SEA GRANT AT THE BLUE CARBON FRONTIER

INTEGRATING LAW, SCIENCE, COMMUNITY VALUES, AND ECONOMICS

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ABSTRACT. Blue carbon resources (coastal and marine habitats that transform and sequester atmospheric greenhouse gases) are essential for climate change mitigation while providing additive ecosystem services. The accelerating interest of businesses in blue carbon offsets has unveiled a new and potentially significant mechanism for financing coastal restoration and other projects. This highly interdisciplinary field is rapidly advancing, yet researchers, resource managers, investors, regulators, and decision-makers need to understand the limitations, uncertainties, and potential for public-private investments in blue carbon systems. We provide an overview of the coastal blue carbon landscape, including the state of scientific understanding of blue carbon resources, the emergence and significance of blue carbon markets, state and federal policy needs and trends, and necessary steps for continued development. This article is informed by the proceedings of the 2023 Blue Carbon Law Symposium (Athens, Georgia), which gathered researchers, legal scholars, business leaders, community stakeholders, policymakers, and others to discuss this emerging field with a focus on law and policy connections and needs.

BRINGING CARBON INTO BALANCE: THE ROLE OF COASTAL ECOSYSTEMS

Mitigating the causes and effects of global climate change requires a portfolio of options that include technological and nature-based solutions. The most recent Intergovernmental Panel on Climate Change states that limiting global average temperature rise to 1.5°C by 2100 will require 380 to 1,000 billion metric tons (or gigatons, Gt) of carbon dioxide (CO_2) removal from the atmosphere (IPCC, 2018; Pathak et al., 2022). Marine systems, both biotic and abiotic, will play a major role in this endeavor: Approximately 93% of the global carbon cycle is contained in the ocean (Feely et al., 2001), and since the industrial era, the ocean has absorbed an equivalent of 39% of anthropogenic carbon emissions, or approximately 500 Gt CO_2 (IPCC, 2005; McKinley et al., 2020). Within the marine carbon cycle, the sliver of productive coastal habitats is paramount: in their meta-study of carbon storage in coastal wetlands, Byun et al. (2019) concluded that "the coastal ecosystem stores more carbon in soil per unit area than any other environment."

Coastal ecosystems, defined here as subtidal, intertidal, and tidally influenced freshwater systems, are integral to the oceanic transfer and storage of carbon and, importantly, to human lives and well-being. Examples of these systems include coastal peatlands and forests, tidally influenced freshwater forested wetlands, salt flat microbial mats, salt marshes, seagrass meadows, kelp and seaweed beds, and mangrove wetlands. Nearly 50% of the world's population lives within 200 km of a coastline, with continuing and rapid expansion (Creel, 2003). Thus, the multitude of coastal ecosystem services to humans, including storm protection, water quality, fisheries production, and economic security, is both highly significant and at high risk of loss or degradation. A global estimate of potential coastal ecosystem rehabilitation and conservation determined that ~3% of greenhouse gas emissions can be mitigated annually (approximately 300 Tg per year; Macreadie et al., 2021). While not a silver bullet for total climate change reversal, the combined benefit of coastal ecosystem services with greenhouse gas sequestration (described here as coastal blue carbon) is worthy of a concerted and holistic effort.

Envisioning and operationalizing a future of blue carbon governance requires a multi-faceted approach centered on up-to-date research, transparent monitoring and reporting, inter-sector and multi-jurisdictional relationships, and community integration for equitable outcomes (Figure 1). Given these needs, national and state Sea Grant programs are positioned to serve an integral role in the development and execution of blue carbon research, education, and implementation.

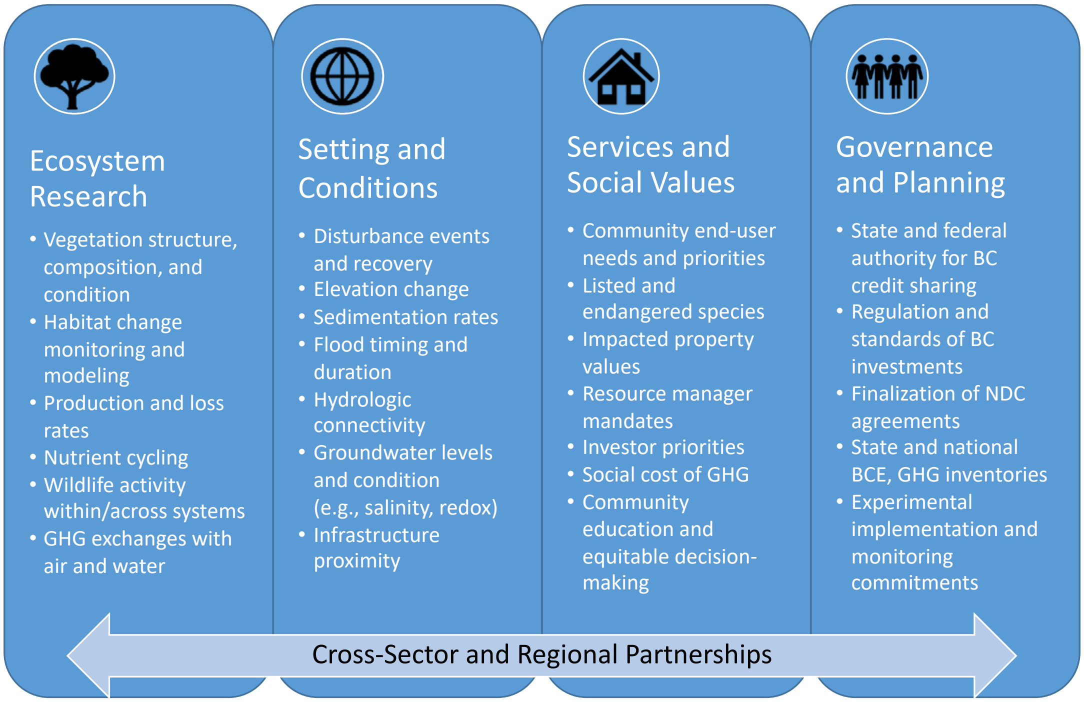

FIGURE 1. Research needs and policy actions listed here spanning natural and social science, community participation, and governance are essential to the continued development of blue carbon ecosystem (BCE) conservation and restoration as a mechanism to enhance coastal and community resilience and mitigate greenhouse gas (GHG) contributions in the United States. The roles of nationally determined contributions (NDC) are described in the Governance section.

DEFINING BLUE CARBON

Blue carbon is the total amount of carbon that has been sequestered from the atmosphere or water through biologically and physically mediated processes of marine, coastal, and tidally influenced ecosystems and stored for a long period (at least 100 years, preferably on millennial timeframes) in either an organic or inorganic state. The term became widely used in 2009 following reports done for the United Nations Environment Program (Nellemann et al., 2009) and the International Union for Conservation of Nature (Laffoley et al., 2009) in an effort to focus on the ecosystem services provided through conservation and rehabilitation of coastal and marine systems (Lovelock and Duarte 2019).

Many public-facing information sources (e.g., Blue Carbon Initiative, 2019; NOAA National Ocean Service, n.d.) discuss blue carbon ecosystems (BCEs) by ecosystem type (i.e., salt marshes, seagrass meadows, and mangrove wetlands). We caution against defining blue carbon by ecosystem type for a few reasons. First, many of these systems are transient and adaptive to changing conditions (e.g., hurricanes, sea level rise), yet buried carbon storage may or may not be altered with changes of habitat type. Second, similar ecosystem types can have different carbon flux directions and rates depending on regions and timeframes. For example, mangrove wetlands store more carbon with maturity (Dontis et al., 2020; Figure 2), and oyster reefs may be carbon sinks or sources depending on geographic and environmental settings (Fodrie et al., 2017). Third, the purpose of blue carbon efforts is to apply management strategies (conservation, rehabilitation, and/or restoration) that maximize carbon sequestration in concert with other important ecosystem services; a system that cannot be actively managed or conserved is therefore not applicable.

FIGURE 2. Productive coastal ecosystems such as this tidal marsh-forest habitat on Wadmalaw Island, South Carolina, produce and trap organic material and sediments that can become buried over the long term, with a net ecosystem balance of carbon storage. *Photo credit: Thierry Dehove/Shutterstock*

THE STATE OF COASTAL BLUE CARBON RESEARCH

Coastal BCE research spanning natural and social sciences has grown exponentially over the past decade,[1] with recent focus on the application of new technologies and integration across spatial and temporal scales (Macreadie et al., 2019; Maurya et al., 2021). Empirical values of carbon stock and storage rates and associated drivers have been globally reported for coastal BCEs, including for mangroves (Sasmito et al., 2020), salt marshes (Macreadie et al., 2013), tidal freshwater forested wetlands (Krauss et al., 2018), macroalgae (Krause-Jensen et al., 2018), and seagrass systems (Colarusso et al., 2023).

Sea Grant programs contribute to the development of coastal BCE research and education across the country (see https://seagrant.noaa.gov/blue-carbon/). For example, MIT Sea Grant staff directly contributed to seagrass carbon storage research for New England habitats (Novak et al., 2020; Lei et al., 2023; Colarusso et al., 2023) and developed a community education program; New York Sea Grant is funding a program to document local eelgrass carbon storage (Lane Smith, New York Sea Grant Research Program Coordinator, *pers. comm.*, 2024); Pennsylvania Sea Grant recently funded external researchers investigating the role of invasive *Phragmites australis* on salt marsh blue carbon storage (Sean Rafferty, Pennsylvania Sea Grant College Research Director, *pers. comm.*, 2024); and Oregon Sea Grant contributed to a report on the state of the science of blue carbon ecosystems in the Pacific Northwest (Lyle et al., 2022).

Several regional and national collectives have been organized to cross-link blue carbon data and outreach. The National Estuarine Research Reserve System's Science Collaborative has supported BCE research and education across the country (see https://nerrssciencecollaborative.org/resource/collection-blue-carbon). The Coastal Carbon Atlas, managed by the Smithsonian Environmental Research Center's Coastal Carbon Network (CCN; https://serc.si.edu/coastalcarbon) provides a valuable compilation of soil carbon storage data for cross-regional comparisons, as well as an indicator of regions in the United States (e.g., mid to southern Atlantic) where carbon storage data are limited (Holmquist et al., 2021). We recommend that all carbon storage data be shared with the CCN to increase credibility and accuracy of carbon storage values.

While the studies and databases noted above provide significant insight on the variability and drivers of coastal carbon storage, what is needed now is actual implementation of coastal BCE projects within the United States to test and observe the effect of management strategies for both natural system and socio-ecological outcomes. Incorporation of blue carbon feasibility assessments and post-project monitoring with ongoing nature-based solution efforts would escalate on-the-ground knowledge of best practices. As the field of BCE advancement nears implementation phase, it remains critical to involve social, governance, and economic sciences in the United States (see Hagger et al., 2020, and Friess et al., 2022, for international perspectives).

BLUE CARBON GOVERNANCE

International Frameworks

Nature-based Solutions (NbS) have been included as an option for mitigating climate change drivers and effects since the initiation of international climate governance over 30 years ago. The Paris Agreement of 2016 replaced binding emissions reduction commitments with a voluntary framework centered on Nationally Determined Contributions (NDCs), nationally appropriate actions to mitigate against and adapt to climate change (Article 4.2 Paris Agreement, 2016; Carlarne, 2023). Some countries have included coastal ecosystem NbS in their NDCs in terms of mitigation and/or adaptation potential (Herr, 2016; Dencer-Brown et al., 2022), though explicit mention of BCEs and concrete targets for use remain limited (Dencer-Brown et al., 2022; Hamilton et al., 2023). There appears to be considerable opportunity for greater inclusion of BCEs into many more NDCs (Dencer-Brown et al., 2022; Hamilton et al., 2023). Such inclusion could prompt nations to adopt domestic strategies for conserving and restoring BCE resources.

A forthcoming driver of BCE projects may be the international voluntary carbon market (described below) provided for in Article 6 of the Paris Agreement (Article 6.4 Paris Agreement, 2016; Carlarne, 2023). Much of the "rulebook" for this market was resolved by agreements in Glasgow in 2021 and in Sharm al-Shiek in 2022 (Carlarne, 2023; Orford, 2023). The global analysis by Bertram et al. (2021), examining the contribution to and redistribution of "blue carbon wealth" by individual countries, may shed light on how this carbon market will perform for blue carbon (Bertram et al., 2021).

US Actions – Federal and State

In the absence of legislation to place primary responsibility for BCE research and policy within any particular agency, most BCE work at the federal level is conducted ad hoc by individual agencies and line offices and has largely consisted of research and technology transfer (e.g., Brodeur et al., 2022). The Biden-Harris Administration's 2023 Ocean Climate Action Plan (OCAP) is the most comprehensive federal policy to date: it identifies conservation and restoration of BCE as a major NbS to address the climate crisis, details six federal actions, and identifies responsible agencies and timelines (Ocean Policy Committee, 2023). Commentators also recommend

[1] A Web of Science citation search for "coastal blue carbon" showed 13 publications in 2012 compared with 233 in 2022, nearly an 18-fold increase over the past decade.

incorporation of BCE into legislation (e.g., RAE, 2022). There is currently no federal BCE law in the United States focused on the carbon storage potential of these systems, though there are numerous statutes and associated regulations that concern the protection and management of coastal wetlands and waters for other purposes (Orford, 2023). Beginning in 2019, several federal legislative proposals concerning BCE have been considered, but none have been adopted (Orford, 2023).

Interest in BCE's climate change mitigation potential and opportunities offered by offset markets have generated activity in some states. In the Pacific Northwest, states and other partners formed the Pacific Blue Carbon Working Group in 2014 to collaboratively fill data gaps for the region's BCE. In North Carolina, BCEs were incorporated into the state's Climate Risk Assessment and Resilience Plan in 2020, supported by BCE mapping conducted by Duke University's Nicholas Institute for Energy, Environment and Sustainability. Virginia, Maryland, Delaware, New Jersey, and New York also worked with the Nicholas Institute to map their BCE resources. Virginia recently adopted targeted statutory amendments to clarify the state's ability to conduct BCE offset projects in state waters and designate responsible state agencies and revenue uses (Va. Code §10.1-1186.6, 2020), prompted by a seagrass restoration project that is the first in the nation to be registered (Stefanie Simpson and Nikki Rovner, The Nature Conservancy, *pers. comm.*, 2023, Blue Carbon Law Symposium). Such legislation may be necessary in states where BCE offset projects are in state waters, as they raise challenging legal questions concerning state authorities and property rights, among other things (Porter, 2020). Other states are integrating the financial values of coastal carbon sequestration into coastal plans. Alaska's governor has encouraged legislative action to capitalize on carbon markets in coastal systems, and Texas has begun calculating the carbon sequestration of its coastal conservation and restoration programs (Orford, 2023). Louisiana has perhaps the most ambitious agenda concerning BCE: it has adopted legislation clarifying the legal status of carbon sequestration activities in terms of property rights (La. R.S. 9:1103, 2010, 2016), and is considering creation of a Louisiana-specific BCE methodology (Terrell, 2023).

CARBON VALUATION AND THE ROLE OF VOLUNTARY MARKETS

Valuation of carbon as a greenhouse gas includes a "social cost" of climate change impacts to local and global human well-being and economies, including long-term impacts of flood risk and changes in energy use needs (EPA, 2017). Bertram et al. (2021) determined that global blue carbon wealth amounts to the order of US$200 billion per year. The United States has one of the largest country-specific social costs of carbon and with that, one of three "highest potential" countries for blue carbon sequestration gains in terms of economic value (Bertram et al., 2021). An approach to directly link financial value of BCEs is the voluntary market to encourage private investments into BCEs.

Voluntary Blue Carbon Crediting and Markets

Under the context of blue carbon crediting, a "project" is a set of management actions to measurably enhance carbon storage in a BCE. Examples include:

- Conservation of BCEs at imminent risk of loss (e.g., conservation easements)
- Implementation of erosion control and/or sediment distribution to avoid coastal wetland loss (e.g., thin-layer sediment placement)
- Improving conditions for enhanced seagrass and/or macroalgae growth
- Creating new migratory space within formerly developed or drained areas for intertidal wetland expansion

The concept behind carbon credits was modeled on previous market-based approaches created in the 1990s to reduce air pollutants (i.e., the Montreal Protocol cap-and-trade system for ozone-depleting compounds, and the Clean Air Act credit-trading system for sulfur dioxide pollution) and influenced by international framework guidelines that developed greenhouse gas reduction commitments (e.g., REDD+ and associated mechanisms). As the name attests, voluntary credits position organizations and entities to demonstrate their environmental commitment and/or to pledge "net zero" greenhouse gas emissions through the purchase of carbon credits.

Accounting protocols for BCE projects were developed in the early 2000s and continue to be updated. The Voluntary Carbon Standard (VCS) program, administered by the nonprofit Verra, was first published in 2006 and updated with ISO standards in 2007 (Verra, 2023). Standardized methods were created under this protocol to (1) determine baseline (no-project) estimates of greenhouse gas sources, sinks, and storage, (2) demonstrate a project's additionality and permanence (see definitions below), and (3) define monitoring strategy to demonstrate measurable outcomes. Voluntary Carbon Units (VCUs) were defined as the removal of one ton of CO_2e. To receive credits, a carbon offset project must meet three fundamental tests:

Additionality

Demonstration that the amount of carbon stored under project implementation (e.g., conservation or restoration) would not have occurred if the project had not taken place, to be validated and verified by a third party. For example, planting mangrove seedlings following a hurricane would not be considered additional if the system is likely to recover on its own, and "leakage" or lateral flow of carbon from outside of the project area must be assessed so that the documented carbon gains are solely due to the project.

Permanence

Demonstration (through modeling) of the likelihood that the carbon will remain stored within the system for at least 100 years. For example, BCEs in hurricane-prone areas are more likely to be damaged or eroded; an additional "buffer fund" may be created to mitigate such potential impacts.

> "For-profit conservation models come with risks such as greenwashing and neo-colonialism. All blue carbon stakeholders must operate to high ethical standards, by following proposed codes of conduct that promote fair, just and equitable marine conservation to overcome some of these social barriers." *– Friess et al., 2022*

Accuracy

A project must have sufficient pre-project data to verify the amount of carbon stored under "baseline" (non-project) conditions, and a robust and defendable monitoring plan to verify additional carbon storage. Standardized monitoring and calculation protocols for BCEs under the VCS program are termed "VM0033" and published at: https://verra.org/methodologies/vm0033-methodology-for-tidal-wetland-and-seagrass-restoration-v2-1/.

In addition to these three tests, project managers must also ensure that the carbon storage has not been "double-counted" through another accounting system, that the project is not mandated by law (e.g., compensatory mitigation), and that the work does not create social or environmental harm.

Community Engagement and Equity

The commodification of natural resources sets the conditions for potential inequitable access and control. Given the strong interest from within the private sector for BCE project development (Friess et al., 2022), there is an imperative to link community education and leadership with BCE project accreditation and value. To this end, the development of "high quality" blue carbon principles was proposed by a consortium of international organizations (Conservation International, 2023). It includes a framework for holistic ecosystem management, adaptive strategies, accounting and monitoring practices, and community empowerment for educated and comprehensive decision-making. As demonstrated by the 2023 Blue Carbon Law Symposium, Sea Grant programs and partners are in a position to translate internationally developed recommendations and frameworks into local- or regional-scale, stakeholder-centered implementation.

HIGHLIGHTS FROM THE BLUE CARBON LAW SYMPOSIUM

The first Blue Carbon Law Symposium (https://www.scseagrant.org/blue-carbon-law-symposium/), co-hosted in 2023 by South Carolina and Georgia Sea Grant programs, the National Sea Grant Law Center, and the University of Georgia's Carl Vinson Institute of Government and School of Law, brought together over 100 representatives in BCE science, policy, implementation, and community engagement to discuss opportunities and challenges to implement blue carbon projects (Figure 3). An associated special issue of the *Sea Grant Law & Policy Journal* can be found online at https://nsglc.olemiss.edu/sglpj/vol13no1/sglpj13.1.pdf. Here, we highlight a few important takeaways from the event for US state and federal policymaking as well as opportunities for increased Sea Grant program participation:

1. Federal agencies have focused on BCE for decades, albeit through lenses other than carbon sequestration. A recurring theme was the need for legislation tasking a federal agency with primary responsibility for overseeing BCE research and policy development through a carbon sequestration lens. Such a leader could coordinate US efforts across agencies, supporting the "all of government" approach advocated by BCE practitioners (RAE, 2022).

2. Coastal resource agencies and BCE practitioners need state-level legal analyses concerning the development of BCE offset projects in state waters. Legislation is likely warranted in many states, in one or more of the following areas: (1) clarification that carbon market activities are consistent with land management mandates, (2) authorization for agencies to enroll land in markets and sell credits, (3) authorization to enter into contracts or agreements to enter carbon markets, (4) delineation of ownership of carbon rights on public lands, (5) authorization for agencies to acquire carbon easements on private lands, (6) direction for use of funds from projects, (7) authorization of long-term lease or sale of rights and credits, and (8) requirements for continued management or maintenance of projects needed to prevent reversal (i.e., a change in a project from a sink to a source).

FIGURE 3. In-person participants of the 2023 Blue Carbon Law Symposium, University of Georgia, Athens, Georgia. *Photo credit*: *Shannah Montgomery, UGA*

3. States may have varying legal regimes and goals for BCE conservation and rehabilitation within their borders, but even with these differences, many concepts are translatable, and states should look to each other for ideas and guidance. For example, Louisiana, as the country's only civil law state, has very specific restoration and fiscal goals for its BCE resources, but its experiences engaging in restoration projects, working with private landowners, establishing ownership of carbon credits, and working towards developing its own BCE methodology could be instructive for other coastal states.

4. Integration of federal, state, and tribal policies for BCE programs must demonstrate equitable private-public partnerships and ensure that carbon sequestration is maintained in concert with (and at times in deference to) other critical ecosystem services that support human well-being, identity, and safety.

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