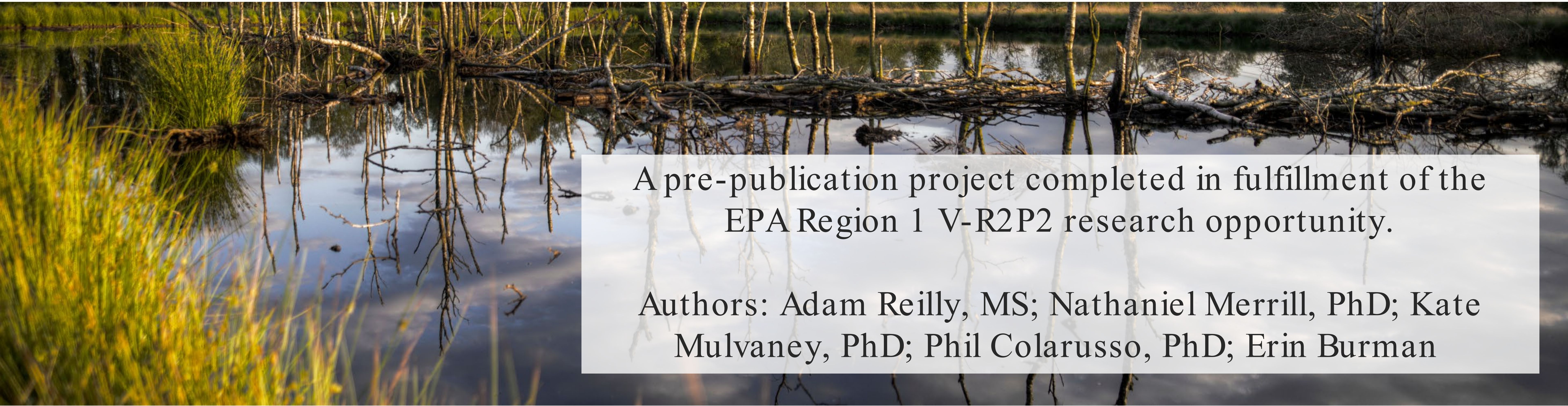
Fantastic Wetlands and Why to Monitor Them:

Salt Marsh restoration has relevant climate impacts that we aren't tracking (yet)



A pre-publication project completed in fulfillment of the EPA Region 1 V-R2P2 research opportunity.

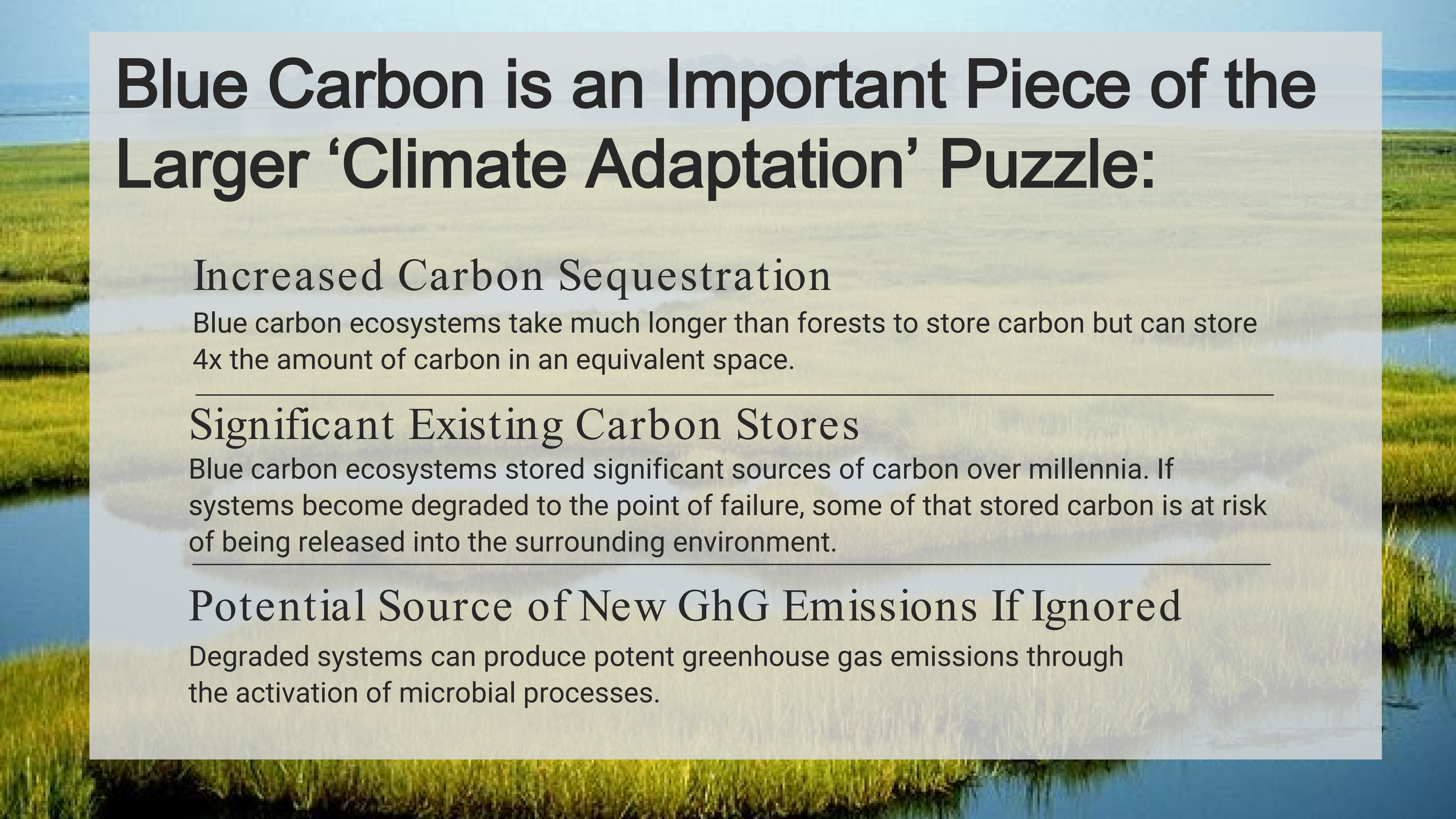
Authors: Adam Reilly, MS; Nathaniel Merrill, PhD; Kate Mulvaney, PhD; Phil Colarusso, PhD; Erin Burman

What is Blue Carbon?

www.iucn.org

Eelgrass video courtesy of Phil Colarusso

NEXT



Blue Carbon is an Important Piece of the Larger ‘Climate Adaptation’ Puzzle:

Increased Carbon Sequestration

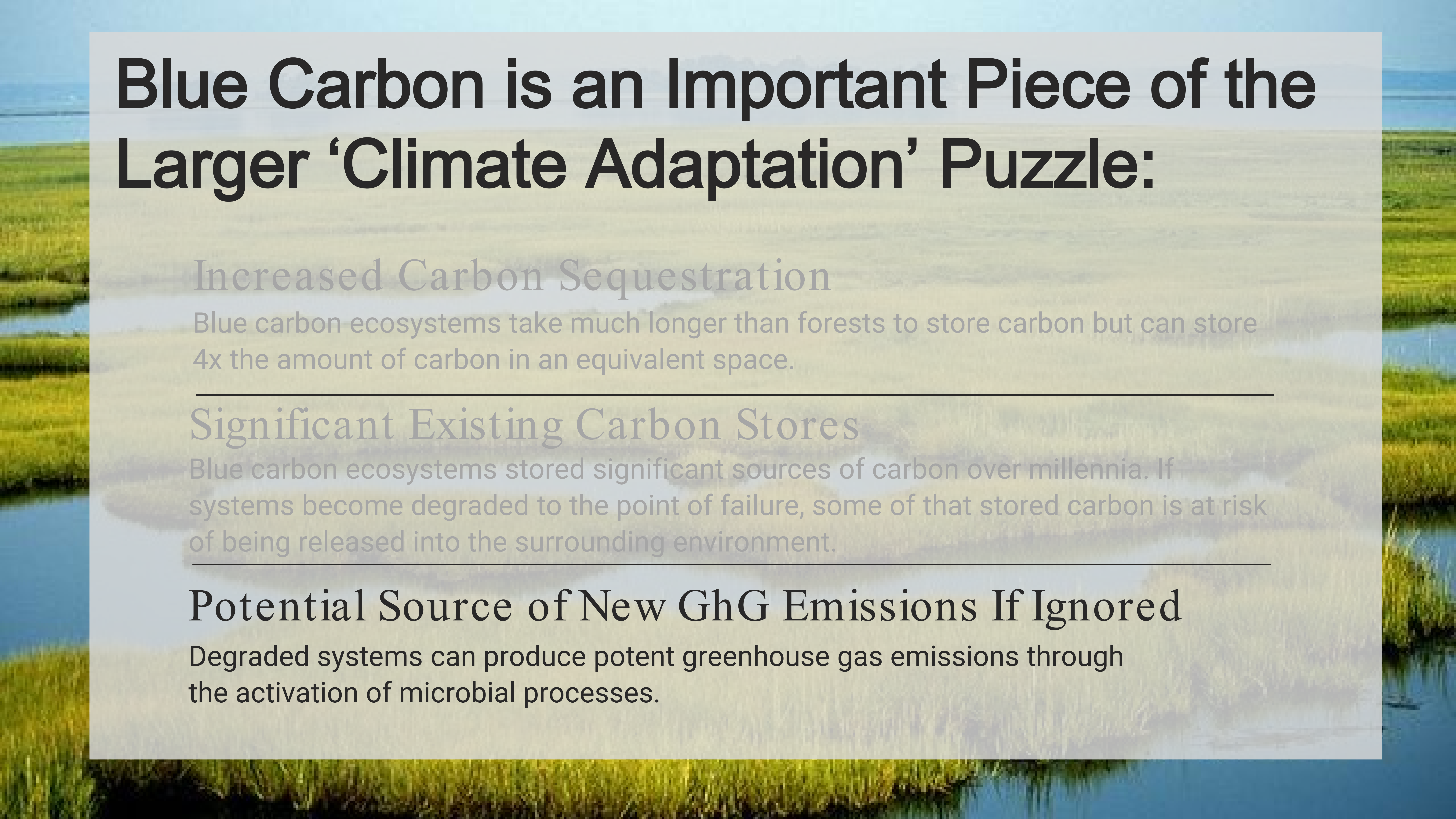
Blue carbon ecosystems take much longer than forests to store carbon but can store 4x the amount of carbon in an equivalent space.

Significant Existing Carbon Stores

Blue carbon ecosystems stored significant sources of carbon over millennia. If systems become degraded to the point of failure, some of that stored carbon is at risk of being released into the surrounding environment.

Potential Source of New GhG Emissions If Ignored

Degraded systems can produce potent greenhouse gas emissions through the activation of microbial processes.



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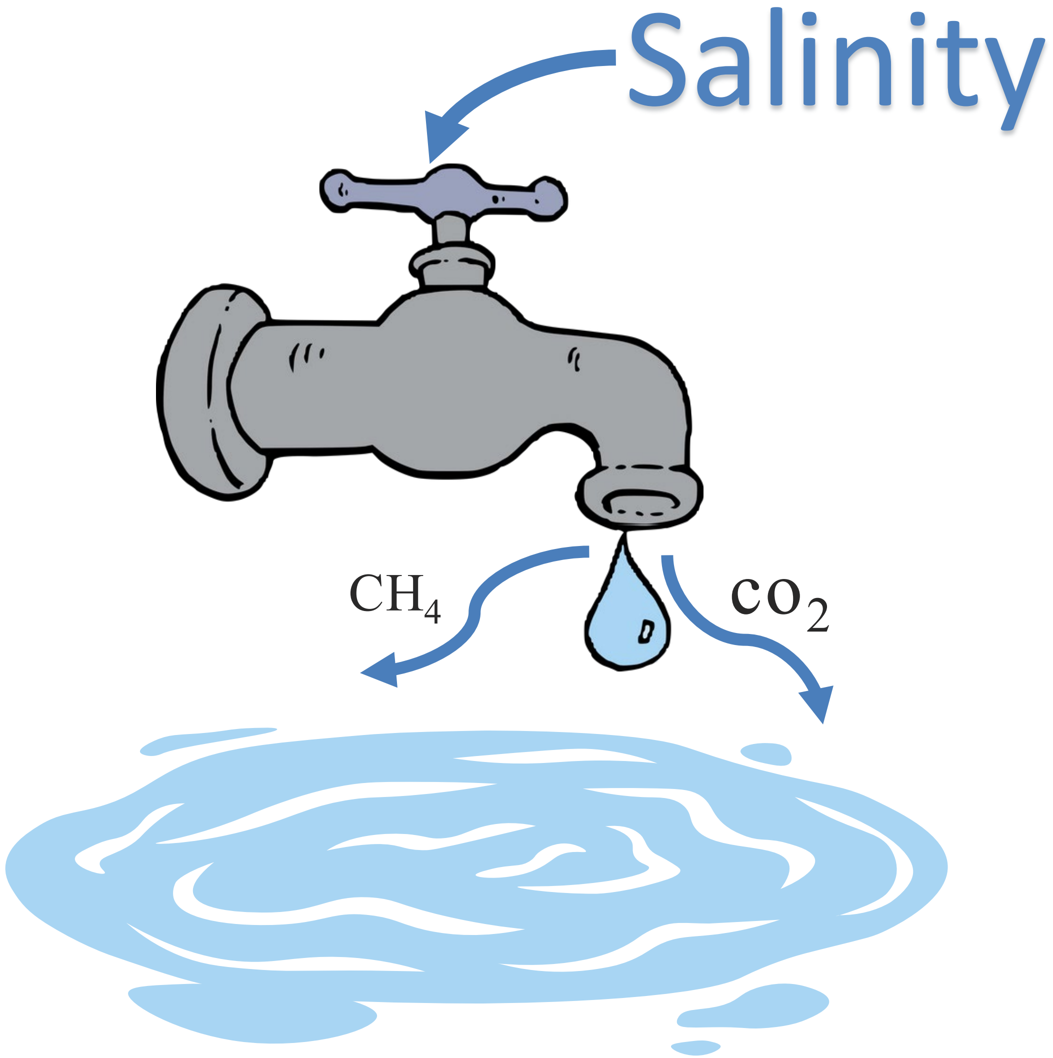
THE PROBLEM



Which Path Forward?

Do Nothing

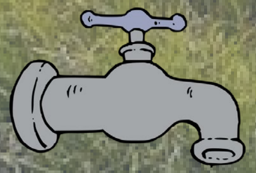
- Worst-case
- Systems degrade at an accelerated rate

Status Quo

- Systems degrade at current rate

Conservation

- Effective
- More immediately addresses GHG emissions



Restoration

- Effective
- Time-consuming
- Costly

NEXT

Conservation at Scale

What we need to know:

- What is the current status of coastal wetlands?
    - Which wetlands are most at-risk?
- How much GHGs are currently being emitted?
    - How much could be emitted?
- What is causing the degradation of which wetland?
    - What needs to be done to conserve that wetland and prevent further degradation?
- How many GHG emissions could be prevented from release?
- What would be the costs incurred from not conserving these sites?
- How can we further promote and monitor future conservation work?

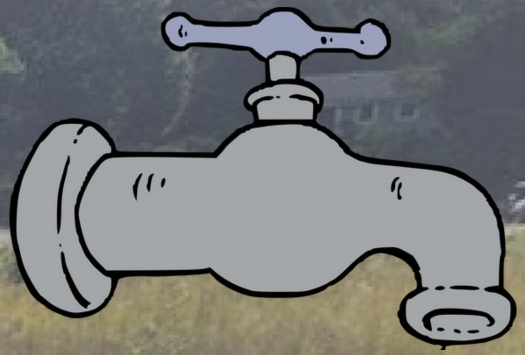
NEXT

How Do We Measure the Benefit of Salt Marsh Restoration?

NEXT

Conservation at Scale

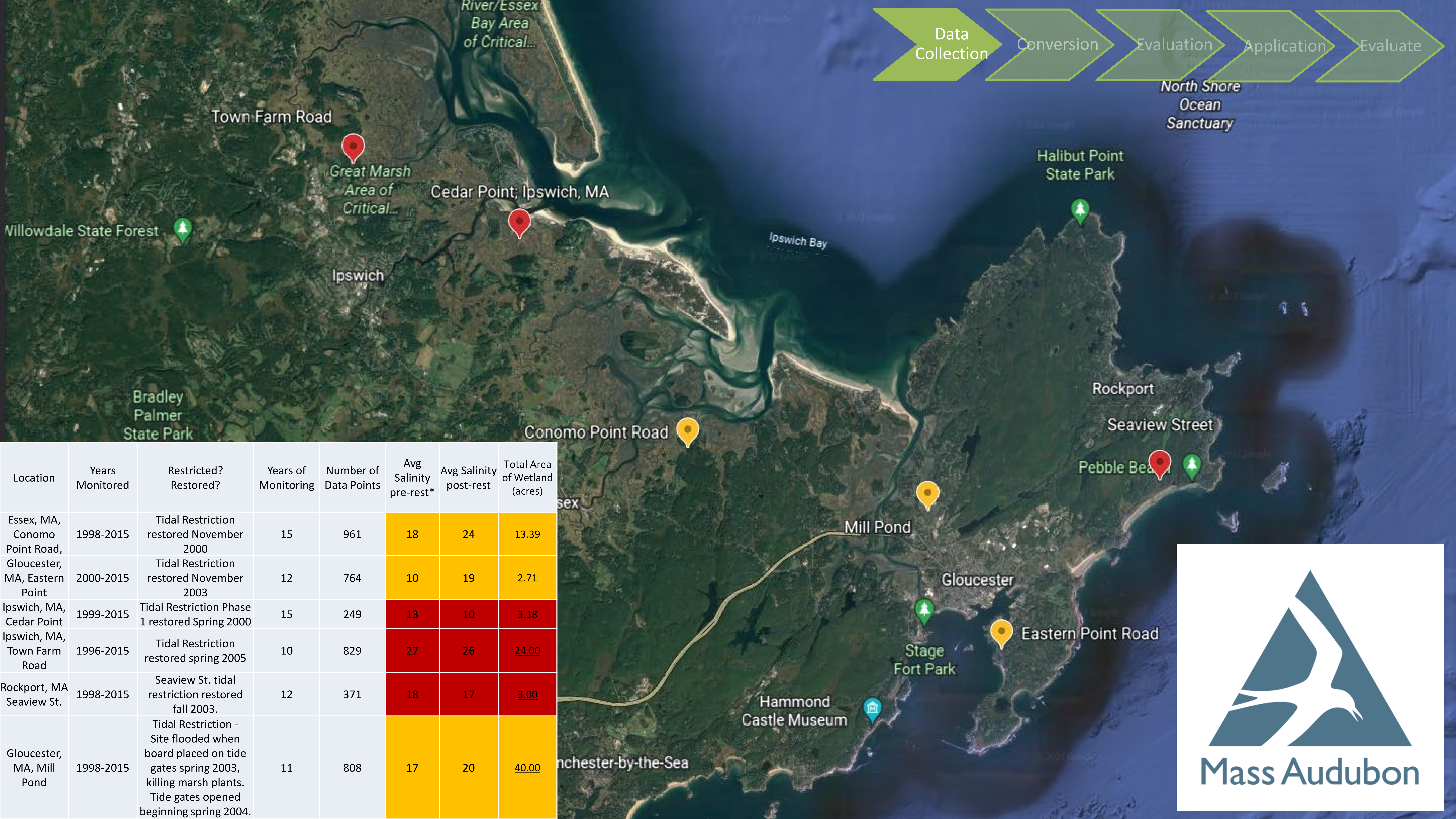
Workplan:



- **Data Collection** — Identify completed salt marsh restoration projects with existing salinity datasets
- **Conversion** — Apply Kroeger et al. (2017) to use improved salinity values to infer avoided methane emissions over project time period.
- **Evaluation** — Infer social benefit value using 2020 Social Cost of Methane to avoided methane emissions (avoided cost as benefit)
- **Application** — Apply avoided methane emissions to carbon-equivalent crediting initiative.
- **Evaluate** — Evaluate and Reassess

NEXT

Data Collection
Conversion
Evaluation
Application
Evaluate



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Mass Audubon

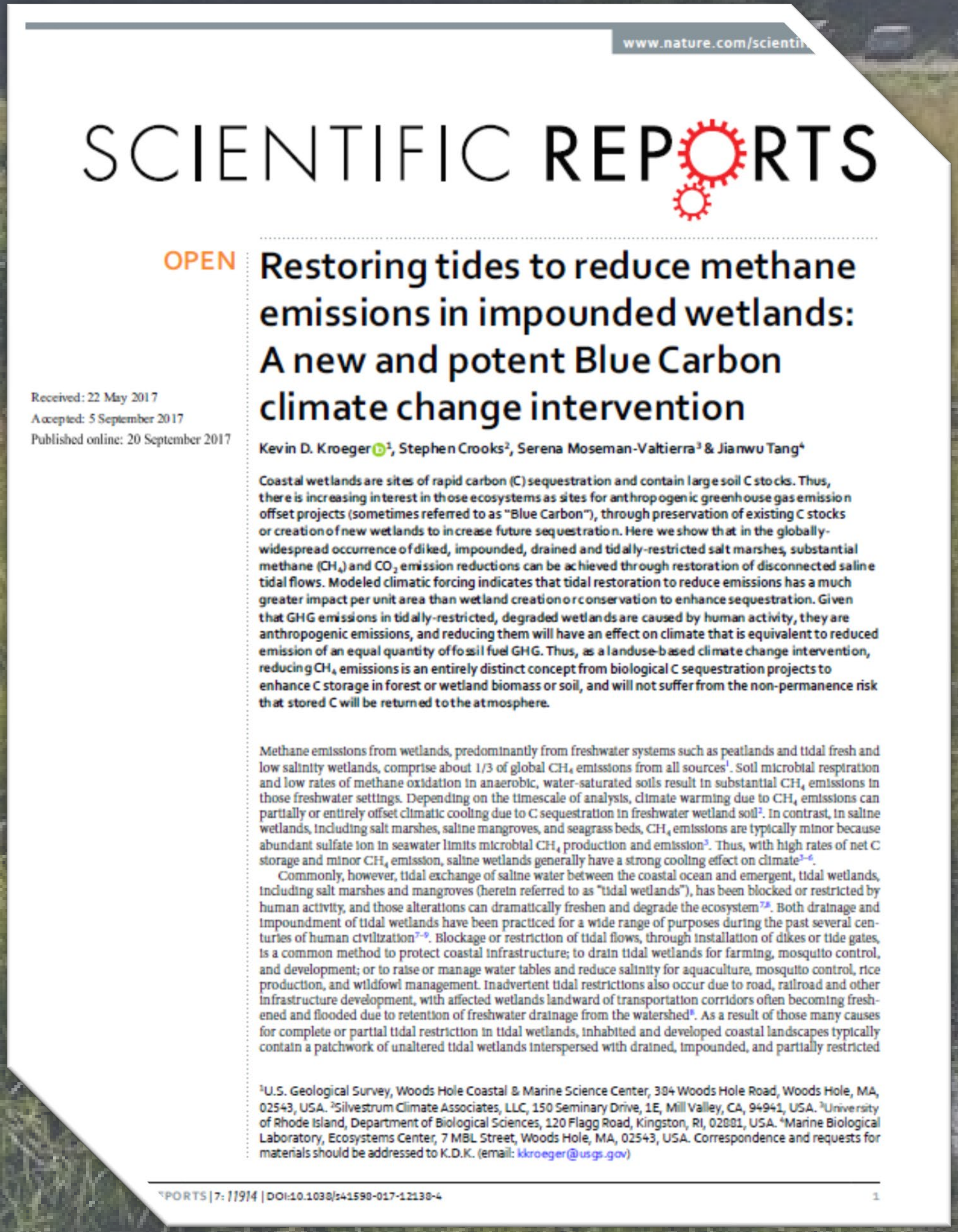
Salinity → Methane

$$\boldsymbol{Avoided\ Methane} = \left[EF_0 * (m^2)\right]^{\dagger} - \left[EF_1 * (m^2)\right]^{\dagger}$$

EF_0 = pre-restoration emissions factor
- **41.6 gC-m^{2}year^{-1} (true mean)**
- **19.4 gC-m^{2}year^{-1} (geometric mean)**

EF_1 = post-restoration emissions factors
- **0.46 gC-m^{2}year^{-1}**

† currently, post-restoration salinity improvements are applied to the entirety of the marsh



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Restoring tides to reduce methane emissions in impounded wetlands: A new and potent Blue Carbon climate change intervention

Received: 22 May 2017
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Published online: 20 September 2017

Kevin D. Kroeger[1], Stephen Crooks[2], Serena Moseman-Valtierra[3] & Jianwu Tang[4]

Coastal wetlands are sites of rapid carbon (C) sequestration and contain large soil C stocks. Thus, there is increasing interest in those ecosystems as sites for anthropogenic greenhouse gas emission offset projects (sometimes referred to as "Blue Carbon"), through preservation of existing C stocks or creation of new wetlands to increase future sequestration. Here we show that in the globally-widespread occurrence of diked, impounded, drained and tidally-restricted salt marshes, substantial methane (CH_4) and CO_2 emission reductions can be achieved through restoration of disconnected saline tidal flows. Modeled climatic forcing indicates that tidal restoration to reduce emissions has a much greater impact per unit area than wetland creation or conservation to enhance sequestration. Given that GHG emissions in tidally-restricted, degraded wetlands are caused by human activity, they are anthropogenic emissions, and reducing them will have an effect on climate that is equivalent to reduced emission of an equal quantity of fossil fuel GHG. Thus, as a landuse-based climate change intervention, reducing CH_4 emissions is an entirely distinct concept from biological C sequestration projects to enhance C storage in forest or wetland biomass or soil, and will not suffer from the non-permanence risk that stored C will be returned to the atmosphere.

Methane emissions from wetlands, predominantly from freshwater systems such as peatlands and tidal fresh and low salinity wetlands, comprise about 1/3 of global CH_4 emissions from all sources[1]. Soil microbial respiration and low rates of methane oxidation in anaerobic, water-saturated soils result in substantial CH_4 emissions in those freshwater settings. Depending on the timescale of analysis, climate warming due to CH_4 emissions can partially or entirely offset climatic cooling due to C sequestration in freshwater wetland soil[2]. In contrast, in saline wetlands, including salt marshes, saline mangroves, and seagrass beds, CH_4 emissions are typically minor because abundant sulfate ion in seawater limits microbial CH_4 production and emission[3]. Thus, with high rates of net C storage and minor CH_4 emission, saline wetlands generally have a strong cooling effect on climate[3–6].

Commonly, however, tidal exchange of saline water between the coastal ocean and emergent, tidal wetlands, including salt marshes and mangroves (herein referred to as "tidal wetlands"), has been blocked or restricted by human activity, and those alterations can dramatically freshen and degrade the ecosystem[7,8]. Both drainage and impoundment of tidal wetlands have been practiced for a wide range of purposes during the past several centuries of human civilization[7–9]. Blockage or restriction of tidal flows, through installation of dikes or tide gates, is a common method to protect coastal infrastructure; to drain tidal wetlands for farming, mosquito control, and development; or to raise or manage water tables and reduce salinity for aquaculture, mosquito control, rice production, and wildfowl management. Inadvertent tidal restrictions also occur due to road, railroad and other infrastructure development, with affected wetlands landward of transportation corridors often becoming freshened and flooded due to retention of freshwater drainage from the watershed[8]. As a result of those many causes for complete or partial tidal restriction in tidal wetlands, inhabited and developed coastal landscapes typically contain a patchwork of unaltered tidal wetlands interspersed with drained, impounded, and partially restricted

[1]U.S. Geological Survey, Woods Hole Coastal & Marine Science Center, 384 Woods Hole Road, Woods Hole, MA, 02543, USA. [2]Silvestrum Climate Associates, LLC, 150 Seminary Drive, 1E, Mill Valley, CA, 94941, USA. [3]University of Rhode Island, Department of Biological Sciences, 120 Flagg Road, Kingston, RI, 02881, USA. [4]Marine Biological Laboratory, Ecosystems Center, 7 MBL Street, Woods Hole, MA, 02543, USA. Correspondence and requests for materials should be addressed to K.D.K. (email: kkroeger@usgs.gov)

NEXT

Salinity → Methane

$$Avoided\ Methane = [EF_0 * (m^2)]^{\dagger} - [EF_1 * (m^2)]^{\dagger}$$

Location	Total Area of Wetland (m^2)	Total Area of Wetland (hectares)	Pre-restoration Emission Factor (g C m−2) /year	Annual CH4 pre-restoration (g)	Total CH4 emssions pre-restoration (from start of monitoring)	Post restoration Emission Factor (g C /m2/year)	Annual CH4 emissions post-restoration (g C)	Total Annual Avoided Ch4 Emissions (g C)	Total Annual Avoided CH4 Emissions (Tons C)
Essex, MA, Conomo Point Road,	54,197	5.42	41.6	2,254,595.20	4,509,190.40	0.46	24,930.62	2,229,664.58	2.23
Gloucester, MA, Eastern Point	10,955	1.10	41.6	455,728.00	1,367,184.00	0.46	5,039.30	450,688.70	0.45
Gloucester, MA, Mill Pond	161,880	16.19	41.6	6,734,208.00	6,734,208.00	0.46	74,464.80	6,659,743.20	6.66

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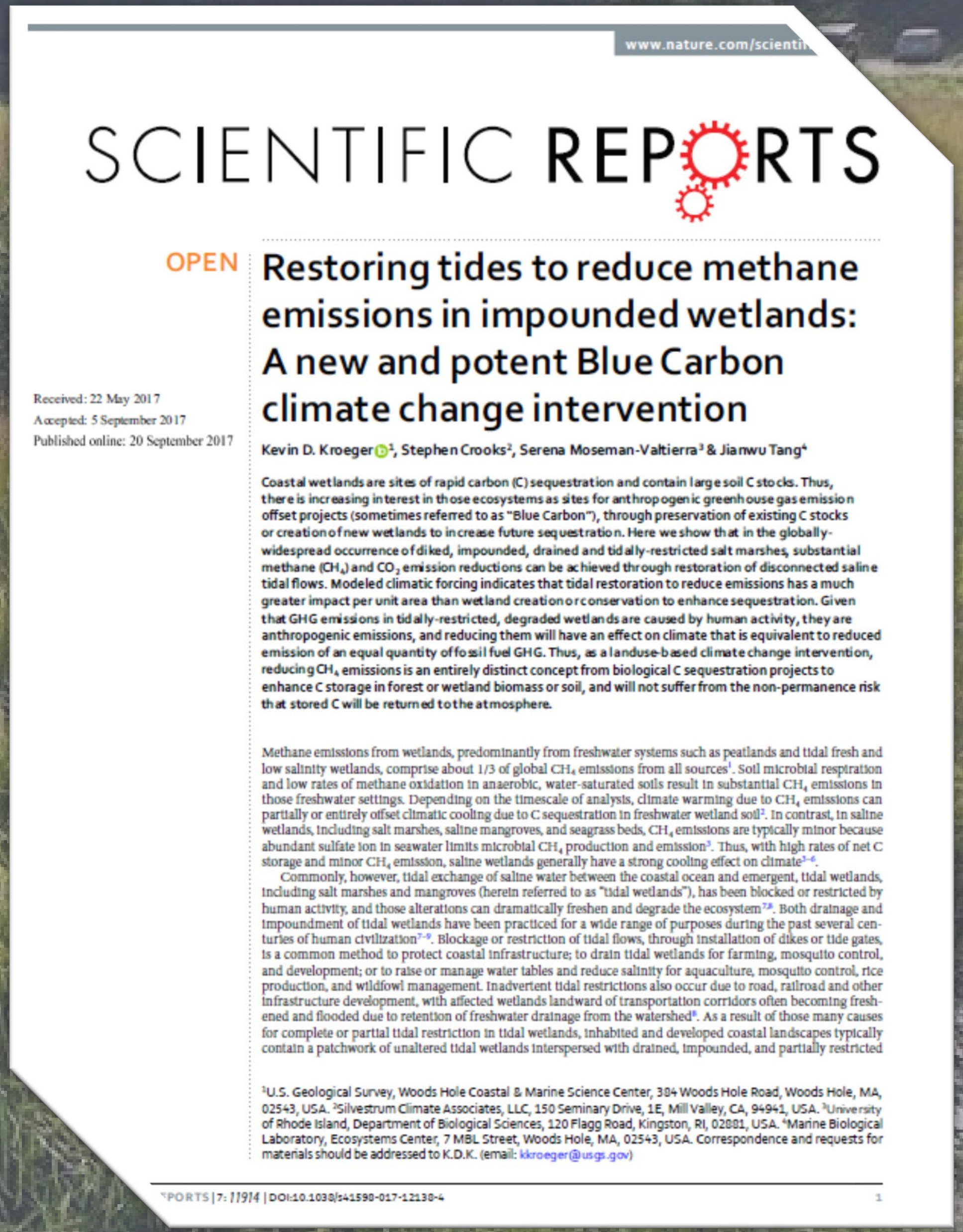

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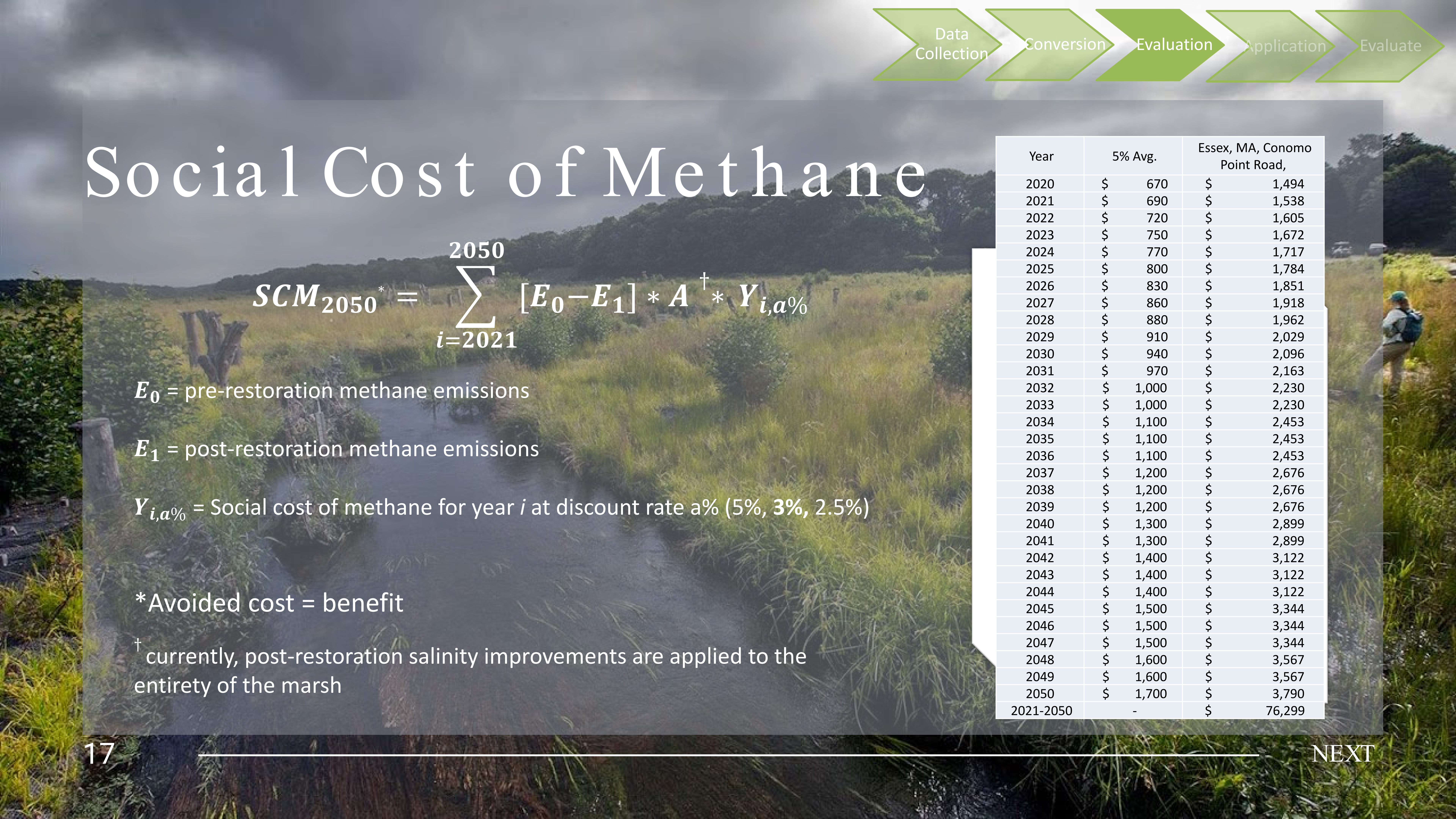

Data Collection
Conversion
Evaluation
Application
Evaluate

Social Cost of Methane

$$SCM_{2050}{}^{*} = \sum_{i=2021}^{2050} [E_0 - E_1] * A^{\dagger} * Y_{i,a\%}$$

E_0 = pre-restoration methane emissions

E_1 = post-restoration methane emissions

$Y_{i,a\%}$ = Social cost of methane for year *i* at discount rate a% (5%, **3%,** 2.5%)

*Avoided cost = benefit

[†] currently, post-restoration salinity improvements are applied to the entirety of the marsh

Year	5% Avg.	Essex, MA, Conomo Point Road,
2020	$ 670	$ 1,494
2021	$ 690	$ 1,538
2022	$ 720	$ 1,605
2023	$ 750	$ 1,672
2024	$ 770	$ 1,717
2025	$ 800	$ 1,784
2026	$ 830	$ 1,851
2027	$ 860	$ 1,918
2028	$ 880	$ 1,962
2029	$ 910	$ 2,029
2030	$ 940	$ 2,096
2031	$ 970	$ 2,163
2032	$ 1,000	$ 2,230
2033	$ 1,000	$ 2,230
2034	$ 1,100	$ 2,453
2035	$ 1,100	$ 2,453
2036	$ 1,100	$ 2,453
2037	$ 1,200	$ 2,676
2038	$ 1,200	$ 2,676
2039	$ 1,200	$ 2,676
2040	$ 1,300	$ 2,899
2041	$ 1,300	$ 2,899
2042	$ 1,400	$ 3,122
2043	$ 1,400	$ 3,122
2044	$ 1,400	$ 3,122
2045	$ 1,500	$ 3,344
2046	$ 1,500	$ 3,344
2047	$ 1,500	$ 3,344
2048	$ 1,600	$ 3,567
2049	$ 1,600	$ 3,567
2050	$ 1,700	$ 3,790
2021-2050	-	$ 76,299

NEXT

Social Cost of Methane

Location	Years Monitored	Restricted? Restored?	Years of Monitoring	Number of Data Points	Avg Salinity pre-rest*	Avg Salinity post-rest	Total Area of Wetland (acres)
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2050	$ 1,700	$ 3,790
2021-2050	-	$ 76,299

NEXT

Data Collection
Conversion
Evaluation
Application
Evaluate

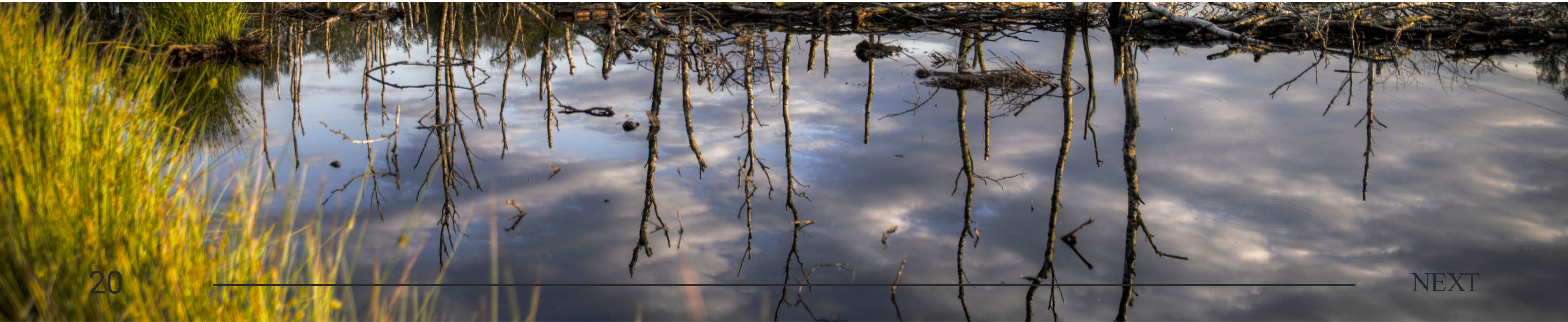
Social Cost of Methane

Year	Avoided social cost of methane (3% average) in 2021 dollars ($/Mt)	Essex, MA – Conomo Point Rd.	Gloucester, MA, Eastern Point	Gloucester, MA, Mill Pond
2021	$1,500.00	$1,540 - $3,344	$311 - $676	$4,599 - $9,990
2022	$1,600.00	$1,642 - $3,567	$332 - $721	$4,906 - $10,656
2023	$1,600.00	$1,642 - $3,567	$332 - $721	$4,906 - $10,656
2024	$1,700.00	$1,745 - $3,790	$353 - $766	$5,212 - $11,322
2025	$1,700.00	$1,745 - $3,790	$353 - $766	$5,212 - $11,322
2026	$1,800.00	$1,848 - $4,013	$373 - $811	$5,519 - $11,988
2027	$1,800.00	$1,848 - $4,013	$373 - $811	$5,519 - $11,988
2028	$1,900.00	$1,950 - $4,236	$394 - $856	$5,825 - $12,654
2029	$1,900.00	$1,950 - $4,236	$394 - $856	$5,825 - $12,654
2030	$2,000.00	$2,053 - $4,459	$415 - $901	$6,132 - $13,319
2021-2050 Total	-	$70,007 - $152,063	$14,151 - $30,737	$209,102 - $454,194

Key:
$EF = 19.4$
-
EF = 41.6

NEXT

What Would Offset Crediting Look Like for Salt Marsh Restoration Projects?



NEXT

Blue Carbon Crediting

Data Collection
Conversion
Evaluation
Application
Evaluate

Blue Carbon Crediting

$$VCU = [E_0 - E_1] * A * GWP_{CH4} + [C_0 - C_1] * A$$

Location EF = 41.6	Years Monitored	Years of Monitoring	Total Area of Wetland (m^2)	Total Area of Wetland (hectares)	Total Annual Avoided CH4 Emissions (Tons C)	GWP	Annual g CO2e (methane)	Tons of CO2e annually (methane)	Tons of CO2e Over Monitoring Period	VCUs over Monitoring Period (Methane)	VCUs Over Monitoring Period (assuming $20/ton)
Essex, MA, Conomo Point Road,	1998-2015	15	54,197	5.42	2.23	27.2	60,646,876.58	60.65	909.70	909.70	$ 18,194.06
Gloucester, MA, Eastern Point	2000-2015	12	10,955	1.10	0.45	27.2	12,258,732.64	12.26	147.10	147.10	$ 2,942.10
Gloucester, MA, Mill Pond	1998-2015	11	161,880	16.19	6.66	27.2	181,145,015.04	181.15	1,992.60	1,992.60	$ 39,851.90

Putting it Together

There are 475 salt marshes in Massachusetts with tidal restrictions (as of 2010)

- 2,304 acres (932 hectares)
- 383 tons of Methane, annually (10,434 tons of CO_2-equivalents)
- $208,679/year in carbon credits ($20/ton)

By 2050 (with an EF of 41.6):

- 11,508 tons of methane avoided
- 313,019 tons of CO_2e
- $6,260,372 in credits
- $17,721,225 - $35,318,163 in social benefit value

Massachusetts Coastal Wetlands and Salt Marsh with Tidal Restrictions (2010)

This map processes the McGarrigal et al., 2017 data layer and identified 475 salt marsh with tidal restrictions in Massachusetts.

McGarigal K, Compton BW, Plunkett EB, Deluca WV, and Grand J. 2017. Designing sustainable landscapes. Report to the North Atlantic Conservation Cooperative, US Fish and Wildlife Service, Northeast Region. | Earthstar Geographics

Takeaways and Caveats

- If applied to a future project, this methodology could produce blue carbon credits.
- GWP of methane could increase
  - 100-year GWP 27.2 ± 11
  - 20-year GWP 80.8 ± 25.8
- Per unit cost of CO_2e could increase

- Several assumptions were applied:
  - Choice of Emissions Factor
  - Quality of data
  - Use of salinity as methane proxy (versus direct capture)
  - Distributional extent of salinity changes
    - Still an open question
  - Monitoring interval

Why Care?

JetBlue is the First U.S. Airline to Commit to and Achieve Carbon Neutrality for All Domestic Flying

Aug 13, 2020

-- Preparing for a New Climate Reality, JetBlue Begins Offsetting Emissions for All Domestic Flights and Investing in Sustainable Aviation Fuel, Significantly Reducing its Contribution to the Climate Crisis --

Global Change Biology

Volume 28, Issue 4
February 2022
Pages 1433-1445

PRIMARY RESEARCH ARTICLE | Open Access

Systematic over-crediting in California's forest carbon offsets program

Grayson Badgley, Jeremy Freeman, Joseph J. Hamman, Barbara Haya, Anna T. Trugman, William R. L. Anderegg, Danny Cullenward

First published: 20 October 2021 | https://doi.org/10.1111/gcb.15943 | Citations: 3

See commentary on: https://onlinelibrary.wiley.com/doi/10.1111/gcb.16008

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Abstract

Carbon offsets are widely used by individuals, corporations, and governments to mitigate their greenhouse gas emissions on the assumption that offsets reflect equivalent climate benefits achieved elsewhere. These climate-equivalence claims depend on offsets providing real and additional climate benefits beyond what would have happened, counterfactually, without the offsets project. Here, we evaluate the design of California's prominent forest carbon offsets program and demonstrate that its climate-equivalence claims fall far short on the basis of directly observable evidence. By design, California's program awards large volumes of offset credits to forest projects with carbon stocks that exceed regional averages. This paradigm allows for adverse selection, which could occur if project developers preferentially select forests that are ecologically distinct from unrepresentative regional averages. By digitizing and analyzing comprehensive offset project records alongside detailed forest inventory data, we provide direct evidence that

Recommended

The Matter of Carbon: Understanding the Materiality of tCO2e in Carbon Offsets
Adam G. Bumpus
The New Carbon Economy, [1]

Tree species mixing can amplify microclimate offsets in young forest plantations

Environment

A Nonprofit Promised to Preserve Wildlife. Then It Made Millions Claiming It Could Cut Down Trees.

The Massachusetts Audubon Society has managed its land as wildlife habitat for years. Here's how the carbon credits it sold may have fueled climate change.

by Lisa Song, and James Temple, MIT Technology Review

May 10, 2021, 5 a.m. EDT

WHAT WE KNOW

Degraded wetlands off-gas GhG emissions.

These emissions are not being factored into State emissions reduction targets.

Salt marsh restoration projects already qualify for carbon credits

There is opportunity to combine salt marsh restoration (culvert widening) with climate resilience goals, especially with BIL funding

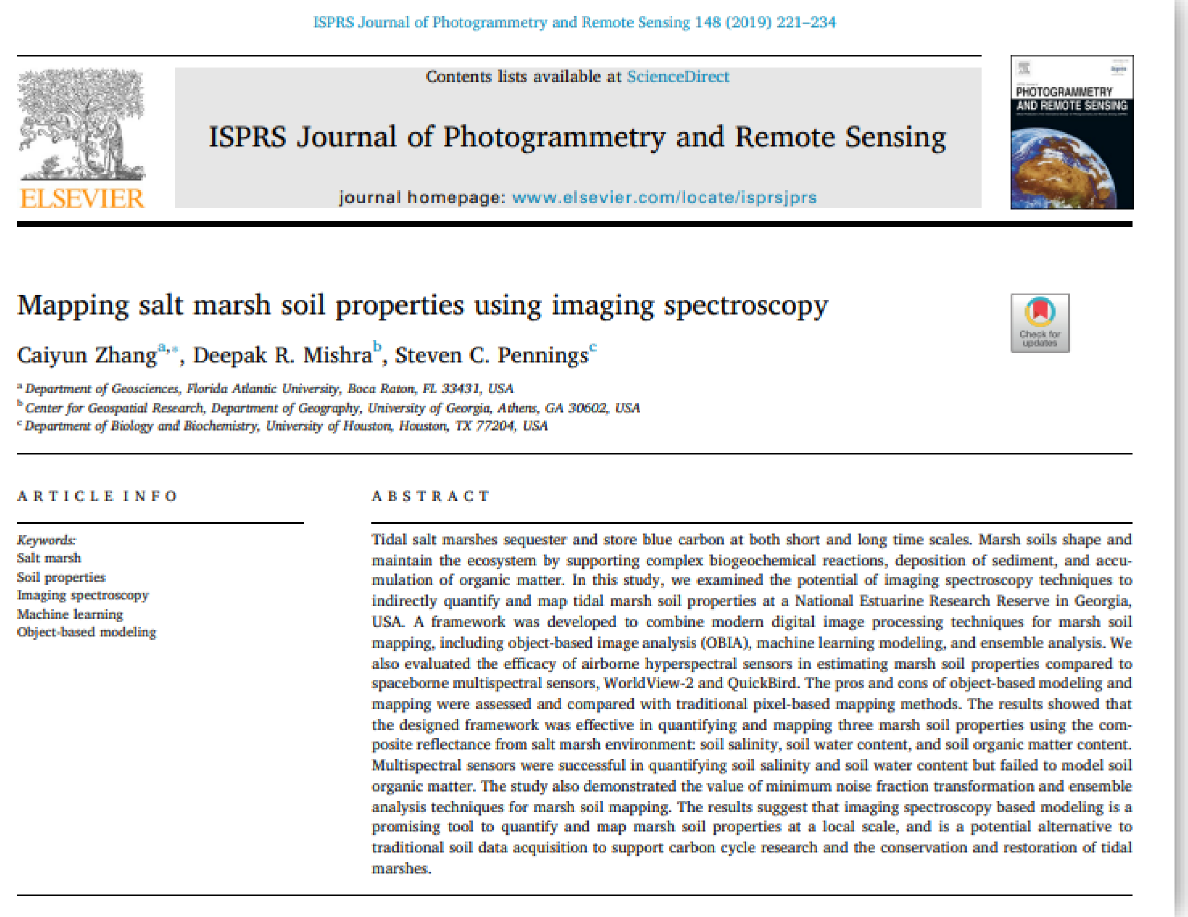
WHAT WE DON'T KNOW

The distributional extent of these GhG emissions or restoration effects

How to monitor cost-effectively

Next Steps

Demonstrate a satellite monitoring technique (with *in situ* calibration) to infer the distributional extent of salt marsh restoration projects.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Mapping salt marsh soil properties using imaging spectroscopy

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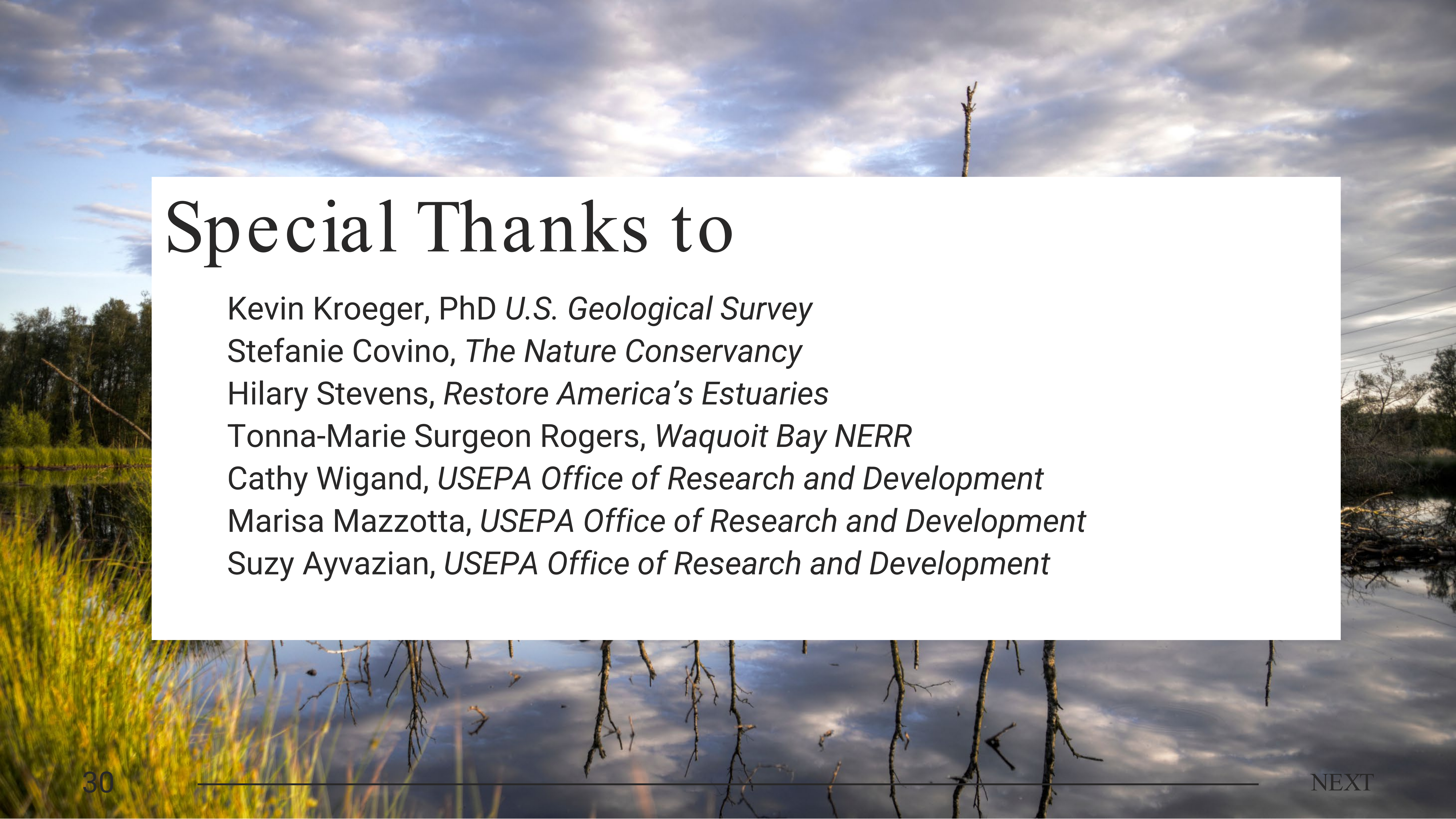
ABSTRACT

Tidal salt marshes sequester and store blue carbon at both short and long time scales. Marsh soils shape and maintain the ecosystem by supporting complex biogeochemical reactions, deposition of sediment, and accumulation of organic matter. In this study, we examined the potential of imaging spectroscopy techniques to indirectly quantify and map tidal marsh soil properties at a National Estuarine Research Reserve in Georgia, USA. A framework was developed to combine modern digital image processing techniques for marsh soil mapping, including object-based image analysis (OBIA), machine learning modeling, and ensemble analysis. We also evaluated the efficacy of airborne hyperspectral sensors in estimating marsh soil properties compared to spaceborne multispectral sensors, WorldView-2 and QuickBird. The pros and cons of object-based modeling and mapping were assessed and compared with traditional pixel-based mapping methods. The results showed that the designed framework was effective in quantifying and mapping three marsh soil properties using the composite reflectance from salt marsh environment: soil salinity, soil water content, and soil organic matter content. Multispectral sensors were successful in quantifying soil salinity and soil water content but failed to model soil organic matter. The study also demonstrated the value of minimum noise fraction transformation and ensemble analysis techniques for marsh soil mapping. The results suggest that imaging spectroscopy based modeling is a promising tool to quantify and map marsh soil properties at a local scale, and is a potential alternative to traditional soil data acquisition to support carbon cycle research and the conservation and restoration of tidal marshes.

"Keeping Carpinteria Salt Marsh connected to the tides" University of California Natural Reserve System. Image courtesy of Andy Brooks



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NEXT

THANK YOU

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