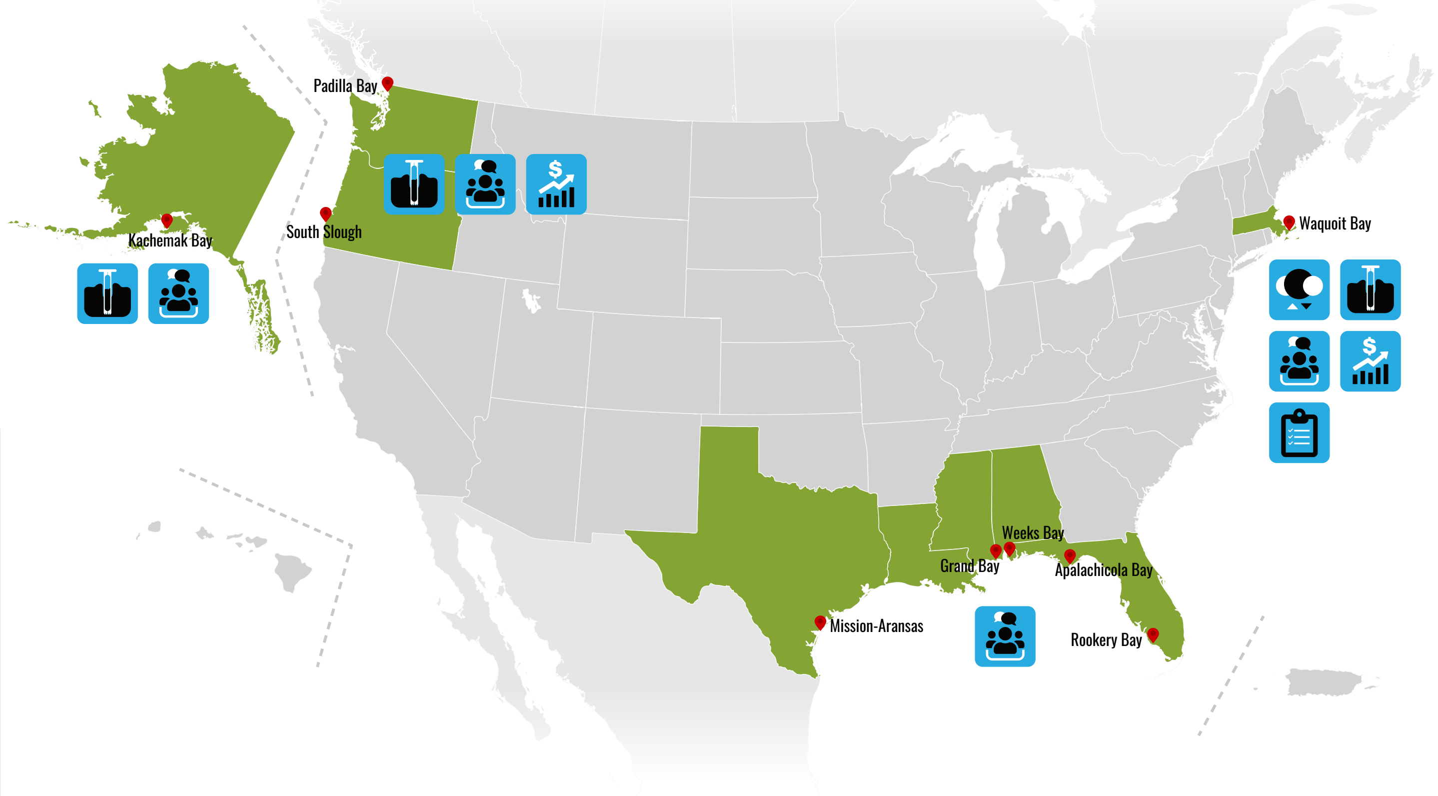
Advancing the use of blue carbon for coastal systems

Blue carbon is the term for greenhouse gas carbon that is captured and stored by coastal ecosystems.

NERRS Science Collaborative



Assessing carbon stocks

Carbon stock assessment involves quantifying the amount of carbon that is stored in wetland soils and contained in plants, above and below ground. This information is critical for quantifying the carbon storage potential of wetlands.

Quantifying greenhouse gas emissions and carbon sequestration rates

Gases are continually being exchanged between soils and the atmosphere. Researchers have been measuring the flux of gases, such as carbon dioxide and methane, from different types of wetlands to better understand how restoration actions might impact carbon storage.

Identifying and engaging partners

Blue carbon opens up opportunities to address a variety of coastal challenges in innovative ways and engage diverse partners. This requires understanding the local or regional context and being thoughtful about when the concept can be applied, who to engage, and how.

Evaluating carbon market feasibility

Voluntary carbon markets offer an opportunity to financially support wetland restoration or protection projects, but the process for putting a dollar value on a project's carbon impact is data-intensive, complex, and requires verification. A feasibility assessment is the first step in considering a blue carbon offset project.

Leading demonstration projects

In some cases, enough data and momentum exist for partners to advance blue carbon demonstration projects, which build on feasibility studies and follow approved carbon methodologies to show proof-of-concept.

MAY 2020

ADVANCING THE USE OF BLUE CARBON FOR COASTAL SYSTEMS

About the NERRS

The National Estuarine Research Reserve System (NERRS) is a national network of 29 coastal reserves located in 24 states and Puerto Rico. Each site includes programs focused on land stewardship, research and scientific monitoring, training programs for the public and local officials, and education.

About the NERRS Science Collaborative

The NERRS Science Collaborative is a NOAA-funded program that provides grants and other support for user-driven collaborative research, assessment, and transfer activities that address critical coastal management needs identified by the reserves.

Blue carbon refers to the greenhouse gas carbon that is captured and stored by coastal ecosystems

Coastal wetlands capture carbon dioxide from the atmosphere and permanently store carbon in wetland soils. This "blue carbon" service can be used to inform and incentivize wetland restoration; however, the science behind blue carbon and the role of carbon finance in support of coastal restoration and conservation are still emerging.

Since 2010, the National Estuarine Research Reserve System (NERRS) and its partners have been filling key information gaps and fostering collaborations to advance understanding and application of blue carbon for the management of coastal wetlands. Projects have helped to quantify the carbon storage potential of coastal wetlands, predict greenhouse gas fluxes, and assess the market feasibility of using carbon offsets to support wetland restoration.

Researchers from the Bringing Wetlands to Market project collect samples and sensor data to measure fluxes of several forms of carbon carried by tidal water exchange between the Sage Lot Pond salt marsh and the Waquoit Bay estuary at the Waquoit Bay Reserve.
Photo credit: Alison Leschen, Waquoit Bay National Estuarine Research Reserve

About this document

Representatives from the projects featured in this brief participated in a panel webinar on March 17, 2020 to discuss lessons learned and next steps, opportunities, and needs for blue carbon and wetland management.

This document was prepared by NERRS Science Collaborative staff, with input from Craig Cornu, Tonna-Marie Surgeon Rogers, Stefanie Simpson, Coowe Walker, and their project partners.

National Estuarine Research Reserve System Science Collaborative

This management brief features the work of teams in four regions across the United States that have received support through the NERRS Science Collaborative. We emphasize key aspects of their work: developing models that predict carbon fluxes locally and evolving them to increase regional relevance; assessing and cataloging carbon stocks for regional and national use; performing assessments and feasibility studies to explore restoration financing through carbon markets; and developing resources and strategies for communicating with communities and decision makers about advancing the use of blue carbon for coastal systems.

PARTNERS IN THE NORTHEAST

Waquoit Bay Reserve assembled a diverse set of partners for the Bringing Wetlands to Market (BWM) project, including: **federal agencies:** Woods Hole Coastal and Marine Science Center (U.S. Geological Survey), and Cape Cod National Seashore (U.S. National Park Service); **non-profits:** Friends of Herring River, Manomet Center for Conservation Sciences, Restore America's Estuaries, National Estuarine Research Reserve Association, and Friends of the Waquoit Bay Reserve; **academic and research institutions:** Marine Biological Laboratory (University of Chicago), West Virginia University, Florida International University, Smithsonian Environmental Research Center, and University of Rhode Island; **consultants:** Environmental Science Associates, TerraCarbon LLC and Silvestrum Climate Associates LLC; and **local organizations:** Herring River Restoration Group and Friends of Herring River.

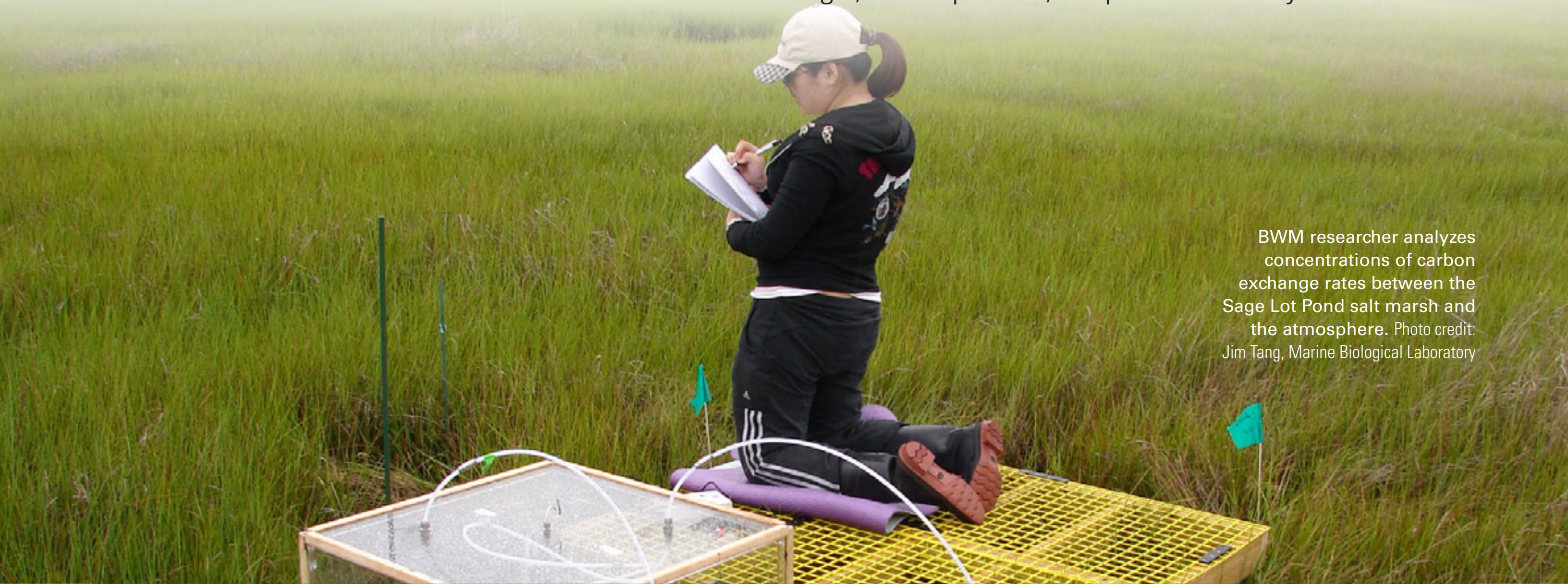
BRINGING WETLANDS TO MARKET IN MASSACHUSETTS

In 2011, inspired by new research on how carbon is stored in wetland soils, and hoping to incentivize and encourage investment in wetland restoration, conservation, and innovative climate change research, the Waquoit Bay Reserve and a broad team of partners began the **Bringing Wetlands to Market (BWM)** project — one of the first collaborative research projects of its kind exploring blue carbon science and application in coastal management. In Phase 1 of the project, the team examined the relationship among salt marshes, climate change, and nitrogen pollution, and developed tools designed to leverage the "blue carbon" stored in wetlands to achieve broader management goals. Soon, this work garnered interest from a range of other stakeholders working at the national, regional, and local levels, and researchers interested in exploring the carbon sequestration potential of salt marshes and other coastal systems. Project partners worked with interested teams to transfer findings, tools, and lessons from the project to other regions through the Reserve system and partner networks. *See "Partners in the Northeast" box for more information.*

In the first phase, the project team sought to develop the scientific information needed to:

1. Make informed decisions about carbon and nitrogen management;
2. Bolster wetland protection and restoration strategies; and
3. Develop policy frameworks and market-based mechanisms that would reduce greenhouse gases and sequester carbon.

By the time Phase 1 wrapped in 2015, the diverse team of experts had produced the first iteration of a novel, user-friendly model based on in-situ field observations called the **Coastal Wetland Greenhouse Gas Model**. The model predicted greenhouse gas fluxes at four Waquoit Bay Reserve target sites, representing latitudinal and nitrogen-loading gradients with similar elevation and vegetation. The team then used these greenhouse gas data to estimate the net atmospheric carbon removal — essentially the maximum carbon storage potential — of their sites based on three variables: sunlight, soil temperature, and porewater salinity.



BWM researcher analyzes concentrations of carbon exchange rates between the Sage Lot Pond salt marsh and the atmosphere. Photo credit: Jim Tang, Marine Biological Laboratory

CARBON MARKETS

There is no one-size-fits-all solution for financing large wetland restoration projects, and participation in compliance or voluntary carbon markets could open new avenues for project feasibility. As of January 2020, there are two major regulatory compliance carbon markets in the U.S., as well as a growing marketplace made up of voluntary transactions. **Compliance markets** are the result of government regulation to reduce greenhouse gas emissions, and allow regulated entities to obtain and surrender emissions permits or offsets in order to meet predetermined regulatory targets. **Voluntary markets** refer to collective voluntary transactions, tracked globally; there is no single centralized voluntary carbon marketplace. (**State of the Voluntary Carbon Markets Report 2017, Forest Trends**).

Wetland projects have not yet been approved as carbon offset opportunities in regulated markets, so projects are currently relying on voluntary markets; however, new types of offset projects that are successful in voluntary markets are more likely to be adopted within regulated markets. Over the longer term, breaking into compliance markets could raise the value of offsets generated through wetland restoration, and provide more financial support for restoration projects.

The Waquoit Bay team also supported development of the first methodology for securing credits for blue carbon through the **Verified Carbon Standard**, a voluntary greenhouse gas offset program. Approved in November 2015, it is categorized as a Restoring Wetland Ecosystems methodology. Essentially, the methodology treats wetlands' ability to sequester and store carbon as an ecosystem service, and provides a means of accounting for greenhouse gas reductions that result from wetland restoration and protection activities. *See "Carbon Markets" box for more information.*

As end user interest in blue carbon continued to grow, so did the need to expand the scope and applicability of the Coastal Wetland Greenhouse Gas model, which required the team to fill more information gaps. In the second phase of Bringing Wetlands to Market, the team expanded the original model's geospatial scope beyond the Waquoit Bay Reserve and produced the Coastal Wetland Greenhouse Gas Model 2.0 to help predict carbon dioxide and methane fluxes, and assess the carbon storage potential of wetlands across the mid-Atlantic coast.

Over the course of the project, the science team made several key observations that informed revisions to the expanded model. They also helped advance learning around an important new angle of the blue carbon and wetlands story; particularly, that tidally-restricted, impounded wetlands are a common — and manageable — source of anthropogenic methane emissions. As a result, restoring tidal flow to those degraded wetlands provides one of the biggest opportunities to create resilient marshes that prevent the release of methane, build elevation, and store carbon. Compared to projects promoting carbon sequestration in forests or wetland soil, which rely on a process of gradual sediment accumulation over a prolonged time period, restoration of tidal flow as an intervention strategy provides quick and sustained climate benefits in the form of avoided methane emissions.

A significant quantity of field data, gathered in support of enhancing the robustness, validity, and evolution of the model, fed into another accomplishment: a first of its kind carbon market feasibility study for the **Herring River Restoration Project**. Among the largest ecological restoration projects in the Northeast, the effort has garnered attention from land management groups, restoration practitioners and conservation organizations alike. The market feasibility team concluded that the Herring River project will produce carbon benefits and is eligible as a carbon offset project under a voluntary market. They also determined that over a 40-year time frame, selling carbon offsets for at least $10 per ton in a voluntary market would produce enough revenue to cover the up-front costs associated with auditing the carbon calculations and compiling data for the restoration project (if pursued as a blue carbon market project) — with enough additional revenue to support long-term monitoring. Monitoring is often underfunded, but is critical for tracking a project's success and carbon impact. Potential reduction estimates vary, but mid-range projections indicate that about 85,000 tons of carbon dioxide equivalent gases would be removed over the 40-year period.

ROADSHOW DIALOGUES

As an end user engagement strategy, Bringing Wetlands to Market team members took their information "on the road" to have discussions with key decision makers at the state level in Massachusetts. During these Roadshow Dialogues, the team conducted interviews and facilitated focus group style conversations in the offices of key project stakeholders.

Through these dialogues, project teams gathered direct feedback on the research plan and outreach tools from intended end users. In the Gulf, a project team leveraged workshop and Roadshow Dialogue results to produce outreach materials for the region.

In an effort to further enhance the outreach and engagement potential of blue carbon work and BWM, the project team also led the development of a blue carbon science curriculum which examines the relationships among salt marshes, climate change, and nitrogen pollution, and illustrates the economic value of salt marshes as carbon sinks. Geared toward the high school level, the curriculum includes modules to familiarize students with a range of related concepts including wetland ecology, the carbon cycle, scientific research, ecosystem service valuation, and stewardship challenges.

A central aspect of the BWM project in Massachusetts included sustained engagement with a suite of stakeholders and extensive outreach on blue carbon concepts to many audiences in the state and in other regions of the country. The team built awareness about blue carbon through decision-maker workshops, policy briefings, roadshow dialogues *(see "Roadshow Dialogues" box for more information)*, teacher workshops and public seminars, and developed a suite of communication products to help explain concepts. The team also played a key role in catalyzing other blue carbon projects within and outside the Reserve system, and educating a diverse range of coastal managers, restoration practitioners, land managers, policymakers, government officials, students, and community members about the value of coastal wetlands and the blue carbon benefits they provide.

These efforts all emphasized how and where end users could capitalize on blue carbon to advance restoration, coastal resilience, and climate action goals. Thanks to the team's work in the region, resource management agencies have gained awareness of blue carbon approaches; for example, increased support for tidal restoration from federal, state, and local partners helped inspire the integration of tidal restoration in coastal wetlands into the 2019 Climate Stewardship Act, and official guidance from the U.S. Environmental Protection Agency, National Academy of Sciences, and International Panel on Climate Change Wetlands Supplement. In addition, their outreach work sparked continuing conversations with Massachusetts agencies considering wetland management approaches for greenhouse gas management.

Photo credit: Waquoit Bay NERR.

PACIFIC NORTHWEST REGIONAL PARTNERS

In January 2014, following the Verified Carbon Standard's approval of a methodology for tidal wetland and seagrass restoration, Oregon's South Slough Reserve hosted a series of workshops that focused on how blue carbon finance could help support tidal wetland restoration in the Pacific Northwest. The **Pacific Northwest Coastal Blue Carbon Working Group** (Working Group) formed soon after to begin work on filling important blue carbon data gaps for tidal wetland restoration practitioners and coastal resource managers in the region. The Working Group's efforts are guided by a research framework that outlines goals, objectives, and methods for collecting and sharing Pacific Northwest blue carbon data.

Working Group membership includes biophysical, social, and economic scientists, coastal planners, land managers, restoration scientists and practitioners, regional tribal groups, conservation finance and carbon accounting interests, and members of organizations working on carbon policy initiatives. Members represent a broad swath of organization types including state and federal government agencies, academic institutions, consulting firms, and non-profit organizations.

BLUE CARBON IN THE PACIFIC NORTHWEST

In 2016, the Pacific Northwest Blue Carbon Working Group (Working Group) initiated the first comprehensive **blue carbon stock assessment** for Pacific Northwest tidal wetlands. The project quantified carbon stocks and associated environmental variables at 34 tidal wetland sites in estuaries representing the Pacific Northwest's three geographically distinct coastal regions: Salish Sea/Puget Sound, Columbia River estuary, and outer coast estuaries from Washington to northern California. The project also initiated the development of a Pacific Northwest blue carbon database and began populating it with data from previous blue carbon projects before adding the project's new carbon stocks data. A partnership with the Smithsonian Environmental Research Center's online **Coastal Carbon Atlas** has ensured easy access to the data. *See "Pacific Northwest Regional Partners" box for more information.*

The team's research included quantifying total ecosystem carbon stocks for the full range of Pacific Northwest tidal wetland classes (e.g., seagrass beds, low and high elevation marshes, forested tidal swamps) and found that they significantly increased along the intertidal elevation-salinity gradient, with the lowest carbon stock quantities found in lower-elevation seagrasses (217 Mg C per hectare) and highest concentrations found in higher-elevation forested tidal wetlands (1064 Mg C per hectare). *See "Quantifying Pacific Northwest Carbon Stocks" box for more information.*

In general, the project team found that the total ecosystem carbon stocks present in Pacific Northwest coastal wetlands exceeded expectations suggested by the mean global estimates reported elsewhere. More specifically, the team's estimates of the carbon stored in their seagrass sites were 65% higher than global estimates for seagrass. In high marshes, the team calculated the ecosystem carbon stocks at 551 MgC/ha, double the amounts reported for global marshes (255 MgC/ha) and for marshes in the continental United States (270-307 MgC/ha, based on estimates from 2016 and 2018). By these estimates, Pacific Northwest tidal wetlands represent a significant source of stored carbon and restoring the ecosystem services of degraded tidal wetlands could provide an important mechanism for sequestering carbon.

Padilla Bay Reserve's Jude Apple helping establish a carbon stocks coring transect in a Padilla Bay eelgrass bed as the tide drops.
Photo credit:Leila Giovannoni

QUANTIFYING PACIFIC NORTHWEST CARBON STOCKS

The project team measured combined soil and aboveground carbon in four Pacific Northwest wetland classes in megagrams of carbon per hectare (MgC/ha). One Mg is equal to approximately 1.1 tons of carbon. For reference, an average passenger vehicle in the U.S. emits about 4.6 tons (or 4.2 megagrams) of carbon dioxide each year.

Tidal wetlands can be net carbon sinks that convert atmospheric carbon dioxide into plant biomass, and permanently bury that carbon-rich biomass in oxygen-deprived wetland soils. Tidal wetlands converted to other land uses such as agricultural lands not only store much less carbon, but as the former wetland soils dry out, the soils' organic fraction decomposes and releases long-stored carbon into the atmosphere in the form of methane and other greenhouse gases.

Two years into the carbon stocks assessment project, the Working Group began evaluating the potential of **blue carbon finance** for wetland restoration projects in three Pacific Northwest estuaries. Building on new and established relationships, and new and existing data, the project team implemented the **Pacific Northwest Blue Carbon Finance Project** designed to demonstrate for end users how blue carbon finance could be used to help support tidal wetland restoration initiatives in the region. Washington's Snohomish estuary, the first of the project's three sites, provided an example of a blue carbon data-rich system. The other two sites — Skagit Estuary, Washington and Coos Estuary, Oregon — represented areas with less available blue carbon data, but where reserves and their local partners could provide local leadership to facilitate project development, and capacity to share lessons learned. To the extent possible, the team worked with local partners in each estuary to develop blue carbon feasibility assessments exploring technical, financial, legal, and organizational aspects of landscape-scale blue carbon project development.

Both Working Group projects culminated in three joint results-sharing workshops at the end of 2019 involving project team members and end users from both projects. At the workshops, local and regional end users attended presentations that shared both projects' results, and participated in discussions about opportunities, research needs, and challenges associated with carbon finance opportunities in the Pacific Northwest carbon project designers, validators, and verifiers, planners from carbon standards and registries, policy makers, tidal wetland restoration planners, designers and practitioners, estuarine wetland scientists, developers of carbon project methodologies and educators."

The Working Group continues to grow and expand its outreach as interest surrounding blue carbon develops in the region. To date, their work has provided regional decision makers with a more complete picture of the potential carbon stocks across a range of habitat classes in the region, which will help guide ongoing coastal restoration and climate change mitigation efforts. What's more, the projects have enhanced understanding of data used to evaluate blue carbon projects among researchers and decision makers, and have identified remaining data gaps which provide opportunities for future exploration.

Carbon stocks coring in a former tidal wetland converted to a pasture in the Coos estuary, Oregon. Photo credit: Leila Giovannoni

PARTNERSHIPS IN THE GULF COAST

To promote estuary restoration and protection, Restore America's Estuaries coordinated with the Apalachicola, Grand Bay, Mission-Aransas, Rookery Bay, and Weeks Bay reserves to create a Gulf Coast Blue Carbon Network. Other partners have included the Waquoit Bay Reserve, Gulf of Mexico Regional Coastal Training Program Initiative, Tierra Resources LLC, NOAA Office of Habitat Conservation, TerraCarbon, U.S. Fish and Wildlife Service Coastal Program, and the Weeks Bay Foundation.

ESTABLISHING A BLUE CARBON NETWORK IN THE GULF COAST AND CARIBBEAN

In 2015, around the time the Verified Carbon Standard approved a methodology for securing blue carbon credits through tidal wetland restoration, reserves and partners in the Gulf began having their own discussions about the greenhouse gas implications of their land use decisions. *See "Partnerships in the Gulf Coast" for more information.*

The **Gulf Coast Blue Carbon Network** sought to strengthen connections within the Reserve system by identifying end user needs, establishing local support, providing technical assistance, and conducting educational workshops about blue carbon as an ecosystem service. By leveraging these initial activities into more workshops in Texas, Florida, Louisiana, and Puerto Rico, the effort reached over 300 coastal management professionals across the Gulf states and Caribbean. Afterward, Restore America's Estuaries (RAE) provided additional support to participants including regular blue carbon email updates and newsletters, and financial, technical, and collaborative support on blue carbon related proposals. The workshops and follow-up efforts led to the development of new workshops geared toward municipal staff across the region, as well as an ongoing educational blue carbon webinar series hosted by Restore America's Estuaries that reaches a national network.

In one instance, RAE's technical support on a group's research proposal helped secure funding to transfer lessons learned from **Waquoit Bay Reserve in Massachusetts to Mission-Aransas Reserve in Texas**. Leveraging approaches and lessons learned from the Bringing Wetlands to Market project, in combination with feedback from the recent Gulf workshops, the Mission-Aransas team held two workshops for state and local planners in Texas.

Photo credit: Mission-Aransas National Estuarine Research Reserve

Group photo from a blue carbon workshop coordinated by Restore America's Estuaries, the Gulf of Mexico Coastal Training Program Initiative, and the Mission-Aransas Reserve.
Photo credit: Stefanie Simpson

The first workshop (December 2017) deepened stakeholder interest in and familiarity with blue carbon concepts, and helped participants find ways to integrate blue carbon into their work. During the workshop, the team led participants through focus group-style discussions based on the Roadshow Dialogues model developed at Waquoit Bay reserve. Using participant feedback, the team produced a targeted needs assessment detailing local requirements for moving ahead on blue carbon initiatives, which focused on financial dimensions linking the public and private sectors. The team later compiled the information into a **summary report** outlining the needs, lessons learned, recommendations, and next steps for blue carbon finance research in Texas.

The second workshop (September 2018) included research presentations from local blue carbon specialists, as well as three members of the Waquoit Bay Bringing Wetlands to Market team, which enabled a transfer of knowledge, approaches, and lessons learned between the New England and Texas researchers. As a result, the two teams developed professional relationships that could enable future collaborations.

Importantly, both workshops opened avenues to improve communications with local and regional stakeholder groups by more effectively gauging their interests and connecting them to blue carbon. Through tested communication techniques, developed through the Roadshow Dialogues model, the Mission-Aransas team gained a clearer picture of the different interests, issues, and questions of their local stakeholder groups. *See "Roadshow Dialogues" box on page 4 for more information.*

VALUING ECOSYSTEM SERVICES IN THE KENAI PENINSULA

In Alaska, the lives and livelihoods of community members are closely tied to fish and wildlife resources. As a result, the Kachemak Bay Reserve is heavily invested in understanding how environmental changes will impact the ecosystem services associated with these resources. This focus and their approach to understanding ecosystem services has forged long-standing partnerships with groups such as the Kachemak Heritage Land Trust, Cook Inlet Region Inc., the U.S. Fish and Wildlife Service Conservation Office, the Nature Conservancy, Silvestrum Climate Associates LLC, the Smithsonian Environmental Research Center, and many other regional stakeholder groups.

ASSESSING PEATLAND CARBON STORES IN ALASKA'S KACHEMAK BAY

Understanding the amount of carbon stored in wetlands is important both from an ecosystem service perspective and for determining the feasibility of blue carbon projects in any region. One way Alaska differs from other regions is in its abundance of peat wetlands, or "peatlands," over the seagrasses and saltmarshes found in other systems.

Peatlands are unique wetland systems that are widely known to store vast amounts of carbon in their deep organic soils. Dead leaves and roots of peatland plants decompose very slowly and accumulate in the soil, forming peat. However, if peatland soils dry out, that dead plant material can begin decomposing quickly and become a large source of greenhouse gas emissions. Peatlands also provide other ecosystem services; for example they help modulate stream temperatures and provide a food source for connected salmon streams.

In Alaska, the Kachemak Bay reserve led a project that explored opportunities for long-term **blue carbon research** and stakeholder engagement in the Lower Kenai region. The team's approach involved gathering experts to inform Kachemak Bay reserve staff about blue carbon, which they accomplished through webinars that covered blue carbon concepts, characteristics of the region's ecosystems, and socioeconomic conditions. *See "Valuing Ecosystem Services in the Kenai Peninsula" box for more information.*

Afterward, the project team engaged community councils, regional land use planners and permitters, conservation non-profits, and the Kachemak Heritage Land Trust in exploring the potential application of blue carbon in Alaska. These discussions helped the team recognize that the region could become a leader in valuing peatlands and creating additional incentives to protect peatlands.

Thanks to these discussions, the team's research plan includes assessing existing peatland extent and condition in the Kachemak Bay region, summarizing previous studies and data for peatlands, and developing sampling strategies and methodologies for measuring peatland carbon.They also developed communications strategies to continue momentum and build support for protecting peatlands.

As a result of in-depth stakeholder engagement campaigns, the Kachemak Bay reserve has garnered support for further peatland research in the Kenai Lowlands region, and enhanced their capacity for partnership with a diverse and growing network of local stakeholder organizations.

High school students from Tyonek hold a soil core taken from a peatland. The students learned how peatlands store carbon, and how you can read geomorphic history in a soil core. For example, the students were able to see a line of volcanic ash in the core from past eruption activity. Photo credit: Coowe Walker, Kachemak Bay National Estuarine Research Reserve

LESSONS LEARNED

Representatives from the projects featured in this brief participated in a panel webinar on March 17, 2020 to discuss lessons learned and next steps for blue carbon and wetland management. Here, we summarize panelist responses to the first discussion prompt, which invited panelists to share one or two of the most important lessons they have learned through their work.

Craig Cornu, Project Manager, Estuary Technical Group, Institute for Applied Ecology, Oregon

- Unless the price of carbon rises dramatically, the potential funding provided by carbon finance will only cover a portion of the costs of tidal wetland restoration projects.
- Scale turns out to be an issue for developing financially viable blue carbon projects. This creates a great incentive for forming collaborations that can advance bigger, landscape-scale wetland restoration projects that can attract carbon financing.
- Our work has found that the most viable blue carbon opportunities in the Pacific Northwest are related to the restoration of forested tidal wetlands. This finding provides further motivation to focus restoration efforts in the Pacific Northwest on forested tidal wetlands, which historically provided juvenile salmon with critical summer rearing habitat, but have been almost entirely converted to other land uses.

Tonna-Marie Surgeon Rogers, Reserve Manager & Coastal Training Program Coordinator, Waquoit Bay National Estuarine Research Reserve, Massachusetts

- Blue carbon has very broad applicability, beyond just carbon market considerations, in the coastal management world. We have learned that the information emerging from cutting edge blue carbon research can be used to inform a wide range of management actions and environmental policies; this includes greenhouse gas inventories, climate action plans, coastal resilience projects, wetland conservation and restoration projects, ecosystem service valuation, and public education and outreach. Even in places where carbon market projects may not be viable or might take time to come to fruition, this should not limit looking at other opportunities to apply blue carbon.
- Our team's work in New England has helped to focus attention on the importance of considering methane emissions from tidally impounded wetlands as an important greenhouse gas source, as well as the need to better understand the carbon impact of different wetland management actions. Restoring tidal flow and increasing the salinity in previously impounded and/or degraded wetlands can significantly reduce methane emissions. This presents a widespread opportunity for climate benefits.

Coowe Walker, Reserve Manager, Kachemak Bay National Estuarine Research Reserve, Alaska

- We are realizing that Alaska's vast peatlands provide numerous benefits to salmon populations and also store large amounts of carbon. Quantifying and sharing information about peatland blue carbon provides opportunities to engage new partners and advance efforts to protect the multiple benefits provided by peatlands.
- Our peatlands are large and very vulnerable to development, so we are optimistic that we can attract carbon financing for preservation efforts.

Stefanie Simpson, Coastal Wetland Program Manager, the Nature Conservancy

- There is growing interest from the private sector to purchase blue carbon offsets, but meeting the demand at scale is challenging. Priority projects that can deliver a "larger bang for the buck" include avoided conversion (aka protection) projects, where there is high risk of development, restoration that has occurred in the past five years (as this is the time limitation to generating credits from past activities), and restoring impounded wetlands, thus restoring salinity and halting methane emissions (e.g. Herring River project).
- Where possible, offset revenues should compliment other sources of income (e.g. sustainable livelihood projects, ecotourism, etc.) that can support communities managing these projects.

NEXT STEPS AND OPPORTUNITIES FOR MOVING BLUE CARBON WORK FORWARD

This section summarizes key next steps and opportunities that the panel identified for moving blue carbon work forward.

Assessing carbon stocks

- We need to understand the factors that affect carbon storage. In Alaska, we're looking to understand the causes and carbon stock implications of increasingly dry conditions we're observing in our peatlands. For example, beaver activity is likely critical to sustaining inundation in peatlands, which in turn ensures long-term carbon storage.

Quantifying greenhouse gas emissions and carbon sequestration rates

- We need additional research on methane emissions from different least-disturbed wetland types, different land uses, and under different hydrologic conditions to better calculate the net carbon impact of wetland management.

Identifying and engaging partners

- The last decade of blue carbon research and related management efforts has shown how collaborative engagement with a range of stakeholder groups has helped to fuel a rapid pace of learning around blue carbon. We need to continue to harness, distill and communicate findings from the research to diverse stakeholder groups ranging from resource managers to policymakers to students and regular citizens, to better capitalize on blue carbon benefits and support wetlands management and conservation.

Evaluating carbon market feasibility

- We need to get wetland restoration and conservation projects to be accepted as carbon offsets in regulated compliance carbon markets, which likely means first showing success in voluntary carbon markets.

Leading demonstration projects

- We need more demonstration projects to show how greenhouse gas calculations can come together to calculate the net carbon impact of a wetland project, and to establish the viability of blue carbon financing for wetland projects in a way that attracts potential investors.

Photo credit: Kachemak Bay National Estuarine Research Reserve

RESPONDING TO COMMON QUESTIONS ABOUT BLUE CARBON

Why the name blue carbon?

- **A:** Blue carbon specifically describes the carbon captured by the world's ocean and coastal ecosystems. The term has gained familiarity over the past couple of decades and provides a memorable way to talk about the complex topic of coastal carbon storage.

Markets and Pricing

What is the current price being paid for blue carbon?

- **A:** From the voluntary carbon market perspective, which is summarized annually in the State of the Voluntary Carbon Market Report from Ecosystem Marketplace, the average price for land use projects is around $3-5 per metric ton of carbon dioxide equivalent (tCO2e). Projects that have co-benefits, such as charismatic or prestigious qualities that appeal to buyers, tend to raise values closer to $8-10 tCO2e. In general, demand is currently high for blue carbon offsets, and supply is currently low; developers can therefore set higher prices, which is a benefit for them. Corporations buying offsets are usually looking for tens of thousands or hundreds of thousands of credits to offset their unavoidable emissions, which means they are usually looking for portfolios of projects.

  Regulated compliance markets have not yet accepted wetland projects as acceptable offset projects, as they generally look for success on the voluntary market before integrating new project types; this is another reason why pilot projects are important for convincing the regulatory market to get involved.

What qualifies as a co-benefit, and do you have to quantify them too?

- **A:** Co-benefits are any additional benefits provided by a project beyond greenhouse gas mitigation. For coastal wetlands, co-benefits include, but are not limited to, improved improved water quality, fisheries habitat and nursery, flood reduction, storm attenuation, community resilience, biodiversity, and many others. In general, land-use projects do not need to quantify these benefits, but there are additional standards and methodologies that can be applied to a project to quantify and verify these benefits. Examples include Verra's Climate, Community and Biodiversity Standard and their Sustainable Development Verified Impact Standard. Applying these additional standards provides a mechanism for quantifying and verifying co-benefits with the intended approach to stack benefits and sell offsets at a premium price.

How much work has been done in credit stacking — one project earning credits in several markets? What are your experiences or thoughts on credit stacking?

- **A:** See answer to co-benefits above. Credit stacking is allowed but should avoid double-counting.

Does preserving carbon that would otherwise soon be lost (e.g. due to wetland loss) count for sequestration in voluntary or regulated carbon markets?

- **A:** Yes, preventing the loss of carbon already stored in an ecosystem, which requires demonstrating that there's a risk to that area, can qualify for credits in a voluntary carbon market. Demonstrating risk in this case means evaluating the conversion rate for the surrounding area and using this to quantify the potential carbon impacts of altering intact wetlands.

  Another important distinction to make is that conservation activities must account for potential leakage when making the case for protecting wetlands. For example, outright prohibition of development could result in a company moving its development activities to an area with less stringent emission regulations, which can actually lead to an overall increase in emissions and does not qualify as legitimate conservation. Instead, people should make a case for moving development to more upland areas, which does qualify.

Thinking about scale and importance of pilot demonstration projects, is there a minimum amount of carbon offsets that market partners seem to be looking for?

- **A:** It varies depending on the habitat type and region, and it tends to be more about making the project itself financially viable at a particular scale and less about making it of interest to an offset buyer. Part of the reason feasibility assessments are needed is because there are startup costs associated with bringing a project to market, and the scale needs to be enough to justify the investment. In many cases, bundling smaller scale projects together into a larger-scale project can help justify the investment costs since those up-front costs are relatively fixed.

What are some criteria for making a project financially viable?

- **A:** The quantity of carbon credits to be generated, which is achieved through avoided emissions and/or carbon sequestered in a project, and scale are important factors and seem to be the most important determinants of financial viability. In Alaska, this makes us optimistic that we can develop financially feasible carbon projects because the peatlands of the region cover thousands of hectares and are many meters deep. Additional ecosystem values of carbon projects also contribute to financial viability. For example, the fact that Kenai Lowland peatlands are important to sustaining salmon streams in the region combined will enhance the market appeal of peatland carbon projects.

Greenhouse Gas Flux and Carbon Sequestration Potential

Does anyone have experience with methane release from coastal habitats versus carbon dioxide sequestration amounts and its significance?

- **A:** This is an accounting game. For a viable project you need the captured/avoided greenhouse gas emissions to be greater than ongoing emissions, taking into account the greater global warming potential of methane over carbon dioxide. A project in California aiming to rewet wetlands was able to achieve a sequestration rate greater than the rate of methane emissions. HydroFocus is leading a project to complete the verification of over 50,000 tons of carbon dioxide equivalent gases (CO2e) for 1,700 acres of wetlands constructed on agricultural lands in California using the **American Carbon Registry methodology published in 2017**. Here methane emissions from the wetlands are offset by carbon dioxide sequestration and the stopping of baseline carbon dioxide emissions due to the oxidation of organic soils. U.S. Geological Survey researcher Lisa Marie Windham Myers also **published data** showing uptake of nitrous oxide by impounded coastal peatlands in California's Sacramento Delta.

Could you speak a bit about the thawing of permafrost, the huge loss of carbon that would mean and how that can be mitigated?

- **A:** The Kenai Lowlands region where the Kachemak Bay NERR is working is in south-central Alaska, which is a region without permafrost. The loss of carbon from permafrost thawing in more northern regions is a real threat. There are scientists working on ways to mitigate these losses, for example by proactively placing reflective glass beads across the landscape to reduce thermal gain and thawing. In the Kenai Lowlands, where we don't have permafrost, we are concerned about the peatlands drying as the climate warms. We are hopeful that management techniques, such as reintroductions of beavers will help keep peatlands inundated and avoid carbon losses due to drying.

How does carbon sequestration potential of coastal wetlands compare with the potential of forest carbon sequestration? When a state has to prioritize forest project investment versus coastal wetland investments (for maximum carbon sequestration per dollar invested), how do these two compare?

- **A:** In general, it depends on the location. Mangroves tend to be a large carbon store due to their large biomass. Overall, coastal wetlands all capture and store carbon in the soil at a much greater rate than their terrestrial counterparts on a per acre basis.

  In Alaska, we initially looked at coastal salt marshes, but found that they were not storing very much. Peatlands were a much larger store of carbon because they're huge systems (thousands of hectares) composed of stored organic material (meters deep of peat) that has not decomposed thanks to the cold and wet conditions.

  In the Pacific Northwest, the lower you are in the tidal frame, the lower the carbon storage potential is; for example, eelgrass beds store less carbon. Forested tidal wetlands were found to store a great deal of carbon because they were storing it in soil, aboveground biomass, and downed wood on the wetland surface. Forested tidal wetlands in the Pacific Northwest are unique because those wetlands, which are actually low-salinity or freshwater tidal wetlands that emit quite a bit of methane, store enough blue carbon to outpace the methane emissions.

All coastal areas have huge quantities of excess nitrogen, and there is an effort to establish a nitrogen-trading system. Can these two markets be combined or at least addressed in parallel?

- **A:** In theory, yes; these two markets could combine for premium offsets.

Are monitoring efforts of above water (e.g. salt marshes) and adjacent submerged vegetation coordinated? To what degree are these comparable? How relevant are seagrasses in blue carbon market science?

- **A:** Monitoring efforts should include both above and belowground biomass. In some projects, adjacent vegetation may need to be monitored as well, depending on risks of leakage or other unintended effects on surrounding areas. Seagrasses are relevant in that they capture and store carbon in the same way other coastal wetlands do. There is an added challenge to monitoring these habitats but it can be done. The Nature Conservancy is currently piloting our first blue carbon offset project in an eelgrass restoration site in coastal Virginia. We expect our first blue carbon offsets to be generated from this project by the end 2020.

Do you know of any efforts to map the extent of blue carbon across the United States?

- **A:** The Smithsonian Environmental Research Center has a Coastal Carbon Research Coordination Working Group and Blue Carbon Atlas tool where they are collecting blue carbon data from across the United States. As for mapping habitat, it is sorely needed, especially for seagrass habitat extent. Other mapping resources include NOAA's Coastal Change Analysis Program (CCAP), which produces data and maps using the U.S. Fish and Wildlife Service's National Wetlands Inventory data to detect wetlands using satellite imagery.

Education, Policy, and Planning Implications

Are there unintended consequences of companies continuing with "business as usual" by having an opportunity for offsetting their emissions?

- **A:** Yes. Many organizations set up guidelines or requirements concerning what industry partners they will work with, or sell credits to, in order to avoid "green-washing." These guidelines usually prioritize those industries that have created larger greenhouse gas emission reduction plans and have already pursued strategies focused on reducing emissions internally through energy efficiency improvements and renewable energy purchases.

Are there other education plans for middle or high school students?

- **A:** In the Kenai Lowlands, we have explored peatland carbon with Alaska Native students from the village of Tyonek through field trips where the students core peatlands and sample connected streams for juvenile salmon. We are also working on developing education programs for high school math students to calculate peatland volumes for a real-life application of calculus principles.

  Through the BWM project and a related transfer project, the Waquoit Bay Reserve and partners created a blue carbon high school STEM curriculum. This curriculum module, which is linked to the Next Generation Science Standards, introduces many different aspects of the BWM project, science and tools, and provides teaching ideas and activities for sharing it with teachers and students.The Reserve has led several teacher training workshops to share the curriculum and continues to offer workshops on the curriculum today.

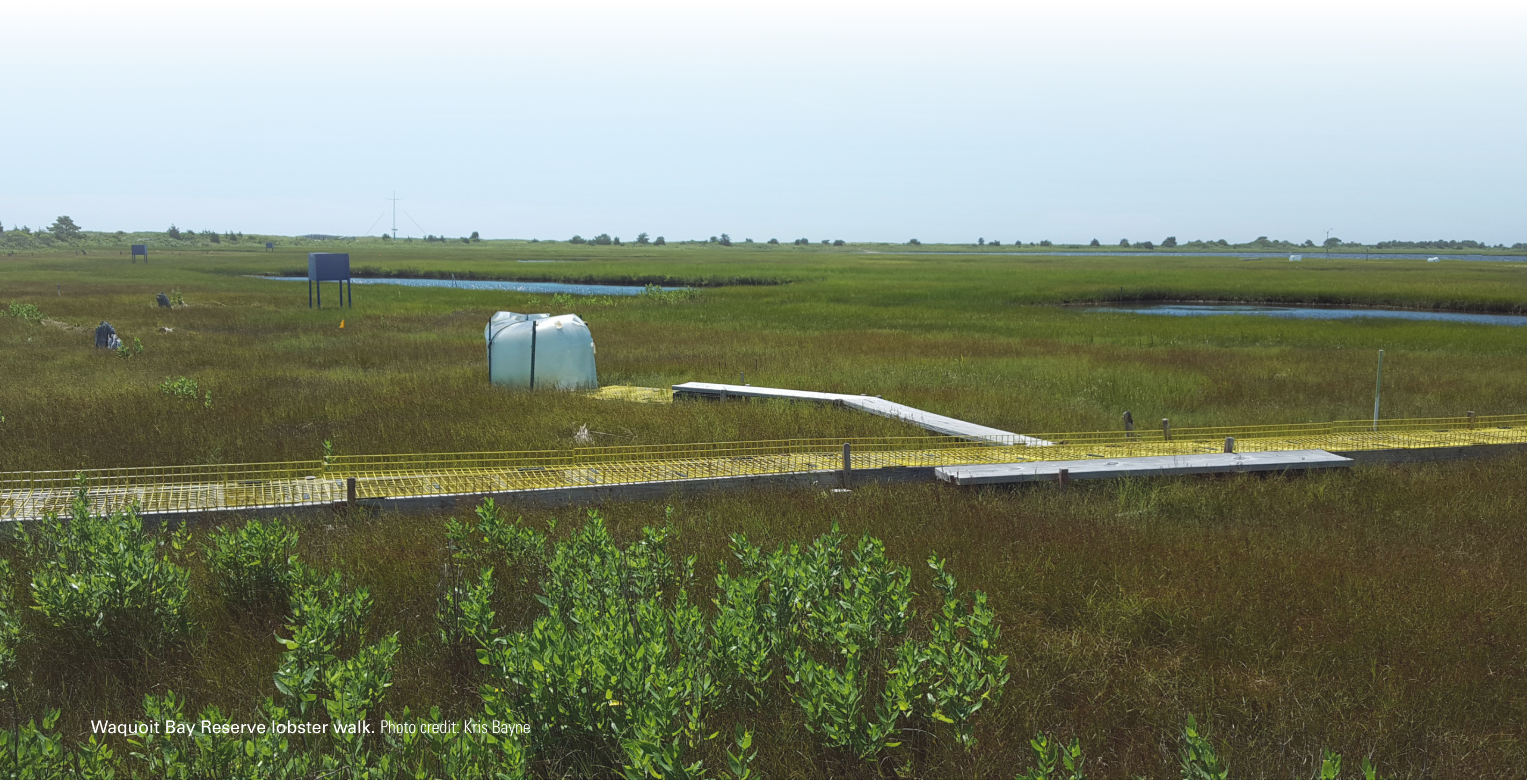
What experience does the panel have with states incorporating blue carbon into climate plans and/or greenhouse gas mitigation goals?

- **A:** In Massachusetts, the Bringing Wetlands to Market project aimed to build awareness around incorporating blue carbon into policy decisions. That engagement with state level stakeholders led to incorporation of language into Massachusetts' climate action plan recognizing the value of wetlands and the climate mitigation benefits they provide by storing carbon. While the language was not very quantitative at that time, in terms of specific greenhouse gas reduction goals, it led to the development of other tools at the state level which further explored the value of wetlands in greenhouse gas mitigation and quantified greenhouse gas emissions of restored aquatic ecosystems. Massachusetts is now going through another update to its greenhouse gas policies, and is integrating and evaluating the role of natural lands (including wetlands and blue carbon) in this process.
- Other bills that have been proposed recently include the **Climate Stewardship Act** introduced September 2019, and the **Blue Carbon for Our Planet Act** introduced January 2020. The **U.S. Climate Alliance** is also working with states to frame larger greenhouse gas reduction goals that include natural climate solutions such as blue carbon.

HIGHLIGHTED PROJECTS

This management brief spotlights the work of seven projects funded by the NERRS Science Collaborative between 2011 and 2018.

PROJECT TITLE	PROJECT LEAD	RESERVE(S), STATE
Bringing Wetlands to Market Phase 1: Nitrogen and Coastal Blue Carbon (2011)	Tonna-Marie Surgeon Rogers, Waquoit Bay NERR tonna-marie.surgeon-rogers@state.ma.us	Waquoit Bay, MA
Bringing Wetlands to Market Phase 2: Expanding Blue Carbon Implementation (2015)	James Rassman, Waquoit Bay NERR james.rassman@state.ma.us Tonna-Marie Surgeon Rogers, Waquoit Bay NERR tonna-marie.surgeon-rogers@state.ma.us	Waquoit Bay, MA
Quantification and Dissemination of Carbon Stocks Data for Pacific Northwest Tidal Wetlands (2016)	Craig Cornu, Institute for Applied Ecology cecornu@gmail.com	Padilla Bay, WA South Slough, OR
Feasibility Planning for Pacific Northwest Blue Carbon Finance Projects (2018)	Craig Cornu, Institute for Applied Ecology cecornu@gmail.com	Padilla Bay, WA South Slough, OR
Establishing a Blue Carbon Network for the Gulf Coast (2015)	Stefanie Simpson, The Nature Conservancy stefanie.simpson@tnc.org	Apalachicola Bay, FL Grand Bay, MS Mission-Aransas, TX Rookery Bay, FL Weeks Bay, AL
Bringing Wetlands to Market on the Gulf Coast (2016)	**Project Lead:** Kelly Dunning, Mission-Aransas NERR kellyhdunning@utexas.edu **Contact:** Jace Tunnell, Mission-Aransas NERR, jace@utexas.edu	Mission-Aransas, TX Waquoit Bay, MA
Assessing Kachemak Bay's Blue Carbon Resources (2017)	Coowe Walker, Kachemak Bay NERR cmwalker9@alaska.edu	Kachemak Bay, AK Waquoit Bay, MA



Waquoit Bay Reserve lobster walk. Photo credit: Kris Bayne

ADDITIONAL RESOURCES

Curriculum	
	Bringing Wetlands to Market Blue Carbon Science Curriculum (Waquoit Bay NERR)
Fact Sheets	
	Capitalizing on Coastal Blue Carbon (Waquoit Bay NERR)
	Coastal Blue Carbon as an Incentive for Coastal Conservation, Restoration and Management: A Template for Understanding Options (Waquoit Bay NERR)
	Valuing Salt Marshes: What We Learned at the Salt Marsh Symposium (Waquoit Bay NERR)
Reports	
	Herring River Carbon Project Feasibility Study (Waquoit Bay NERR)
	Scoping Assessment for Pacific Northwest Blue Carbon Finance Projects (Pacific Northwest Working Group)
	State of the Voluntary Carbon Markets Report 2017 (Forest Trends)
	Wetlands Conservation Finance: Texas Style (Mission-Aransas NERR)
Tools	
	Coastal Blue Carbon in Practice: A Manual for Using the VCS Methodology for Tidal Wetland and Seagrass Restoration (Waquoit Bay NERR)
	Coastal Carbon Atlas (Coastal Carbon Research Coordination Network)
	Coastal Wetland Greenhouse Gas Model (Waquoit Bay NERR)
	Kenai Wetland Maps (Kachemak Bay NERR)
	Natural Capital Rack Card (Mission-Aransas NERR)
	Blue Carbon Research Logic Model (Kachemak Bay NERR)
	Talking Points for Communicating Blue Carbon (Gulf Coast Blue Carbon Network)
Videos	
	Blue Carbon: A story from the Snohomish Estuary (Restore America's Estuaries)
	How we respond: Herring River, MA Wetland Restoration (AAAS)
	"Blue Carbon in Practice" Webinar Series (Restore America's Estuaries)
	The Skinny on Blue Carbon (Mission-Aransas NERR)
	Joint NERRS Science Collaborative Blue Carbon Projects Results Sharing Workshop, Everett, WA (Pacific Northwest Working Group)
	Joint NERRS Science Collaborative Blue Carbon Projects Results Sharing Workshop, Coos Bay, OR (Pacific Northwest Working Group)
Webpages	
	What is Blue Carbon (National Oceanic and Atmospheric Administration)
	Bringing Wetlands to Market (Waquoit Bay NERR)
	Herring River illustrates the value of wetlands in reducing greenhouse gas emissions (AAAS, How We Respond)
	Pacific Northwest Working Group webpage
	Restore America's Estuaries Blue Carbon webpage
	VCS Methodology for Tidal Wetland and Seagrass Restoration (Verified Carbon Standard)