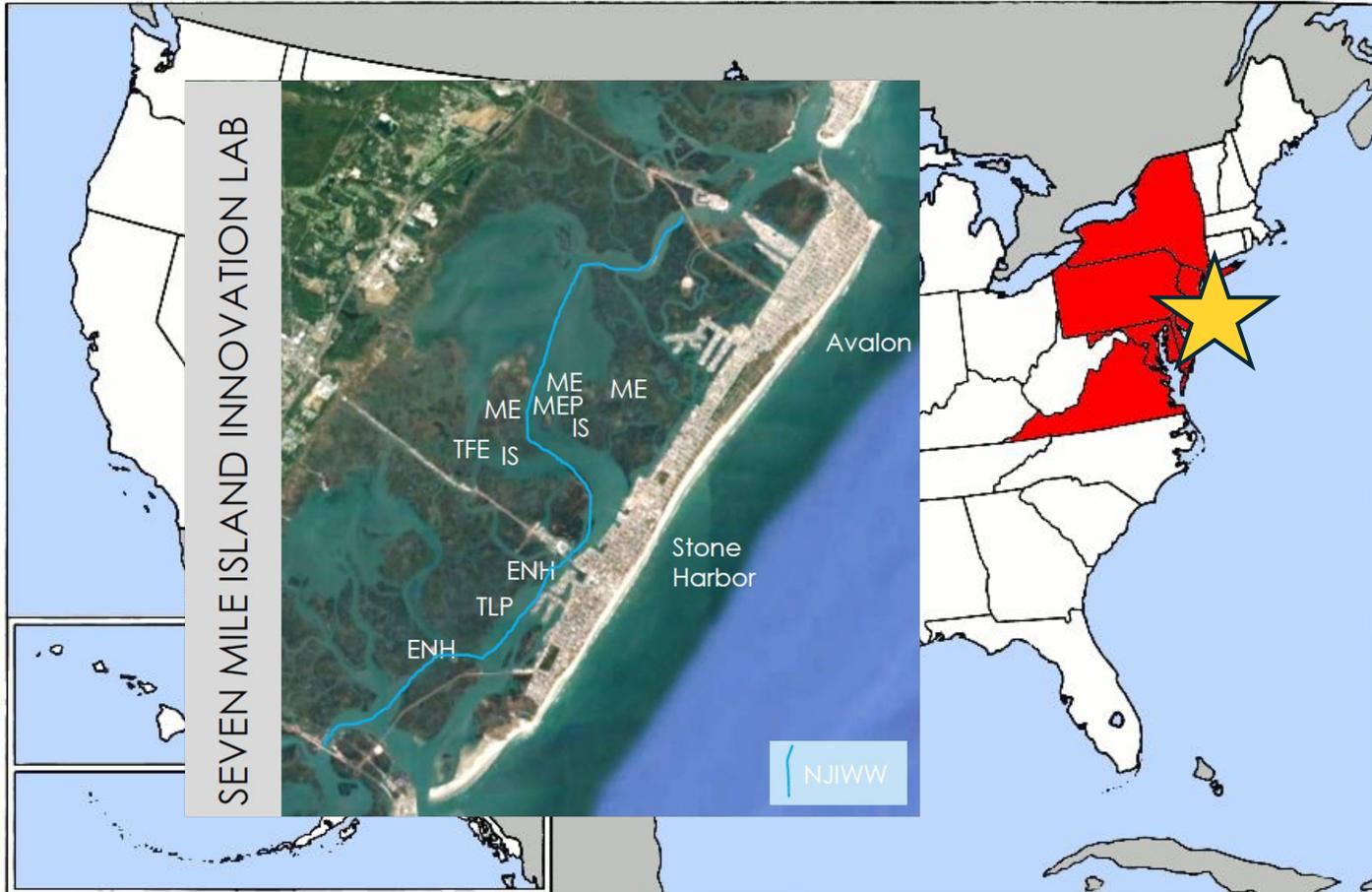
Farmers' opposition to peatland rewetting in Germany; private land barriers in U.S.

Green gentrification and greenwashing

Who benefits v. bears costs?

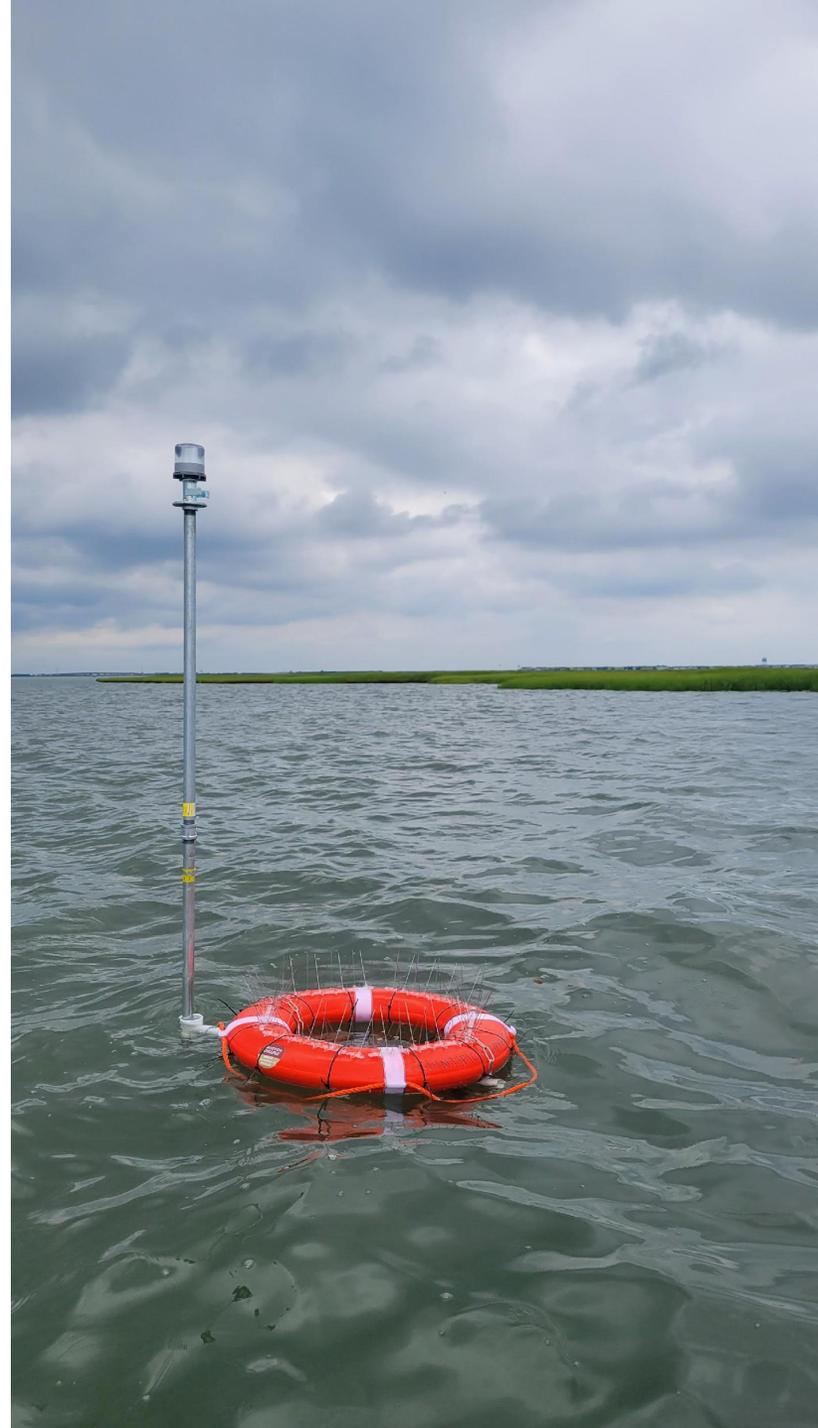
NbS Limits

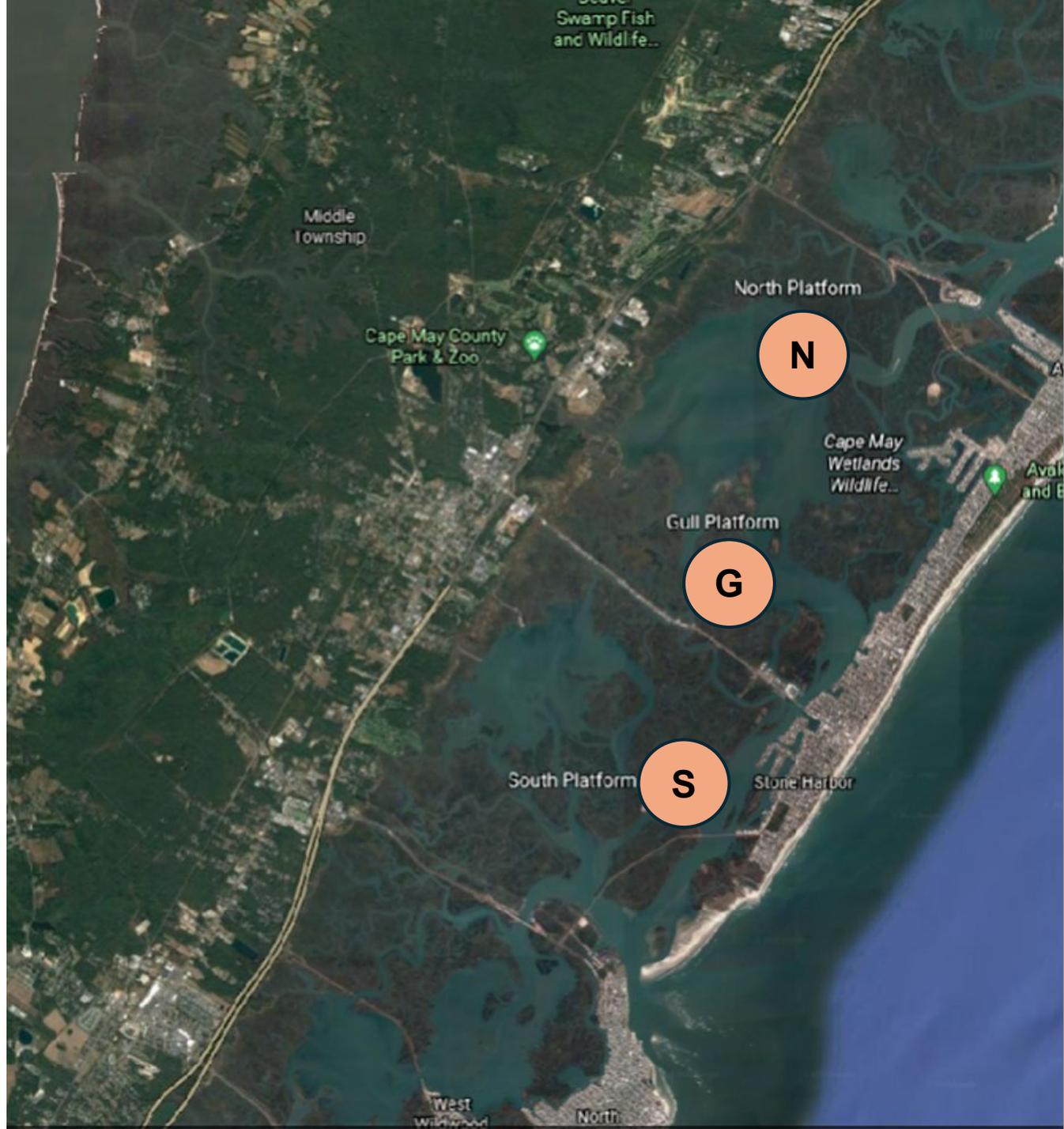
The Seven Mile Island Innovation Laboratory



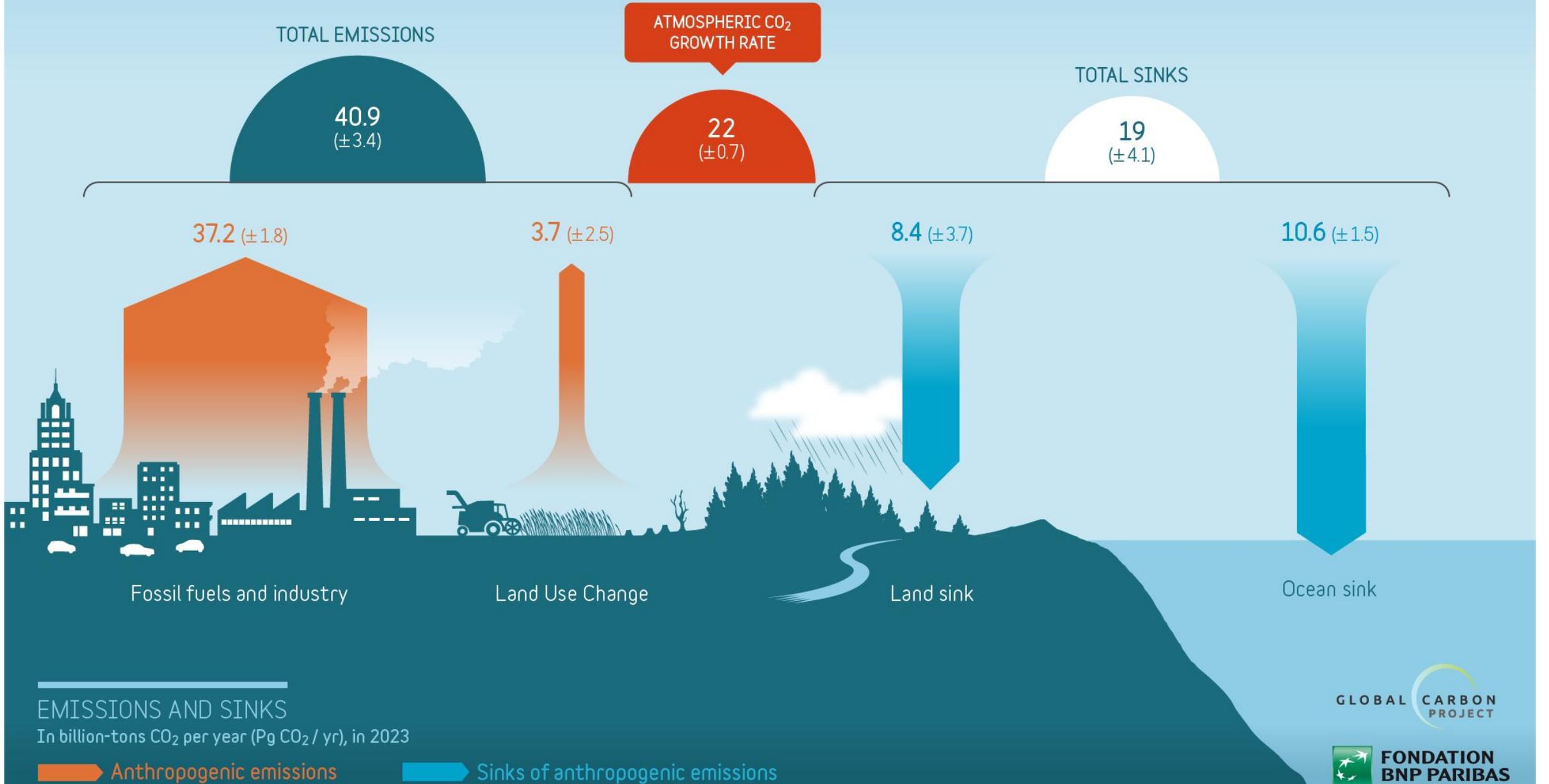
- 62 sq. kilometers of tidal marshes, coastal lagoons, shallow bays, sounds, and tidal inlets
- Test bed to advance and improve dredging and marsh restoration techniques
- Bisected by the Atlantic Intracoastal Waterway which the US Army Corps of Engineers maintains for safe maritime navigation

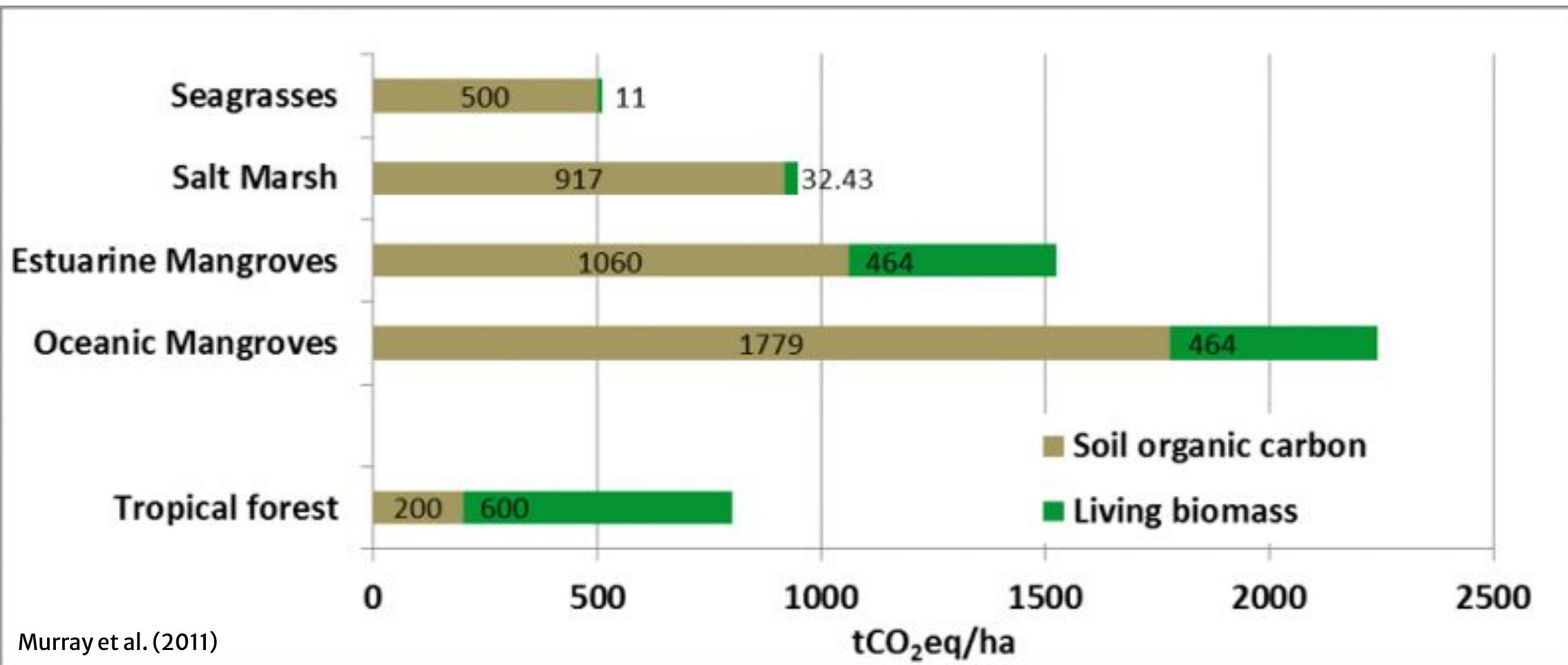


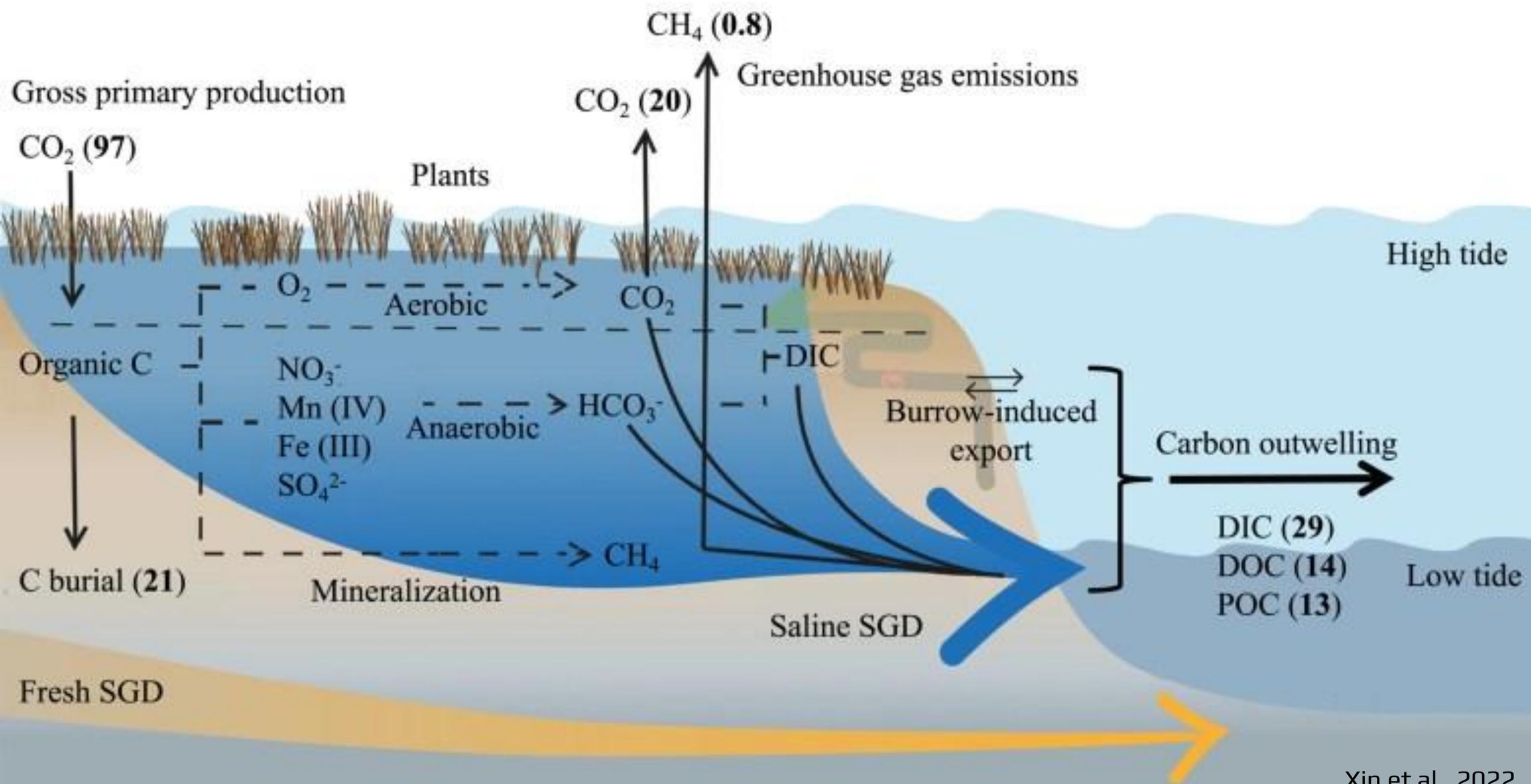




GLOBAL CARBON BUDGET 2023

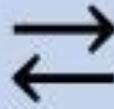






PHOTOSYNTHESIS (P)

WATER + INORGANIC CARBON + NUTRIENTS
 $64\text{H}_2\text{O} + 106\text{CO}_2 + 16\text{NH}_3 + \text{H}_3\text{PO}_4$



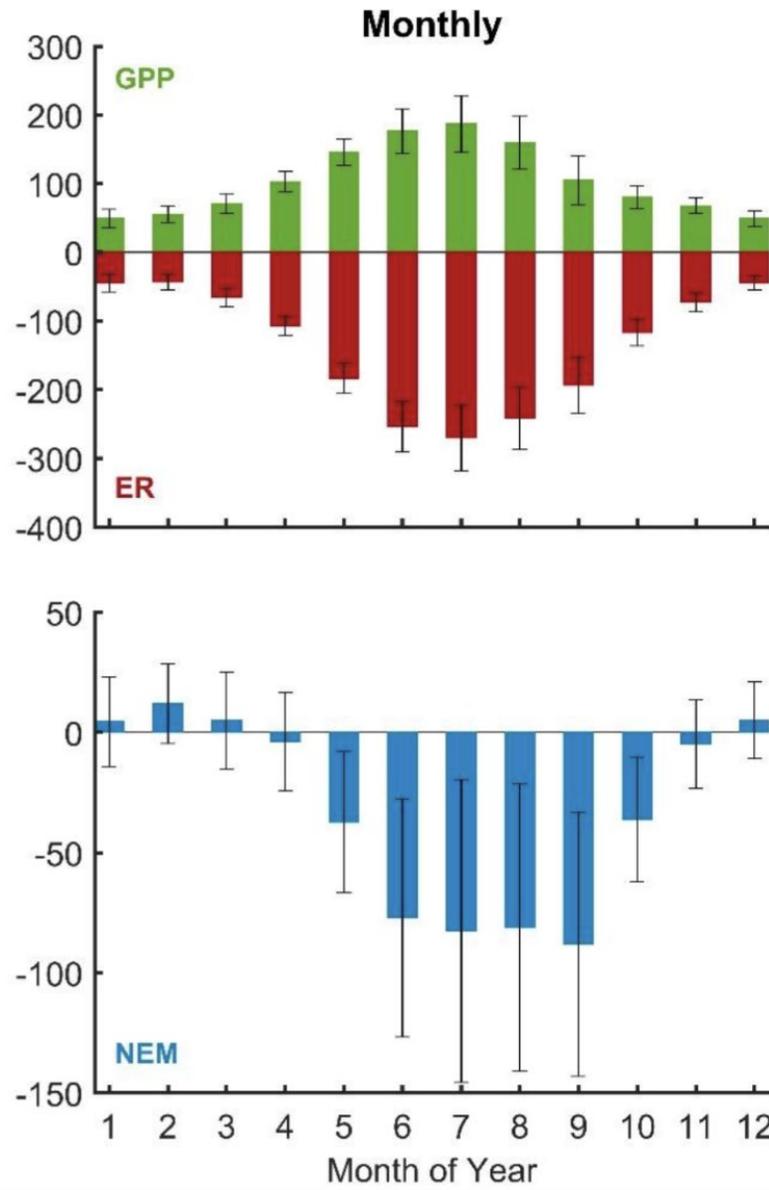
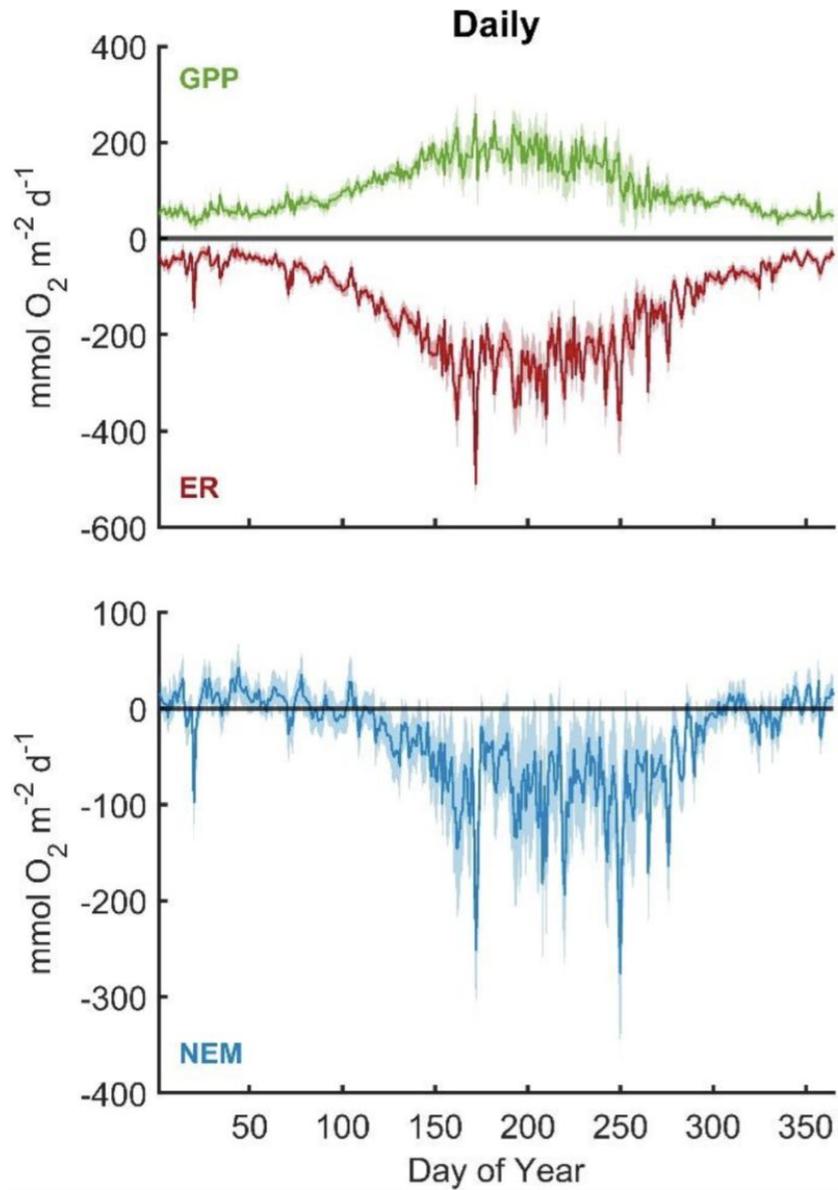
ORGANIC MATTER + OXYGEN
 $\text{C}_{106}\text{H}_{175}\text{O}_{42}\text{N}_{16}\text{P} + 138\text{O}_2$

RESPIRATION (R)

$$\frac{\Delta \text{DO}_{obs}}{\Delta t} = \text{Biological Processes} + \text{Gas Exchange}$$

+ Tidal Advection + horizontal movement
and stratification + bottom-driven
turbulence + ebullition + etc...





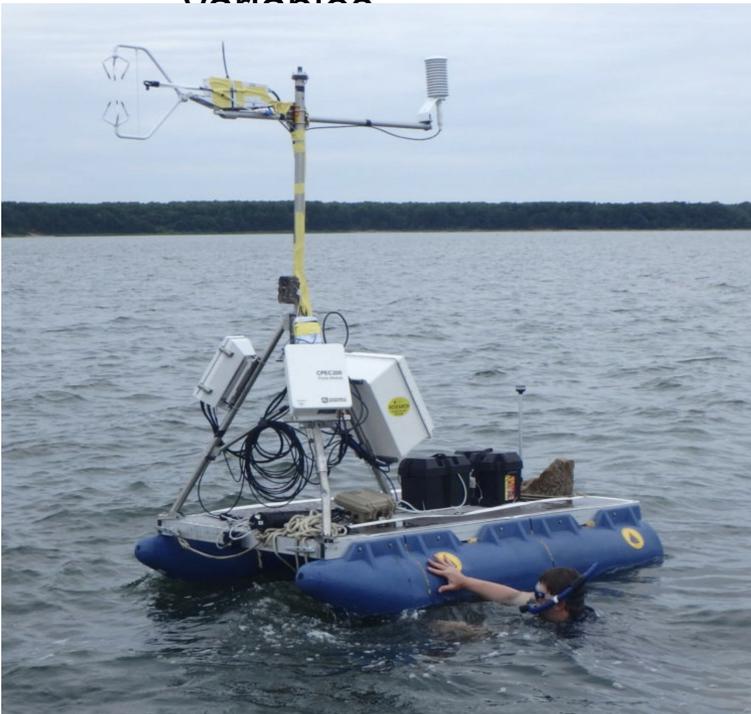
Daily and monthly climatological mean metabolic rates of **a)** gross primary production (GPP) and ecosystem respiration (ER) and **c)** net ecosystem metabolism (NEM), and by month of year for **b)** GPP and ER and **d)** NEM.



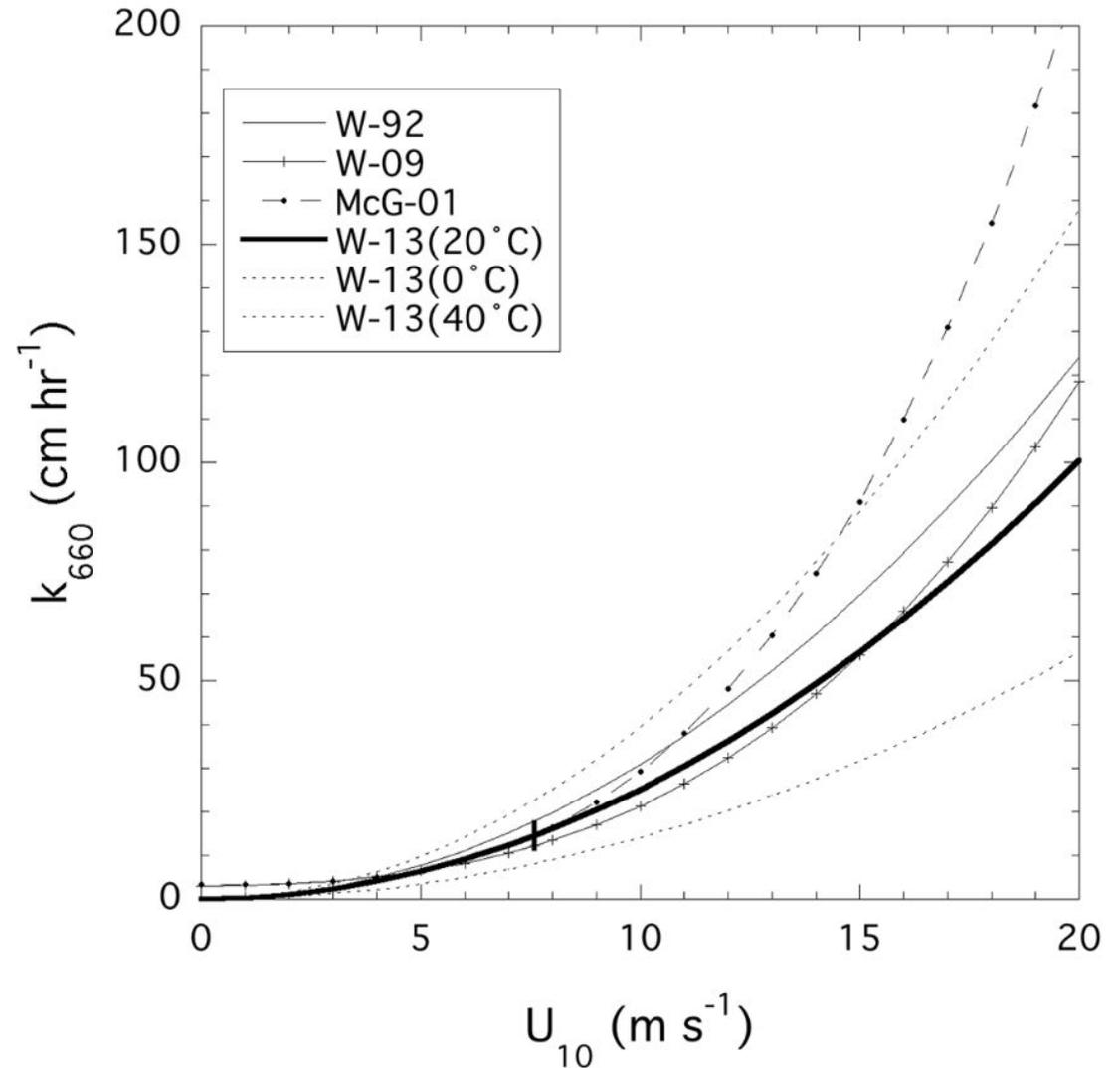
Mean NEM
-29.4 mmol O₂ m⁻² d⁻¹

My future research ideas...

Minimize
variables

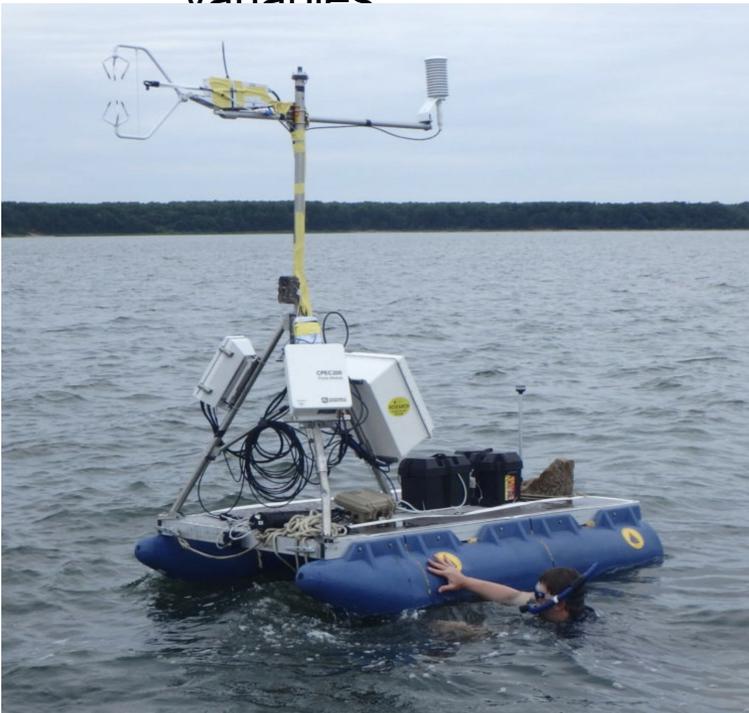


Directly measure gas
exchange
with an eddy covariance
system



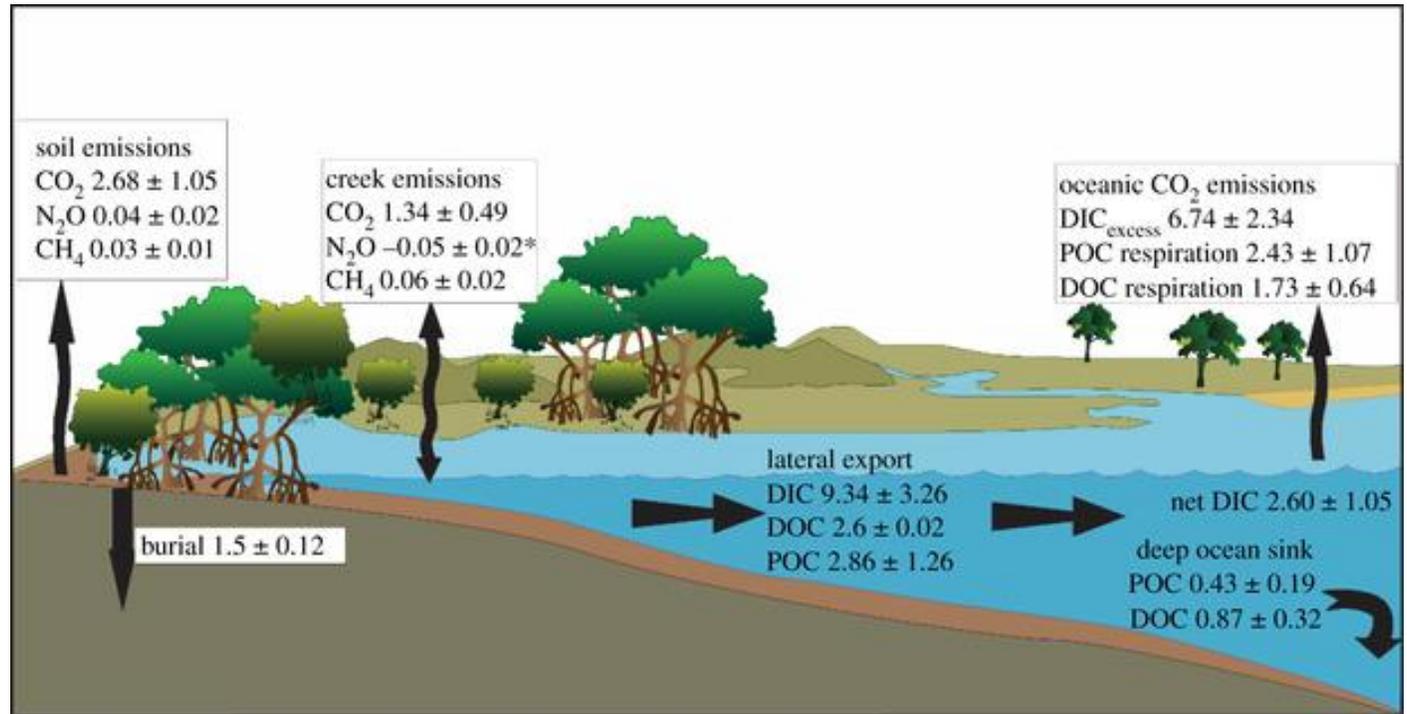
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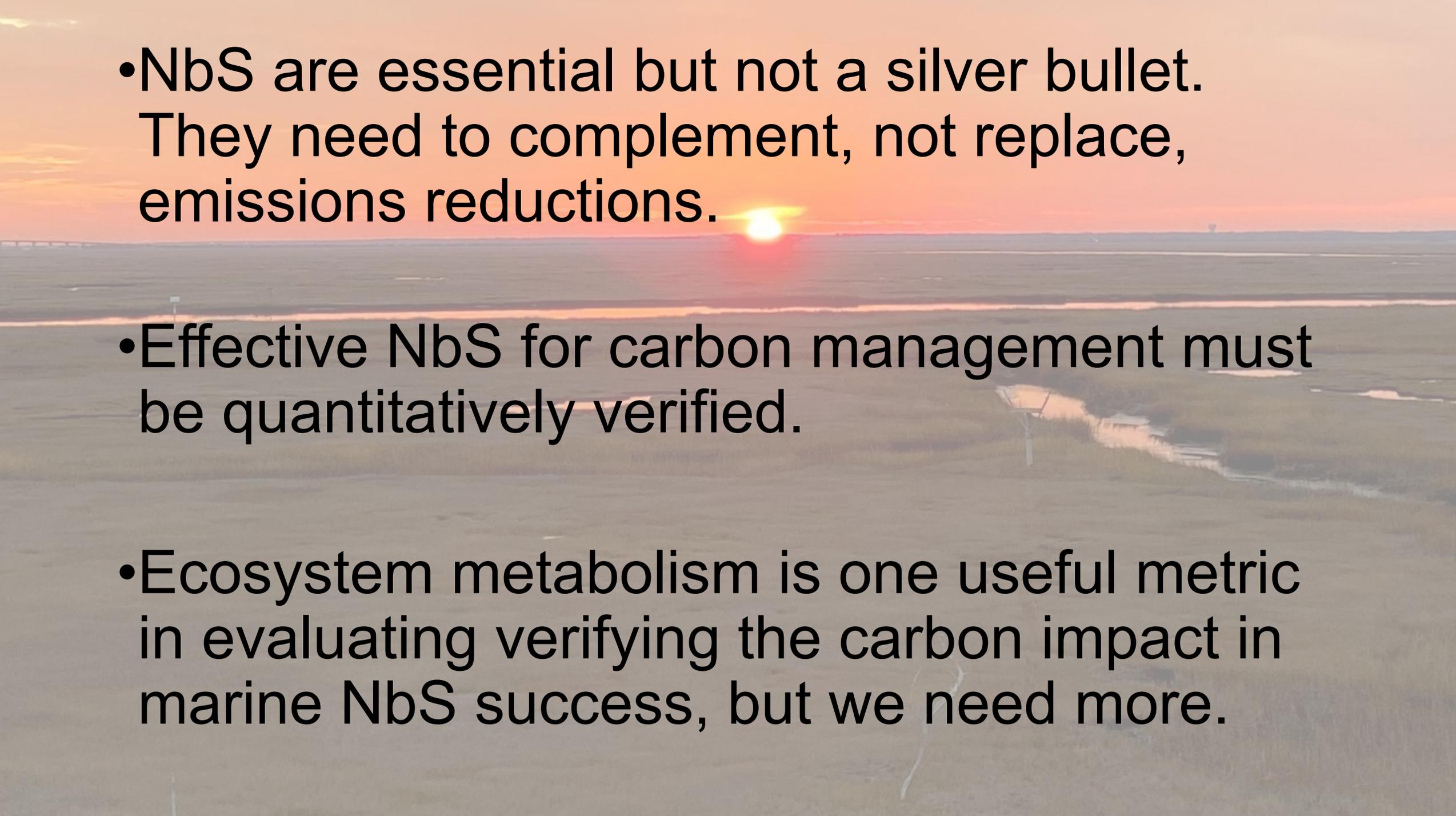


Directly measure gas exchange with an eddy covariance system

Monitor multiple processes in tandem



Measure and model carbon export

- 
- An aerial photograph of a coastal wetland or marsh area during sunset. The sun is low on the horizon, casting a warm orange and red glow over the water and land. A long bridge is visible in the distance on the left side. The foreground shows a mix of water and marshland with some small structures or markers.
- NbS are essential but not a silver bullet. They need to complement, not replace, emissions reductions.
 - Effective NbS for carbon management must be quantitatively verified.
 - Ecosystem metabolism is one useful metric in evaluating verifying the carbon impact in marine NbS success, but we need more.

Ocean-Based Carbon Dioxide Removal: Road Maps

Pathways to accelerate the development and testing of ocean-based carbon dioxide removal approaches.

[About Road Maps](#)

[How to use Road Maps](#)

■ TECHNOLOGY ROAD MAP

■ CROSS-CUTTING ROAD MAP

Read the [core principles](#) guiding our work on carbon dioxide removal and the ocean.

⚡
Electrochemical
CDR

🌿
Macroalgae
Cultivation
and Carbon
Sequestration

📍
Ocean
Alkalinity
Enhancement

🔬
Microalgae
Cultivation
and Carbon
Sequestration

🌳
Blue Carbon
Restoration
and Carbon
Sequestration

👥
Engaging Key
Audiences

📄
Expanding
Finance and
Investment

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