

A Report
from the Coastal & Marine Working Group
of the Maine Climate Council

5 June 2020



June 5, 2020

Hannah Pingree and Jerry Reid, Co-Chairs, Maine Climate Council:

Thank you for the opportunity to be a part of the Maine Climate Council. In fulfillment of the charge provided to us, the 38-member Coastal and Marine Working Group (CMWG) respectfully submits the attached report.

The report includes a summary of the six strategies identified by the CMWG to meet the Council's mission of mitigating and adapting to climate change, as well as detailed strategy templates. These recommendations respond to pressing needs identified by CMWG members and the people who engaged in our deliberations over the last nine months; will assist in Maine's transition to a clean economy; will help our marine-dependent businesses prosper; and have co-benefits for recreation, tourism, health and well-being. We believe these recommendations are actionable and feasible if properly resourced and will support vulnerable coastal communities and economic sectors.

The CMWG members conducted informal and formal outreach to marine and coastal stakeholders. Our work was also enriched by the contributions of members of the public who observed our meetings and provided comments, and those who responded to the CMWG survey in May 2020. However, effective engagement has been challenging given the COVID-19 pandemic and the many competing demands on coastal and marine constituents' time and attention. We strongly recommend that the Council conduct additional outreach and dialogue with stakeholders to inform the next stages of this work.

Finally, while state leadership and funding are integral to the success of many of these recommendations, some strategies can likely be advanced in the short term through partnerships. Others can be implemented in the short term but require legislative guidance. Further outreach, development of ideas, implementation of strategies, and launching of pilot projects will require additional funding for state agencies, municipalities, universities/colleges and non-governmental partners.

We thank you for the opportunity to lead this important conversation and we look forward to interacting with the MCC as you consider our recommendations.

Sincerely,

Heather Leslie, University of Maine
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Kathleen Leyden, ME Dept of Marine Resources
Maine Coastal Program

A REPORT FROM THE COASTAL AND MARINE WORKING GROUP
MAINE CLIMATE COUNCIL

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I. Introduction

In late summer 2019, the Governor's Office of Policy Innovation and the Future assembled the 38-member Coastal and Marine Working Group (CMWG), drawing on a variety of disciplines and organizations. The CMWG membership list is attached in Appendix B. The group convened in August 2019 and met 10 times as a full group. Initial sessions focused on mutual learning through expert presentations, and identification of broad issue areas to be further considered by subcommittees. Six subcommittees were formed and met countless numbers of times to refine the material for consideration by the full CMWG and then presented in this report to the MCC.

The CMWG focused primarily on coastal and marine natural resources and not on the built environment, with the exception of Working Waterfronts. We acknowledge overlaps with other MCC Working Groups (particularly Community Resilience, Transportation, and Energy) and look forward to additional collaboration to reinforce complementary strategies and form potential joint recommendations.

Members of the CMWG conducted formal and informal outreach to stakeholder groups and conducted a survey to gain feedback on its strategies, but effective engagement became limited in early March 2020 due to the COVID-19 public health emergency. A summary of the CMWG survey results is attached as Appendix C and outreach efforts are listed in Appendix D.

II. Caveats

The following caveats describe the limitations of the Coastal and Marine Working Group's effort and how the information in the report should be interpreted and used. This context is critical as the Climate Council reviews the material in this report.

1. The COVID-19 pandemic has heavily affected marine and coast-dependent businesses and will affect the future fabric of Maine's coastal and marine economy in the short and long term. Likewise, the ability of some Working Group members to participate fully and the ability to involve stakeholders and the interested public in our work was constrained. Much more engagement with those who make their living on the water and engagement with coastal municipalities is critical and needs more attention in future phases of the MCC process. CMWG strategies should be considered draft until further vetted with stakeholders and will need to be adapted in light of this reality.

2. The CMWG operated with no additional financial resources and relied on in-kind contributions of staffing from working group members. Our timeframe was limited, and the group relied on existing information.

3. Rough estimates of the costs to implement our recommended strategies have been provided in most of the detailed strategy templates; however, the CMWG did not prioritize strategies based on financial constraints.

4. Several strategies in the package call for new and enhanced work on the part of state agencies. Agencies would require additional staffing, financial resources and legislative guidance to complete this work. Likewise, other organizations (universities and colleges,

non-governmental organizations, municipalities and citizen groups) are potentially ready to help implement the recommendations and will also need increased and new sources of funding.

5. We acknowledge gaps in expertise that limited our ability to analyze certain issues such as equity. CMWG looks forward to assistance from the Governor's Office of Policy Innovation and the Future to more fully examine equity issues.

III. Summary Strategies Recommended by the Coastal and Marine Working Group

The Coastal and Marine Working Group recognizes that decisions about our climate future must rely on sound science that is accessible, credible and relevant to climate-related actions. Of the six strategies summarized below, Strategies 1 and 2 (a state-coordinated monitoring network and two related technical assistance and outreach networks, respectively) are foundational to the other four strategies. In all six strategies, we anticipate close and reciprocal connections between climate-related science and climate-related action.

Strategy 1 - Track coastal and ocean climate impacts to support adaptive decision making.

Establish a state-level strategy and coordinating body (the "Climate Collaborative for Coastal and Ocean Monitoring" or C2COM) to support adaptive decision making in the public and private sectors by collecting, assessing, and disseminating data and information on how climate change is affecting Maine's coastal and marine areas.

Actions:

1. ***Leverage existing private, nonprofit and state monitoring programs*** via sustainable state funding, shared data infrastructure and coordinated leadership. State agencies include (*inter alia)* the Maine Departments of: Environmental Protection; Marine Resources; Inland Fisheries and Wildlife; and the Department of Agriculture, Conservation and Forestry.
2. ***Expand monitoring of coastal water quality***, including nutrients, and acidification to provide actionable information on water quality risks statewide.
3. ***Characterize, map, and track marine and coastal habitats and species***, including economically important and at-risk species.
4. ***Enhance invasive species monitoring and management***.
5. ***Improve tracking of economic and social conditions*** in Maine's coastal communities.
6. ***Enhance and coordinate tracking and modeling of future changes*** to the extent of intertidal habitats and beaches including tidal marshes, mudflats, dunes, and beaches as well as to subtidal habitats, including their flora and fauna.
7. ***Develop and implement a coordinated funding strategy*** that leverages federal, state, foundation, and private sources towards an integrated monitoring system.

<u>Strategy 2</u> - Provide technical assistance on and outreach networks for climate adaptation and mitigation to coastal and marine stakeholders.

Maine's coastal and marine stakeholders want climate information that is relevant to their needs - their communities, their economies, and their natural resources. While some climate information and decision-support tools exist, they can be hard to access or easily use for mitigation and adaptation projects in Maine's coastal and marine areas. As they confront the opportunities and challenges of climate change, climate-related impacts, and the transition to a low-carbon economy, Maine's coastal and marine resource managers, communities, fisheries, aquaculturists, businesses, and residents will benefit from tailored technical assistance and networks to guide effective mitigation and adaptation strategies and create opportunities to share innovations.

<u>Actions</u>**:**

1. Create a ***Coastal and Marine Information Exchange*** to provide accessible, relevant informational and decision support to facilitate climate mitigation and adaptation in Maine's coastal communities and industries. The *Coastal and Marine Information Exchange* in coordination with the *Climate Collaborative for Coastal and Ocean Monitoring* and the *Maine Seafood Business Council* will help support and accelerate mitigation and adaptation actions by coastal and marine stakeholders and improve integration of environmental, economic, and social data to advance understanding of the consequences of climate change and the effectiveness and impacts of mitigation and adaptation strategies in coastal and marine areas.
   - *Engagement*: Develop and implement an effective engagement strategy with coastal and marine stakeholders to identify and address priority climate information needs;
   - *Information Development & Dissemination*: Develop relevant and accessible data, scientific information, and decision-support resources; and create an exchange-infrastructure to disseminate these resources (e.g., web/digital platform, outreach and peer networks, partnerships);
   - *Decision-support*: Increase the development and use of tailored coastal/marine mitigation and adaptation decision-support tools based on stakeholder feedback, improved access to and synthesis of information and monitoring data, and partnership networks with tool developers, outreach professionals, and stakeholders; and
   - *Exchange and Assessment*: Engage with coastal and marine monitoring, stakeholder, manager, and research groups to maintain relevant, useable, and accurate climate information and assess the effectiveness and impacts of mitigation and adaptation strategies in coastal and marine areas. Share and get feedback on Exchange information resources via targeted events for different marine and coastal stakeholders and policy briefings for policy makers.

2. Establish a ***Maine Seafood Business Council*** to provide Maine's seafood harvesters, shoreside businesses, and working waterfronts with access to information and tools that can support operational decisions, capital investments, and long-range planning to implement climate adaptation and mitigation strategies.

- *Information Exchange*: Establish effective means for two-way communication with businesses; and assemble pertinent information from the *Maine Coastal and Marine Information Exchange* for each sector;
- *Business Planning*: Conduct analyses of existing and emerging markets to identify trends and opportunities for growth; and assess existing infrastructure, infrastructure needs, and potential synergies and opportunities that align with future business directions and link to programs that support business improvements (e.g. efficiency and renewable programs);
- *Technical Assistance*: Gather and organize information about business financing for startup, growth, mitigation and adaptation projects; and support implementation of pilot adaptation and mitigation projects in seafood businesses;
- *Communication*: Provide information in forms that are easily accessible to and usable by businesses in the seafood sector; and advise government entities on the needs of marine businesses as they attempt to implement mitigation or adaptation measures.

<u>Strategy 3</u> – Enhance mitigation by conserving and restoring coastal habitats that naturally store carbon (blue carbon optimization).

"Coastal Blue Carbon" is a term that refers to the carbon that is sequestered by coastal ecosystems like salt marshes, seaweeds, and seagrass beds. Healthy coastal and marine areas provide vital benefits to the community, ecosystem, and economy, while performing long term carbon storage and sequestration of greenhouse gases (GHGs) and ameliorating coastal acidification. Essential strategy components include inventorying Maine's blue carbon resources to inform baseline estimates of current storage and sequestration, tracking changes in sequestration/emissions over time, and increasing conservation and restoration of coastal ecosystems to optimize carbon burial and obtain climate mitigation benefits.

<u>Actions</u>:

Determine blue carbon stocks and mitigation values by:

1. Conducting a comprehensive, coast-wide inventory of coastal blue carbon resources* to inform baseline estimates of current storage and sequestration. Track changes in sequestration/emissions over time.
2. Determining the role that strategic management of seaweed aquaculture plays in long term carbon burial and in locally reducing coastal acidification impacts.
3. Encouraging blue carbon habitat conservation and restoration through formal carbon sequestration incentives or carbon permit program.

Blue carbon mitigation potential must be achieved by conserving and restoring:

4. *Tidal marshes*: Identifying priorities to secure greenhouse gas stores from tidal marshes through restoration of currently degraded marshes including restoring tidal flow where possible and conservation of current marshes and migration pathways.
5. *Eelgrass:* Protect current eelgrass and historically-mapped eelgrass habitat from direct and indirect impacts of shoreline development, commercial harvesting activities, and aquaculture operations through informed lease siting and by enhancing local and state

regulations to restrict fishing methods and reduce impacts. Restore eelgrass by improving water quality and promoting transplanting and/or seeding.

6. *Seaweed:* Manage the harvest of subtidal and intertidal species of seaweed through the DMR and use aquaculture techniques to restore kelp.

<u>Strategy 4</u> - Promote climate-adaptive ecosystem planning and management using nature-based solutions

This ecosystem-based adaptation strategy identifies actions that leverage a range of tools (regulatory, voluntary, incentive-based, best management practice) that promote coastal community and ecosystem resiliency through adapting to changing environmental conditions, harnessing our natural resources, and protecting jobs, infrastructure and biodiversity.

<u>Actions</u>:

1. ***Foster climate-adaptive planning*** in marine, coastal, and inland areas for the State and municipalities. Support use of the latest monitoring and assessment information related to climate change and resiliency in coastal areas for land use planning by municipalities and regional Councils of Government. Outreach efforts need to be coordinated across federal, state, and regional programs by a central entity to make information and technical assistance more widely accessible for planners, regulators, landowners, and resource managers.
2. ***Promote nature-based solutions*** (NBS, also known as natural infrastructure or green infrastructure) for climate change related challenges that impact non-tidal and coastal rivers, shorelines, and coastal and marine habitats. NBS foster the value of Maine's natural resources, and proactively mitigate risk for the state's citizens and infrastructure often with less expense. This includes the use of green infrastructure for stormwater management, increased buffering to wetlands and waterways, and "Living Shorelines" (LS) to address coastal erosion issues.
3. ***Conserve and restore ecosystems to foster resiliency.*** Protect ecosystems and restore degraded habitats to benefit biodiversity, rare species, and species most vulnerable to climate change using a variety of tools including voluntary, management, incentive-based, or regulatory.
4. ***Restore hydrological connectivity*** in coastal watershed freshwater streams and tidal systems: Use climate-adaptive upgrades to road crossing infrastructure to improve our climate adaptation and benefit communities, habitats, fish, and other aquatic animal life.
5. ***Protect and restore beaches and sand dunes*** in order to help coastal marshes, beaches and dunes migrate inland with sea level rise and continue to support both biodiversity and community resilience. Consider the use of selective or proactive beach nourishment to help manage coastal erosion while also protecting crucial habitat for rare species.
6. ***Characterize and map marine and coastal habitats*** to inform climate adaptive management, planning, and conservation and restoration priorities.
7. ***Strengthen stormwater management*** tools to reduce nitrogen and pollutant inputs which harm marine life, lead to coastal acidification, and negatively impact shellfish harvesting and aquaculture. Enforce and strengthen land-based stormwater management tools to improve the quality of stormwater runoff and the receiving water downstream.

8. ***Recalibrate and strengthen protections of inland natural resources*** to detain storm flows and recharge groundwater, decrease nitrogen pollution of nearshore waters, reduce flood risks, protect aquifers, and maintain habitat connectivity and climate refugia. Review and reframe regulations as climate-adaptive protection of natural resources, based on current climate projections and Maine monitoring data.

9. ***Improve other regulatory approaches*** to protect coastal areas from development that will impede marsh migration, impact water quality, and directly or indirectly affect the function and viability of coastal habitats.

<u>Strategy 5</u> - Manage for resiliency of Maine's marine fisheries and aquaculture industries in the context of climate change adaptation.

This strategy delineates ways to strengthen fishery management to ensure sustainable fisheries and new opportunities as fisheries adapt to climate change. Further, it highlights market support and business resilience needs, as well as regulatory and policy objectives that are necessary to enable Maine's fisheries and aquaculture operations to remain reliable economic contributors as they adapt to climate change. This strategy relies on and complements the Maine Information Exchange *and* Maine Seafood Business Council *strategies emerging from the Coastal and Marine Working Group.*

<u>Actions</u>*:*

Information support

1. ***Enhance and provide sustainable funding for marine resource monitoring programs*** to better detect changes in ecosystem conditions, including the composition and distribution of species and habitats along Maine's coast, as well as socio-economic conditions related to fisheries and aquaculture.

2. ***Develop stock assessments, ecosystem-based management approaches, risk policies, and harvest strategies that account for ecosystem changes***, including shifts in species-environment relationships and in productivity and distribution of species along the coast.

3. ***Implement forecasts for key environmental parameters at spatial and temporal scales*** that are relevant to business planning, operations, and management of Maine's fisheries and aquaculture sectors.

Market support and business resilience

4. ***Evaluate and implement ways to expand local and direct marketing opportunities*** for sustainably produced Maine seafood.

5. ***Support the growing aquaculture sector*** as a means to increase Maine seafood production, provide important economic opportunities for coastal communities, and harness potential acidification mitigation and other environmental services.

6. ***Develop technical assistance, financing tools, and policy strategies*** to help fishing and aquaculture businesses plan for and transition activities in a changing ocean ecosystem. (See Strategy 4.2 – Maine Seafood Business Council)

Regulatory and Policy

7. ***Evaluate and implement ways in which Maine's fishery and aquaculture laws and regulations can provide the opportunity to address environmental change and emerging fisheries*** while recognizing the need for regulatory stability.

Strategy 6 - Climate-Ready Working Waterfronts

Maine's coastal and marine economy, and the cultural and economic identity of its coastal communities, depends in large part on thriving ports and working waterfronts (WWFs) - small and large, public and private. These facilities provide access and associated facilities for our commercial fishing fleets and aquaculturists, recreational fishing fleets and recreational boaters, marinas and boatyards, and boatbuilders, maritime security, marine transportation of seafood and goods and services, transportation for Maine's islands residents and tourists, and support for other heritage industries. WWFs and Ports need to be prioritized in climate-ready planning, land use planning, infrastructure funding support, and resilience guidance and conservation efforts.

Actions:

1. ***Develop innovative funding mechanisms***: Infrastructure Trust Fund, Revolving Loan Fund or similar mechanism to provide funding for small to medium sized wharf and pier owners to plan for and install resilient infrastructure.
2. ***Improve Guidance and Technical Assistance*** for municipalities and business owners regarding conducting vulnerability assessments, feasibility and design of resiliency measures, and information on funding sources.
3. ***Reform and improve regulatory and non-regulatory approaches to development*** and redevelopment of WWFs to:
    - reduce redundant and confusing statutes and rules,
    - address challenges associated with increased flood insurance costs,
    - and pass regulations that address sea-level rise, flooding, and storm surge as part of a simplified regulatory scheme.
4. ***Publicize case studies of successful examples of mitigation and adaptation*** already happening at Maine's ports and WWFs. Incentivize this work through business recognition programs. Conduct additional education and outreach about the importance of WWFs and Ports to Maine's economy and culture.
5. ***Continue discussions in summer 2020 with the MCC CMWG WWF and Ports subcommittee***, the MCC Transportation Working Group, and a wider circle of port and ferry managers, harvesters and business owners/managers of small to midsize WWFs, cruise ship representatives and NGOs, with the objective of assessing opportunities for reducing emissions at ports and WWFs and associated industries. This includes:
    - potential for a pilot Green Port project to showcase resilient waterfronts,
    - development of best practices,
    - and improved understanding of local and regional threats and opportunities.

Appendix A

Coastal and Marine Working Group Detailed Strategies

Strategy 1 – Track coastal and ocean impacts to support adaptive decision making.

1. Recommended strategy and how it addresses Maine's climate resiliency and mitigation goals.

This strategy establishes a state-led organized network, the Climate Collaborative for Coastal and Ocean Monitoring (C2COM) at the state level that coordinates and expands upon existing governmental and nongovernmental monitoring activity carried out by a variety of organizations. The monitoring would include parameters related to ocean climate change, fisheries adaptation, ocean and coastal physical and ecosystem conditions, biological characteristics of habitats and species, and social and economic conditions of fisheries and resource-dependent coastal communities. C2COM would support adaptive decision making in the public and private sectors by collecting, assessing, and disseminating data and information on how climate change is affecting Maine's coastal and marine areas.

This strategy calls for (1) near term funding to make better use of existing data and fill gaps where we lack essential information and (2) sustained funding to allow us to monitor and respond to changes in the future.

Between existing public and private data sources, Maine already has a wealth of data that can inform climate resiliency and mitigation actions. It needs to identify and collect that data for use, identify data gaps and test the success of pilot projects. In addition to existing information, Maine needs to identify and coordinate research on current conditions and future responses to climate changes including how these environmental changes impact Maine's fisheries and local economies and communities. We need to know how shellfish and finfish are affected by changing climate conditions, such as water temperature and pH, and how, through responsible management, we might lessen impacts on fisheries and marine resources. We need more robust information to determine where and how aquaculture has the greatest potential to yield sustainable harvests. We need to track rising seas, changing weather patterns, development, and working waterfront infrastructure to guide adaptation and lessen future damages to coastal properties, businesses, and infrastructure. We need to better understand changes in coastal ecosystems to make wise choices about where to locate new infrastructure, including new energy sources, to minimize impacts to aquatic resources and habitats and increase benefits to residents and businesses. To mitigate CO_2 increases, we need an inventory of plant communities that sequester carbon, including marshes and eelgrass beds. We will also need to know how we can manage these plant communities to protect and improve their productivity.

Substantial data are already being gathered by federal and state agencies; municipalities; colleges and universities; non-profits; and the private sector. However, efforts are poorly coordinated and chronically underfunded; significant data gaps remain. Maine should develop a model for gathering this data and a system for disseminating it so public and private sector decision makers can access it to support decisions that respond constructively to coastal change. Addressing this need requires a robust twenty-first century coastal information infrastructure that combines Monitoring (tracking changes in time and space), Mapping (assembling geospatial information), and Modeling (making use of available data to evaluate and forecast).

This strategy was prepared by the Coastal and Marine Working Group for consideration by Maine Climate Council on June 17-18, 2020. More discussion of this strategy with stakeholders is needed to refine the recommended actions for inclusion in the Maine Climate Action Plan.

a. For adaptation strategies, what climate impacts does it address? How will this strategy reduce the vulnerability of Mainers to the impacts of climate change?

This strategy underlies all climate impacts in the coastal and marine environment. We cannot make our coast and coastal and marine industries resilient without the data that enables us to understand what is changing, how changes are likely to continue to occur, and what measures work best to address impacts of climate change. Coastal and marine monitoring and mapping determine baselines, detect changes, and inform climate change planning and adaptation strategies. Parallel tracking of economic and social indicators in coastal areas will clarify impacts, risks, and vulnerabilities.

Maine's coastal and marine environment faces climate impacts from the influence of primary climate drivers, including coastal and ocean acidification (COA); sea level rise (SLR); ocean temperatures; and changes in storm intensity, precipitation and river flow. Maine's coastal economies, fisheries, and ecosystems are facing secondary changes that include impacts to tidal marshes; marine vegetation including eelgrass, kelp and rockweed; primary productivity; marine species distribution; coastal circulation; invasive species; and water quality. Climate-related physical and ecological changes in turn impact human well-being and economic activity by affecting community vulnerability to storms, the health of our fisheries, and the viability of coastal and marine businesses. This strategy will address data gaps that limit our ability to understand how climate change is impacting the coastal and marine environment and will provide support and coordination for existing programs that provide historical data and baselines to allow Mainers assess climate vulnerability.

b. List any site-specific geographies where the strategy would be applied.

Monitoring should be conducted in all state coastal/marine waters as well as in riverine systems. This should be done by region as Maine's coast varies considerably. Data relevant to conditions in Southern Maine may have little relevance to Downeast.

2. What is your measurable outcome for this strategy, assuming all recommended actions to implement the strategy are achieved?

The overall outcome is a unified source of or portal to data to inform governmental and private sector actions intended to make our coastal and marine industries and way of life resilient and adaptive to climate change. There are small scale models already for certain types of ocean climate change research in Maine.

a. For mitigation strategies:

i. What is the estimated CO2e savings (metric tons) by 2025, 2030, 2050?

See Blue Carbon strategy for CO2e saving estimates.

ii. What is the cost effectiveness of those reductions (cost per ton of CO2e reduced) and the total cost?

b. Are outcomes measurable with current monitoring systems?

Not currently, but this strategy is aimed at making the outcomes of other CMWG strategies measurable.

3. What specific actions would be required to implement the strategy, including but not limited to legislation or regulation.

To implement this strategy, the State needs to take positive steps to strengthen statewide data collection, management, interpretation and presentation including:

a. Leverage existing state monitoring programs. State agencies already gather data of direct significance for understanding impacts of climate change on Maine's coast. These agencies include (*inter alia*) DEP, DMR, IF&W and DACF. State monitoring programs can provide the foundation for tracking changes in Maine's coastal conditions, yet funding remains inconsistent, and the priorities of these programs are not focused on gathering and sharing data on climate impacts. State programs can be better leveraged via sustainable state funding, shared data infrastructure and coordinated leadership. The state should establish a systematic coastal and ocean climate change monitoring program to provide timely information to public and private sector actors to facilitate climate adaptation. This framework itself needs to be adaptive, able to respond both to changing understanding of climate change and to evolving social and economic needs. The Collaborative should build upon existing public and private efforts, increase cooperative research and also develop new strategies to address information gaps. A robust program would include:
   - Coordination among agencies and organizations via a state chartered working group, the Climate Collaborative for Coastal and Ocean Monitoring (C2COM) to collect data in a comparable manner that avoids unnecessary duplicative efforts;
   - A focus on delivering actionable information in a timely manner to users (e.g. through dashboards, forums, workshops, listservs in collaboration with the *Maine Coastal and Marine Information Exchange*
   - A strategic vision or plan that addresses specific information needs;
   - Dedicated staff;
   - Stable funding over a period of years to detect, document and understand change.

b. Expand monitoring of coastal water quality, including nutrients and acidification. Climate change and acidification will increase vulnerability of coastal ecosystems and fisheries to water quality challenges, such as eutrophication, harmful algae blooms, and pathogens. A statewide, forward looking water quality and acidification monitoring strategy would leverage existing data collection efforts with new investments in data collection and modeling to provide actionable information on water quality risks statewide.

c. Characterize, map, and track marine and coastal habitats and economically important and at-risk species. Better data is needed to determine how habitats, economically-important species, at-risk species, species complexes and coastal food webs (including eelgrass, rare species, and Species of Greatest Conservation Need as identified in the Maine State Wildlife Action Plan) will adapt or become compromised during the next century in response to climate change. Coordinated long-term mapping and monitoring, expanding on existing efforts, will be essential to inform coastal and marine planning and adaptation. Additionally, working with members of the fishing and local communities to improve historical understanding and future monitoring of coastal habitat and marine resources will be imperative for this action.

d. Enhance invasive species monitoring and management. Climate change exacerbates vulnerability of coastal ecosystems (and thus fisheries and tourism) to disruption by invasive species, from green crab to species that cause harmful algal blooms. Efforts to limit spread or reduce negative impacts of invasives depend on early detection, rapid response, and robust, centralized communication. Improved monitoring will increase awareness of current conditions, likelihood of early detection and therefore promote system resilience and ability of coastal systems to adapt via *native* species migration.

e. Enhance and coordinate tracking and modeling of future changes to the extent of intertidal habitats and beaches including tidal marshes, mudflats, dunes, and beaches to provide information necessary to assess future availability of these habitats for recreation, resource harvest, shorebird feeding, floodwater/storm surge protection, carbon sequestration, etc. This modeling will require establishing or expanding sentinel monitoring programs tracking sediment and sand budgets, changes in elevation, water level, inundation, and vegetation in selected saltmarshes, tidal flats, beaches and dunes.

f. Improve tracking of economic and social conditions in Maine's coastal communities. Changing coastal ocean conditions and sea level rise will affect coastal communities and economies. As communities adapt to a changing coast, they will need robust data not only on how the ocean is changing, but also on how environmental changes are affecting (or are forecasted to affect) income and employment, economic opportunities, community risks and social needs. To address this need, a comprehensive coastal monitoring system should track important measures and indicators of economic activity, social well-being and community resilience in order to inform adaptation.

g. Develop and implement a coordinated funding strategy that leverages federal, state, foundation, and private sources towards an integrated monitoring system. The funding strategy should aggressively tap federal sources, like NSF, the Coastal Zone Management Program, NOAA's Ocean Acidification Program, and EPA to address short term needs, but also establish long-term stable funding (principally state-funded) that can sustain a decades-long program.

Specific actors needed for implementation: Department of Environmental Protection (DEP), Department of Marine Resources (DMR), Department of Inland & Fisheries & Wildlife (IF&W), Department of Conservation, Agriculture & Forestry (DACF), Casco Bay Estuary Partnership (CBEP), Friends of Casco Bay (FOCB), University of Maine, Downeast Institute (DEI), Bigelow Laboratory, Island Institute, Gulf of Maine Research Institute (GMRI), Northeast Regional Association of Coastal Observing Systems (NERACOOS), Coastal Enterprises, Inc. (CEI), Wells National Estuarine Research Reserve

4. What is the timeframe for this strategy?

	Short-term (2022)	Mid-term (2030)	Long-term (2050)	2070 - 2100
To implement	Establish sustainable funding for relevant state monitoring programs that do not have it. Establish coordination and adaptive management mechanisms (C2COM); include identifying and organizing existing data Invest in enhanced monitoring programs Develop integrated environmental and social indicator structure Develop information sharing, decision support and communications tools with Information Exchange.	Ongoing Programs	Ongoing Programs	
To realize outcomes	Better information produces better decisions right away. Improve baseline estimates of coastal carbon sequestration to guide mitigation efforts. Strengthen adaptation strategies Review and strengthen existing regulations to address sources that exacerbate ocean climate change, e.g. stormwater and nutrient pollution, and make the coast more resilient	Cumulative benefits of better adaptation actions	Cumulative benefits of better adaptation actions Support Blue Carbon Optimization	Benefits are cumulative

5. Please analyze the Recommended Strategy against the following criteria.

Workforce - Will the strategy create new jobs, prevent job loss, or cost the state jobs?	The goal is to help our coastal and marine waters stay healthy enough to support our coastal and marine economy and way of life. The data can be used to help shift jobs to new opportunities, This is already occurring as more people transition to a blend of wild harvesting and aquaculture. Robust information on conditions and projections of changes in marine and coastal ecosystems and economies, will allow businesses to make better decisions, including hiring and capital investments to adapt to changing conditions. Decisions by fisheries and other regulators grounded in better data will protect fisheries and coastal ecosystems, and thus jobs that depend on marine harvests, including aquaculture. Publicly available information, especially real-time information, can enhance recreation and indirectly support jobs in recreation, tourism, and retail.

This strategy was prepared by the Coastal and Marine Working Group for consideration by Maine Climate Council on June 17-18, 2020. More discussion of this strategy with stakeholders is needed to refine the recommended actions for inclusion in the Maine Climate Action Plan.

	By supporting long-term planning and adaptation by both public and private sector actors in coastal communities, this strategy will also reduce economic disruptions and job loss due to storms and other catastrophic events. Environmental monitoring currently supports many dozens of jobs in Maine with nonprofits, private business (such as consulting firms, equipment manufacturers and analytical laboratories), universities and state and federal agencies. Expanded monitoring will create additional jobs in each of these sectors. Monitoring supports a technically sophisticated workforce with readily transferable skills in science, laboratory methods, data analysis and computer science. Maine's decentralized environmental monitoring structure also provides training to numerous interns and seasonal employees.
Benefits (non-workforce) - What are the expected co-benefits of this strategy (e.g., improved health, increased economic activity, wildlife habitat connectivity, reduce natural hazard risk, increased recreation, avoided damage)?	Our understanding of the climate has direct implications for both private and public decisions. For example, sea level and storm intensity have implications not only for designs of coastal infrastructure, but also on key operational decisions such as when and where to fish, or what strategies to use to protect vessels and other mobile assets during storms. Our coastal and marine resources do so much more that support our economy. They provide recreation and solace to Mainers and visitors to our State. They provide home to unique flora and fauna. Our iconic coastline with its sandy beaches to craggy bold coast defines Maine. Our summer and fall tourism industry draws largely on these resources, including whale and puffin cruises, ferries to island communities, days at beaches, and so much more. Better information on the condition of Maine's coast and its marine resources will support adaptive choices at local and state levels on everything from municipal capital investments to regulatory processes. Better understanding of coastal change will support mitigation efforts by documenting carbon sequestration by marine ecosystems and informing siting of renewable energy facilities. ● Increased Carbon Sequestration (see Blue Carbon Optimization Strategy): Knowledge of where potential exists for sequestering carbon based on knowledge of current and historical eelgrass beds ● Improved aquaculture siting based on water quality and other environmental conditions avoids economic damages and enhances economic activity ● Assessment of vulnerability of commercially harvested shellfish beds due to climate impacts order to prioritize areas for mitigation actions ● Improved assessments of the health of Maine's finfish and invertebrate stocks to better manage the fisheries and increase economic activity

	• Better informed infrastructure siting; e.g., wind farm locations, as well as other alterations; e.g. dredging, minimizes marine resource impacts and helps avoid economic damages
Costs – What are the estimated fiscal costs and other costs to carry out this program. To the state? To municipalities? What resources do you anticipate needing to inform Mainers about the strategy and the opportunity/costs of the strategy? Where would financing likely come from?	A coastal monitoring program focused on coordination and planning could be started with a modest allocation of staff resources. However, a robust program to meet the state's long-term needs will require dedicated staff and funds for expanded data collection, data management, and communication. The following paragraphs provide a partial listing of costs, but still need further development. Maine DEP has developed a list of resource needs for its Marine Environmental Monitoring Program, which would supplement existing resources to allow monitoring for coastal acidification impacts as well as eelgrass mapping as part of its Comprehensive Monitoring & Assessment Strategy submitted to EPA in 2018. These needs are projected to have an annual cost of approximately $450,000. No similar published estimates of costs of monitoring needs are available for other state agencies, but costs are likely to be of similar magnitude. The amount needed to provide full funding for the continuation of critical monitoring programs at DMR could be up to $650,000. Due to increasing operating costs each year, funding would need to be increased by about 5% each year after the first year of funding. Many current programs that track changes in the marine environment are not funded by the state and are chronically underfunded. These established programs provide valuable baselines to track changes due to climate change, however, without consistent funding the long-term time series these programs provide are in jeopardy. Coastal monitoring conducted by nonprofit organizations, researchers and volunteers is thought to cost more than a million dollars annually. The proposed coordination structure, C2COM, will require both dedicated staff and the ability to contract for technical services, such as information technology, graphic design and data analysis. An initial budget could be on the order of $200,000 annually. (Cost efficiencies could be generated by integrating C2COM management with the Marine Information Exchange). Gaps in critical data still exist and new monitoring programs need to be established, for example, to monitor coastal acidification at more locations around the coast, to track changes in coastal habitat, and to develop robust indicators of social wellbeing for coastal communities. Costs of such programs are difficult to estimate, as costs will depend on which information gaps are addressed, and how. Addressing top priority information needs would cost in the hundreds of thousands of dollars annually, with costs distributed among several state agencies, non-profits, and the private sector.
Equity - Is this strategy expected to benefit or	Part of the reason for suggesting that monitoring be set up by region is to identify needs and solutions specific to each locale. In this way, equity

burden low-income, rural, and vulnerable residents and/or communities? What outreach has been/will be undertaken to understand the impact of the strategy on front-line communities?	can be best achieved. Better data on coastal change will help identify populations at risk due to climate change and associated ecological change. The information can be used to inform efforts to reduce the effects of unequal exposure to disaster, public health, or economic risks. Outreach through stakeholder surveys is on-going; will need to assess and report on responses.
Proven strategy & feasibility – Has this strategy been implemented successfully elsewhere? Is it feasible with today's technology? What barriers to implementation exist (e.g., financial, structural, workforce capacity, public/market acceptability)?	Maine has the opportunity to be a national leader by building a comprehensive coastal and marine information system to support climate mitigation and adaptation. Many examples share components of the proposed strategy, demonstrating that available technologies can be leveraged to increase salience of data provided by multiple institutions for supporting private and public decisions. Many states have more robust coastal monitoring infrastructure than Maine, providing examples of how such systems can be organized. The **State of Washington** has what is probably the most robust coastal and marine monitoring program in the country (largely state funded). The **Chesapeake Bay Monitoring Program**, is a multi-state program focused principally on water quality, that involves states, federal agencies and academic institutions in a coordinated monitoring effort. The **California Cooperative Oceanic Fisheries Investigations** (CalCOFI) program (a partnership between academic, federal, and state institutions) has collected hydrographic and biological data on California's coast since 1949. Programs sharing marine and coastal data on line are common within oceanographic and marine science communities. Some are also data integrators, gathering information from multiple sources to facilitate comparisons and interdisciplinary studies. Examples include the **Norwegian Marine Data Centre**, and **Australian Ocean Data Network**. **NERACOOS** is a regional organization managing coastal buoys and other monitoring infrastructure and presenting data online both in technical data formats and user-friendly visualizations. (Other members of **IOOS** provide similar services globally). The Maine Ocean and Coastal Acidification Partnership (**MOCA**) provides a recent model for statewide collaboration for coordinating monitoring and science priorities. **Casco Bay Estuary Partnership** leads a regional monitoring network to improve coordination of monitoring at a regional scale. The primary barriers to implementation of this strategy is lack of resources available to collect, analyze, interpret and share actionable data on the condition of Maine's coast. A secondary barrier is likely to arise from structural resistance to the types of change needed to effectively coordinate data collection, distribution and interpretation across state agencies and organizations with different mandates, cultures, and priorities.

Legal authority - Does the strategy require new statutory (legal/legislative) authority?	A law establishing a statewide marine monitoring program already exists (38-A M.R.S. § 410-F) , but it provides no funding mechanism and does not prioritize gathering data to support climate adaptation. A bill before the legislature in the current session (LD 559, as amended) addresses the need for monitoring eelgrass, an important component of this strategy. Enabling legislation to establish both the "Climate Collaborative for Coastal and Ocean Monitoring" and the "Maine Marine and Coastal Information Exchange", would clarify goals, establish interagency coordination, and provide dedicated funding for monitoring, coordination, data management, and communications with end-users.

Strategy 2 - Provide technical assistance on and outreach networks for climate adaptation and mitigation to coastal and marine stakeholders.

A - Maine Coastal and Marine Information Exchange

1. Recommended sub-strategy and how it addresses Maine's climate resiliency and mitigation goals.

Maine's coastal and marine stakeholders want climate information that is relevant to their needs - their communities, their economies, and their natural resources. While some climate information and decision-support tools exist, they can be hard to access or easily use for mitigation and adaptation projects in Maine's coastal and marine areas. In other instances, data, information, and tools are missing or incomplete because underfunded and uncoordinated monitoring and technical assistance networks are struggling to address fully the priorities and needs of coastal and marine stakeholders. Whereas, in other cases, barriers to constructive information exchange involve missed opportunities resulting from fragmented peer to peer networks, sector, organization, & agency silos, and limited resources to get the word out about successful climate mitigation and adaptation projects and innovations. Nonetheless, the benefits from tailored information exchange to guide effective mitigation and adaptation strategies in marine and coastal areas are increasing markedly as Maine's coastal and marine resource managers, communities, fisheries, aquaculturists, businesses, and residents confront the opportunities and challenges of climate change, climate-related impacts, and the transition to a low-carbon economy.

By acting as the clearing-house for coastal and marine data, information, and decision-support tools and strengthening collaborative partnerships and innovation networks, *the Maine Coastal and Marine Information Exchange* in coordination with the *Climate Collaborative for Coastal and Ocean Monitoring* and *Marine Seafood Business Council* will provide leadership of and support for timely and relevant climate information exchange; accessible and usable decision support tools aligned with the evolving decision-making needs of diverse coastal and marine stakeholders; a robust, comprehensive, responsive, and agile coastal and marine monitoring program; and cross-sector partnerships and climate innovation networks around coastal and marine mitigation & adaptation success and decision-relevant climate data collection, analysis, and communication. *The Marine Information Exchange* will facilitate climate mitigation and adaptation strategies in coastal and marine areas by:

- developing climate information tailored to the needs of coastal and marine stakeholders,
- engaging regularly with diverse coastal and marine stakeholders to understand their climate information needs, identify information and decision-support gaps, and develop potential means to fill them,
- improving integration of environmental, economic, and social data to advance a more comprehensive understanding of the consequences of climate change and prioritize mitigation & adaptation solutions,
- supporting and accelerating successful mitigation and adaptation actions by coastal and marine stakeholders by cultivating sustained innovations through technology change, collaborative partnerships, and coastal & marine climate innovation networks;

- fostering novel, cross-sector and cross-agency integration and analyses of coastal and marine data to strengthen the support infrastructure for strategic management, planning, & operations and community, business, and household mitigation and adaptation decisions,
- and supporting mitigation and adaptation strategies in coastal and marine areas by developing tailored data, indicators, & resources to track and enhance the effectiveness of different strategies at: reducing greenhouse gas emissions, fostering resilience to climate change, supporting good paying jobs, and minimizing adverse impacts on rural, low-income, and elderly populations and tribal communities.

a. For adaptation strategies, what climate impacts does it address? How will this strategy reduce the vulnerability of Mainers to the impacts of climate change?

Climate Impacts Addressed. In collaboration with the *Climate Collaborative for Coastal and Ocean Monitoring* and *Marine Seafood Business Council,* the Exchange will focus on linking knowledge and information about the climate impacts of expected changes in ocean temperature, sea-level rise and storm surge, ocean acidification, marine ecosystems, markets, public health, & community resilience with actionable climate solutions for coastal and marine stakeholders.

The Exchange's comprehensive and accessible data resources, tools to support management, planning, and business owner & household decisions, and collaborative partnerships & innovation networks will provide critical support to other proposed mitigation and adaptation strategies, including the CMWG's *Climate-Ready Working Waterfronts*, *Promoting Climate-Adaptive Ecosystem Planning and Management Using Nature-Based Solutions, Optimizing Blue Carbon,* and *Managing for Resilient Fisheries & Aquaculture.* Coordinated outreach and events with the *Marine Seafood Business Council* will broaden the awareness and impact of climate innovations in the fisheries and aquaculture sectors. In addition, the Exchange, where appropriate, will develop tailored data resources, decision support tools, and partnerships for coastal and marine stakeholders building on strategies developed by other WG's, including those involving the transportation, electricity, and buildings sectors and community resilience, public health, and emergency management.

Reducing Vulnerability to Climate Impacts. In combination with the Exchange's stakeholder engagement and partnerships, data and decision support resources will enhance understanding of the distributional consequences of climate-related impacts and policy action and inaction in response to climate change. The Exchange's resources will also improve documentation of the resiliency and vulnerability of coastal/marine populations, communities, industries, and businesses, including particular effects on rural, low-income, and elderly populations. Further, the Exchange could help prioritize improved understanding of adaptive capacity and tools for strengthening adaptive capacity in vulnerable areas. The Exchange will offer improved, accessible, and transparent data resources documenting the impacts of climate change on social, economic, and environmental systems. These resources will support the assessment of the benefits and costs of particular mitigation and adaptation projects and the development of climate solutions. Greater integration of data and information on disparate parts of Maine's communities (i.e., social, economic, biophysical, & ecological systems) and outreach focused on the interactions between economic, environmental, and public health will enhance understanding of the impacts of climate change and the transition to a low-carbon economy,

including greater recognition of those coastal and marine people, businesses, and communities who are more vulnerable to climate impacts and those who may benefit or be disadvantaged by particular mitigation and adaptation strategies.

b. List any site-specific geographies where the strategy would be applied.

Marine and coastal areas statewide

2. What is your measurable outcome for this strategy, assuming all recommended actions to implement the strategy are achieved?

The Exchange is not a stand-alone mitigation strategy. Rather, by design, it links with and strengthens the proposed CMWG (and other WG) strategies to increase and accelerate CO2e savings and increase the cost effectiveness of reduction strategies in Maine's coastal and marine areas. One measure of the Exchange's success could be the extent to which its work and resources complement the success of other strategies by increasing or accelerating adoption of particular mitigation and adaptation technologies, completion of particular mitigation or adaptation projects, or achievement of particular mitigation or adaptation objectives. Similarly, the success of the Exchange could be assessed in terms of enhancing the net benefits or cost effectiveness of emission reductions or adaptation strategies. Additional measurable outcomes include visits to the web digital platform, use/download of Exchange data resources, decision-support tools, and educational/outreach materials as well as participation in and evaluations of Exchange events (i.e., symposia, policy briefings, & workshops), partnerships, and innovation networks.

a. For mitigation strategies:

i. What is the estimated CO2e savings (metric tons) by 2025, 2030, 2050?

ii. What is the cost effectiveness of those reductions (cost per ton of CO2e reduced) and the total cost?

b. Are outcomes measurable with current monitoring systems?

Yes and No. Monitoring of the Exchange's impact and performance outcomes would be a priority of the strategy itself and therefore not require new monitoring systems. Formal impact evaluation of the Exchange's causal impact on the other strategies would require careful data collection and analysis as the MCC strategies move forward.

3. What specific actions would be required to implement the strategy, including but not limited to legislation or regulation.

Specific actions required for implementation.

The Maine Coastal and Marine Information Exchange requires the following actions:

a. Establish an effective means for engagement and information exchange with coastal and marine stakeholders to identify priority climate information needs & ways to address these needs (e.g.,advisory panel of representatives from the private, nonprofit, and public sectors; peer to peer networks; partnerships, and place- & sector-based events);

b. Develop relevant data, information, and decision-support resources tailored to the needs of coastal and marine stakeholders, including resources that integrate environmental, economic, and social information to track the effectiveness and impacts of mitigation and adaptation strategies in coastal and marine areas;

c. Develop core infrastructure for disseminating climate data, information, decision-support tools, research, and outreach materials (e.g., create information exchange clearing-house, host a user-friendly web/digital platform; peer to peer networks; place-based partnerships);

d. Increase the dissemination and development of tools to support & accelerate coastal/marine mitigation and adaptation actions (e.g., strategic partnerships with established, successful decision-support tool developers; incentives for the development of new support tools and climate solutions; promotion of effective mitigation and adaptation projects and strategies)

e. Hold biannual symposia (Spring, Winter) in collaboration with the *Climate Collaborative for Coastal and Ocean Monitoring* and *Marine Seafood Business Council* to share information; coordinate data collection and monitoring efforts;identify/address new information and decision-making needs; and assess mitigation and adaptation strategies (with careful attention to support broad attendance by managers, practitioners, businesses, community leaders, and leadership within different coastal and marine sectors);

f. Host targeted events for different marine and coastal stakeholders, including coastal municipal officials, tourism and hospitality businesses, fishermen, aquaculturists, working waterfront and marine transportation officials, and coastal residents seeking to pursue climate mitigation and adaptation projects, and organizations documenting or researching the drivers and impacts of climate change in marine and coastal areas; and

g. Organize regular policy briefings for policy makers, especially state legislators, to provide, among other items, centralized, transparent tracking of mitigation and adaptation projects in coastal and marine areas.

Specific actors needed for implementation: staff or faculty from DEP, DMR, MEGIS, DACF, Maine Colleges and Universities & other Research Institutions, Maine Sea Grant, Non-government organizations (e.g., Maine Climate Change Adaptation Providers Network (CCAP); The Maine Ocean and Coastal Acidification Partnership (MOCA); Casco Bay Estuary Partnership Monitoring Network; Maine Center for Coastal Fisheries; Island Institute; Gulf of Maine Research Institute; Maine Lobstermen's Association, Maine Aquaculture Association, Friends of Casco Bay, Coastal Enterprises Institute)

4. What is the timeframe for this strategy?

	Short-term (2022)	Mid-term (2030)	Long-term (2050)	2070 -2100
To implement	X			
To realize outcomes	X	X	X	X

5. Please analyze the Recommended Strategy against the following criteria.

Workforce - Will the strategy create new jobs, prevent job loss, or cost the state jobs?	Yes, the Exchange will create new jobs or prevent job loss as those who rely and seek to rely on our coastal and marine resources as they change their businesses, public policies, and behaviors in response to climate change. By helping improve the quality of decision-relevant information about climate change, reducing uncertainty, and shoring up the decision infrastructure for management, planning, and operations, the Exchange offers businesses, residents, fishermen, aquaculturists, non-government organizations, community officials, and state resource managers etc tools to navigate the risks and opportunities of climate change and therefore maintain/create new jobs. In addition, data science and analysis as well as communication skills fostered by the Exchange are in great demand by employers.
Benefits (non-workforce) - What are the expected co-benefits of this strategy (e.g., improved health, increased economic activity, wildlife habitat connectivity, reduce natural hazard risk, increased recreation, avoided damage)?	The expected co-benefits of the Exchange include increased economic activity or avoided losses in economic activity in coastal & marine communities; avoided damages to property, buildings, and infrastructure from sea-level rise, flooding, increased precipitation, and erosion; improved resilience of coastal and marine communities and ecosystems, and potentially improved health (associated with improved air and water quality) and recreation/tourism experiences. The Exchange's commitment to tailored information exchange will focus efforts on opportunities for strengthening the decision infrastructure and information basis for a variety of decisions via improved detection and anticipation of changing conditions, dissemination of usable knowledge about and tools to support mitigation & adaptation innovations, and outreach, partnerships, and network-building to ensure the exchange and its coastal and marine climate innovations remain responsive to the climate information and decision needs of coastal and marine stakeholders. Specific examples of potential co-benefits by CMWG strategy include: ● *Climate-ready working waterfronts.* The Exchange could accelerate the adoption of working waterfront mitigation and adaptation strategies and induce technological innovations and learning that generate significant co-benefits. Improved information about vulnerabilities, including flooding, erosion, sea-level rise impacts; changing fisheries, trade, and tourism opportunities; and specific adaptation & mitigation technologies or planning tools will support reduced natural hazard risks, increased tourism and recreation, increased economic activity, and avoided damages to critical infrastructure, natural resources, and local economies.. ● *Climate-adaptive planning and management.* The Exchange could enhance the effectiveness of the blue carbon strategy, ecosystem conservation and restoration efforts, sand dune management, beach nourishment strategies, and living shorelines approaches by accelerating the development of state-

	of-the-art mapping and modeling tools, adoption of adaptation planning tools,and streamlining regulatory and carbon asset/credit generation processes. These activities could result in co-benefits such as avoided damages to natural resources, increased recreation, and reduced flooding of houses and businesses. ● *Managing for Resilient Fisheries & Aquaculture.* In collaboration with the *Climate Collaborative for Coastal and Ocean Monitoring* and *Marine Business Council,* the Exchange could develop real-time decision-support tools to help the fishing and aquaculture industries adapt to changing conditions and generate increased economic activity. Shellfishermen and aquaculturists stand to benefit significantly from improved anticipation, detection, and monitoring of changing water quality conditions and harmful algal blooms. Further, the Exchange could accelerate the adoption of new technologies and induce innovation in the marine fishing sector to lessen their exposure to climate impacts. Attuned to the unique needs of marine and coastal stakeholders, the Exchange will also produce additional co-benefits by supporting the mitigation and adaptation strategies of other WGs (e.g., transportation, energy, community resilience and emergency management) through data resources, decision-support tools, technical assistance and education, and outreach tailored to coastal and marine stakeholders.
Costs – What are the estimated fiscal costs and other costs to carry out this program. To the state? To municipalities? What resources do you anticipate needing to inform Mainers about the strategy and the opportunity/costs of the strategy? Where would financing likely come from?	Initial steps to launch the Exchange, such as creating the advisory panel, hosting initial workshops, and piloting initial data products based on current data resources, could be achieved at modest costs. For example, efforts such as the Maine Ocean and Coastal Acidification Partnership could be adapted for this purpose. A robust and agile Exchange will, however, require dedicated staff and resources. The Exchange could strategically cultivate public-private partnerships that would evolve into shared funding models. Costs will scale with the level of information, services, and communication or engagement provided. Two to four staff members would enable the Exchange to create new data systems & outreach and engagement resources, host events and facilitate cross-sector and cross-agency dialogues, and develop decision-relevant climate information at costs ranging between $200K-450K per year.
Equity - Is this strategy expected to benefit or burden low-income, rural, and vulnerable residents and/or communities? What outreach has been/will be undertaken to understand the impact of the strategy on front-line communities?	By enhancing understanding of the distributional consequences of climate-related impacts and policy action and inaction in response to climate change, the Exchange could improve documentation of the resiliency and vulnerability of coastal/marine populations, communities, industries, and businesses, including particular effects on rural, low-income, and elderly populations. Further, there is potential to build new resources and partnerships focused on increasing benefits to low-income, rural, and vulnerable residents, businesses, and/or communities from climate strategies in marine and coastal areas. More broadly, open access to data resources, decision tools, and networks is consistent with

	equity goals. Ongoing outreach with front-line coastal and marine stakeholders conducted by the Coastal and Marine Working Group will inform the design and function of the Exchange.
Proven strategy & feasibility – Has this strategy been implemented successfully elsewhere? Is it feasible with today's technology? What barriers to implementation exist (e.g., financial, structural, workforce capacity, public/market acceptability)?	While there are numerous models of effective data management & delivery and data-based exchange organizations, we are still looking for models that emulate all of the features of the proposed Exchange. Many data clearinghouses at the national and state scale are not well-suited or tailored to meet the needs of Maine's marine and coastal communities and industries. Despite this gap, the Exchange is feasible with today's technology. Barriers to implementation involve dedicated staff and funding to support the proposed exchange activities; robust, comprehensive monitoring information; and standardized data systems to simplify and encourage integration of cross-sector, -agency, and -system data. Key Maine-based examples of effective data & information management and delivery include:Maine Climate Change Adaptation Providers Network (CCAP); The Maine Ocean and Coastal Acidification Partnership (MOCA); Casco Bay Estuary Partnership Monitoring Network; Maine Center for Coastal Fisheries; Maine Adaptation Toolkit; Maine Flood Resilience Toolkit; Municipal Planning Assistance Climate Adaptation; Island Institute WayPoints; and Maine SeaGrant..
Legal authority - Does the strategy require new statutory (legal/legislative) authority?	While the Exchange could be started under existing authorities, legislation establishing and supporting the Exchange would increase the likelihood of its success and ultimate benefits to coastal and marine stakeholders. Such legislation could also support an ability to seek federal funds or other means of supporting the Exchange. The Exchange is similar in some respects to the Maine Library of Geographic Information Board, though the Exchange places a much greater emphasis on being a consumer-facing organization and on the importance of supporting outreach, engagement, and technical assistance/decision-support resources in addition to data. (http://www.mainelegislature.org/legis/statutes/5/title5ch163sec0.htm)

6. Rationale/Background Information

In collaboration with the *Climate Collaborative for Coastal and Ocean Monitoring* and *Marine Business Council*, the Exchange's centralized data resources, information exchange systems, and data-based partnerships & coastal climate innovation network address significant information barriers, including fragmented and under-funded coastal and marine monitoring networks; uncoordinated data storage, integration, and analysis efforts; disparate, competing, or missing decision-support tools for marine stakeholders; and limited cross-agency and –sector integration of data streams to track climate impacts and inform mitigation and adaptation decisions by coastal and marine stakeholders. By providing leadership of and support for integration of environmental, economic, and community data at spatial and temporal scales of relevance to coastal and marine stakeholders and their day to day decisions, the Exchange will strategically fill critical information

gaps documenting environmental, economic, and community impacts of climate change, identify opportunities for strengthening the resilience of marine and coastal industries and communities, and reveal opportunities for linking climate solutions with economic development opportunities..

Data. Coastal and marine stakeholders want data and information that is relevant to their area, fishery, community, business, and industry. Many available climate resources are not readily usable or remotely tailored for these stakeholders. Strategic integration, analysis, and communication of coastal and marine monitoring data will support mitigation and adaptation by strengthening the scientific foundation for evidence-based decision-making, learning, and technological advances.

Decision-support tools. Decision-support tools co-developed by the Exchange and marine and coastal stakeholders will build on these improved data resources and provide tailored, relevant, and nimble decision support for a range of climate-related decisions by a variety of coastal and marine stakeholders. Given the range of stakeholders in marine and coastal areas, these tools will vary from maps and graphs to visualization and interactive modeling tools to potential new apps for mobile devices to networks of technical and outreach professionals.

Partnerships and coastal climate innovation network. Strengthening connections across marine sectors, coastal municipalities, and other stakeholder groups will create mechanisms for learning and innovation, technology change, and the emergence of partnerships and innovation networks around coastal and marine mitigation & adaptation success and decision-relevant climate data collection, analysis, and communication. These partnerships could generate mitigation and adaptation opportunities and financing that individual actors or groups could not pursue individually and accelerate the development and adoption of mitigation and adaptation strategies. Further, the emergence of a robust coastal climate innovation network could create opportunities for novel technological advances, new business development opportunities, and collaborations with coastal groups beyond Maine.

Regular and meaningful engagement with diverse coastal and marine stakeholders, ranging from municipal leaders to state legislators to business and industry leaders to residents to marine resource managers, will provide mechanisms for real-time feedback on the adequacy of current data streams and decision-support tools and for informing priorities for subsequent data collection, decision-support tools, and mitigation and adaptation projects. Tapping the experiences and knowledge of and working collaboratively with these individuals, organizations, communities, and businesses will be critical to the success of the Exchange's deliverables, events, partnerships, and networks. Regular collaboration with and feedback from its diverse stakeholders will ensure that information and decision-support tools are actually usable by marine and coastal decision-makers.

By strengthening decision-support resources for Maine’s coastal communities, fishermen, aquaculturists, businesses, coastal resource managers, residents, visitors, and researchers, the Exchange strives to reduce the costs of and seize opportunities for climate solutions. Broadly, the Exchange is envisioned as an "accelerator" for mitigation and adaptation strategies by helping spread the word about or inspiring the development of feasible, cost-effective climate solutions. While the Exchange's information resources, tools, and partnerships will particularly strengthen Maine's efforts to advance *climate-ready working waterfronts, resilient fisheries & aquaculture, climate-adaptive planning and management;* and *resilient communities,* additional benefits are expected associated with dissemination of tools and resources tailored to coastal and marine stakeholders related to climate strategies involving transportation, energy, and building sectors, emergency management, and public health.

Strategy 2 - Provide technical assistance on and outreach networks for climate adaptation and mitigation to coastal and marine stakeholders.

B - Maine Seafood Business Council

1. Recommended sub-strategy and how it addresses Maine's climate resiliency and mitigation goals.

Maine's seafood harvesters, shoreside businesses, and working waterfronts will need access to information and tools that can support operational decisions, capital investments, and long-range planning to implement climate adaptation and mitigation strategies. The Maine Seafood Business Council (MSBC) will routinely work with businesses to understand their information needs and represent these interests in collaborations with the *Maine Information Exchange* and other data and information providers. The MSBC will play a key role in compiling, synthesizing, and communicating to the marine seafood sector the best available environmental, economic, and other information relevant to current conditions as well as expected conditions over upcoming years and decades. In addition, the MSBC will consolidate information for businesses on potential mitigation options, how they could be applied in different types of businesses, and financing mechanisms or pilot program opportunities to offset their costs.

a. For adaptation strategies, what climate impacts does it address? How will this strategy reduce the vulnerability of Mainers to the impacts of climate change?

This strategy helps businesses better prepare for and respond to changing environmental conditions. For businesses that depend on harvesting or growing marine organisms, environmental changes can cause significant disruptions. Forward-looking information and tools can help individual businesses make better informed decisions, and the aggregation of these decisions makes the seafood sector stronger. Additionally, in the marine seafood sector, mitigation and adaptation are not mutually exclusive. Seafood businesses may transition to a lower carbon economy as a means to save and stabilize costs that, in turn, boosts business resiliency in the face of numerous climate threats to the sector. Renewable energy, fuel switching, and energy efficiency measures can buffer marine seafood businesses from shifts in the ecosystem. From a business adaptation perspective, controlling energy costs helps ensure the harvester or grower, working waterfront, and supply chain businesses are all able to better manage variability in the quantity, timing, and quality of the seafood product. Doing so has a direct impact on the profitability of businesses in this sector, and many businesses that have implemented some of these ideas have been able to distinguish themselves in the market.

b. List any site-specific geographies where the strategy would be applied.

Fishing vessels, aquaculture farms, fishing co-ops, seafood dealers, processors, wholesalers, and trucking companies up and down the coast.

2. What is your measurable outcome for this strategy, assuming all recommended actions to implement the strategy are achieved? Reduced emissions and jobs created.

Measurable outcomes for this strategy include the number of seafood businesses participating in and seeking information from the MSBC; number, quality, and uses of information products produced by the MSBC; and number and scale of mitigation and adaptation measures implemented by participating businesses. These data would need to be collected on an ongoing basis as part of the work conducted by the MSBC.

a. For mitigation strategies:

i. What is the estimated CO2e savings (metric tons) by 2025, 2030, 2050?

ii. What is the cost effectiveness of those reductions (cost per ton of CO2e reduced) and the total cost?

b. Are outcomes measurable with current monitoring systems?

3. What specific actions would be required to implement the strategy, including but not limited to legislation or regulation.

a. Establish effective means for two-way communication with businesses in each sector to elicit an understanding of business information needs, develop relevant and useful information products, and share those products with different sectors (e.g., advisory panels, peer networks, place-based trainings/convenings);

b. Assemble pertinent information from the *Maine Information Exchange* and other scientific resources for each sector;

c. Conduct analyses of existing and emerging markets as needed to identify trends and opportunities for growth;

d. Assess infrastructure needs and opportunities to align with future business directions and link businesses to programs that support business improvements (e.g. efficiency and renewable programs);

e. Gather and organize information about business financing for startup, growth, mitigation and adaptation projects;

f. Provide information in forms that are easily accessible to and usable by businesses in the seafood sector;

g. Support implementation of pilot adaptation and mitigation projects in seafood businesses (see Section 6);

h. Advise government entities on the needs of marine businesses as they attempt to plan for or implement mitigation or adaptation measures.

4. What is the timeframe for this strategy?

	Short-term (2022)	Mid-term (2030)	Long-term (2050)	2070 -2100
To implement	x			
To realize outcomes	x	x	x	x

5. Please analyze the Recommended Strategy against the following criteria.

Workforce - Will the strategy create new jobs, prevent job loss, or cost the state jobs?	Developing the MSBC will directly support jobs to staff the Council. In addition, it will protect existing marine seafood businesses and support future growth in existing as well as new marine industries in Maine.
Benefits (non-workforce) - What are the expected co-benefits of this strategy?	Marine businesses of all types will benefit from having greater access to information about future climate conditions that may affect their business plans, decisions, and economic outlooks.
Costs – What are the estimated fiscal costs and other costs to carry out this program. To the state? To municipalities? What resources do you anticipate needing to inform Mainers about the strategy and the opportunity/costs of the strategy? Where would financing likely come from?	The MSBC complements and overlaps with a recently funded initiative. The State of Maine (Maine Technology Institute, FocusMaine, and project partners) received a $2 million award from the federal Economic Development Administration (matched with $500,000 from partners) to develop an industry-led roadmap and action plan for economic growth and greater resiliency in its marine economy. The award provides critical funding to support Maine's Marine Economy initiative --a three-year project that will provide strategies to match Maine's marine-related products with global markets and develop strategies to attract investment in new markets. It will also identify new opportunities and barriers to value-added production and will seek ways to maximize efficiencies and returns across the seafood value-chain. Climate change looms as one of the single biggest threats to Maine's marine economy. While the project is still in a formative stage, the synergies between the two efforts will be considered (with potential support/funding) as the EDA project develops. Costs associated with this strategy will scale with the level of information, services, and communication or engagement provided. Two to four staff members would enable the MSBC to facilitate industry dialogues and translate scientific information to business needs at costs ranging between $200K-450K per year. The MSBC would benefit from leveraging existing extension and communication networks, such as those that exist through Sea Grant and fishing and aquaculture industry organizations. However, it should not

	be assumed that these organizations can support additional work for the MSBC without funding for specific roles and tasks. In addition, grant support for Maine-based scientists may be necessary to support analyses requested by the MSBC.
Equity - Is this strategy expected to benefit or burden low-income, rural, and vulnerable residents and/or communities? What outreach has been/will be undertaken to understand the impact of the strategy on front-line communities?	In establishing the Maine Climate Council, LD 1679 provides statutory language that calls for the explicit consideration of... ● "rural communities" ● "persons of low income and moderate income" ● "economic sectors that face the biggest barriers to emissions reductions" ● "vulnerable communities" and ● "natural resource-based industries" ...and for doing so "fairly and equitably" and for "ensuring equity for all sectors and regions of the State." This strategy has potential to positively impact marine seafood businesses of all sizes and scope. Many of Maine's small, independent marine businesses do not routinely have access to understandable scientific information in relevant and useful forms. While larger businesses or unique small operators may have greater expertise to access and understand information on climate projections and impacts and to apply these insights to their business decisions, the MSBC will be critical for ensuring equitable access to this type of information across all marine businesses in Maine. As such, the MSBC will provide resources seafood businesses need to best position themselves to adapt to the changing climate. The MSBC will identify vulnerable regions and/or businesses when considering which businesses to prioritize and include in pilot programs. The future sustainability of businesses will be considered. For example, younger businesses carrying debt are highly vulnerable. Additionally, accessing already allocated quota can be cost prohibitive for many commercial harvesters. To maintain a diverse fishing industry, there may need to be cost-effective tools to help commercial harvesters access new species migrating to the Gulf of Maine, enter the aquaculture sector, or adapt their existing aquaculture business to suit a changing environment.
Proven strategy & feasibility – Has this strategy been implemented successfully elsewhere? Is it feasible with today's technology? What barriers to implementation exist (e.g., financial, structural, workforce	The Alaska Seafood Marketing Institute (ASMI) has implemented a similar strategy. This group's goals are different than ours, but it is a good example of a business/science/political collaboration. ASMI is a public-private partnership between the State of Alaska and the Alaska seafood industry established to foster economic development of a renewable natural resource. It is part of the state in the Department of Commerce, Community, and Economic Development, but has a legal existence independent of and separated from the state. It is governed by a board of directors made up of industry members appointed by the Governor.

capacity, public/market acceptability)?	Another example is Washington State's Department of Commerce's Maritime sector model. The Washington Maritime BLUE2050 is a strategy to ensure Washington is home to the most sustainable maritime industry by 2050 and aligns with the state's plans for deep decarbonization, innovation and workforce development. The model is staffed by a Director for Economic Development for the Maritime sector, who is 50% paid by WA Maritime Federation (including ports, harbors, marinas, boat builders, etc. in addition to fishermen and aquaculturists) and 50% by state government. There is also a 20-member Governor's Maritime Innovation Advisory Council that is composed of business, government, ports, research, labor, Tribal and environmental leaders. A significant barrier to implementation of the MSBC is ensuring a clear value proposition for industry members to actively participate in the council. Messaging to industry will need to honestly, clearly and concisely demonstrate the benefits (and costs) associated with Council membership. As a structure, the MSBC holds great promise in helping seafood businesses access the support they need but successful implementation of this structure needs to be done in a business friendly manner.
Legal authority - Does the strategy require new statutory (legal/legislative) authority?	This strategy does not require any new initial legal authority because it is primarily focused on information sharing and alignment of efforts across business, nonprofit, research, and state agency work. To the extent that the MSBC makes recommendations about changes to state funding priorities or programs, statutory changes may be needed. To the extent that funding and support staff may reside in state agencies, it is likely existing authorities are sufficient to allow their full participation.

6. Rationale/Background Information

Marine seafood businesses are being impacted by climate change in many ways, including rising ocean temperatures and sea level, acidification of coastal waters, and increased frequency and duration of storms. The unpredictability of the marine ecosystem has severe consequences for businesses that rely on harvesting, growing, or selling marine resources. Mitigation strategies in the sector will be more readily adopted if they are part of adaptation efforts.

The scale of the Climate Council's work makes it imperative that marine businesses are included early in both the planning and implementation stages. Without the support of the marine sector, any adaptation or mitigation strategies put forward will likely be less successful. The seafood businesses will be where strategy meets reality, therefore support should be given to those businesses willing to be early adopters of innovative strategies to mitigate and adapt to climate change.

The MSBC will undertake pilot projects with key influencers. The positive stories about how businesses can successfully adapt to and mitigate climate change resulting from these pilot projects

can bolster other Climate Council initiatives, particularly in rural and other natural resource-dependent industries.

Example Pilot Project led by MSBC -

The MSBC will work with Maine's marine seafood sector to provide resources to inform innovative mitigation strategies and guidance on mechanisms to fund implementation of decarbonization. Pilot projects will demonstrate immediate, tangible climate adaptation and mitigation benefits coming out of the MSBC. For context, the seafood sector has significant cooling and freezing needs due to the movement of perishable live or fresh products. Transitioning to renewable energy sources to power this sector's critical cooling and freezing infrastructure will help individual businesses accommodate environmental shifts, control costs, and reduce carbon emissions. Predictability of these costs can help these businesses add a level of stability to an unstable business model and improve profitability.

While the marine seafood sector has a relatively small carbon footprint compared to other sectors in Maine and would normally be eligible to participate in mitigation efforts available to the commercial sector in general, this initiative would prioritize a sector that is already facing numerous impacts from climate change on top of other challenges. By taking early action to prioritize mitigation efforts as a critical step towards adapting to climate uncertainties, it would help cement a foundation for the long-term success of a critical sector of Maine's economy.

Recent activities from several marine seafood businesses along the coast of Maine show the potential for decarbonization projects. Two working waterfront businesses have recently been able to take advantage of the US Department of Agriculture Rural Energy for America Program (REAP). A MSBC pilot initiative would learn from these examples and share best practices with the industry more broadly.

- The Cranberry Island's Fishermen's Co-op recently received funding to place solar panels on their co-op and reduce their energy costs, thus stabilizing a significant cost associated with their business operations. They expect the project to pay for itself in three years.
- Mook Sea Farm, an oyster hatchery and farm, received money from USDA REAP to install solar panels on their new holding facility, reducing costs and uncertainty in a business intimately impacted by ocean acidification and critical for oyster growers across the state.

Role of the MSBC –

The MSBC will develop and transfer socially, economically and technologically feasible options to support the transition of the marine seafood sector to a lower carbon economy, through both increased energy efficiency and use of alternative energy sources. The Council will provide fisheries and aquaculture, shoreside, and transportation businesses with information resources, regulatory structure, and financial assistance to reduce carbon emissions while maintaining a seafood sector that contributes to a diverse range of coastal communities.

In order to achieve the adaptation benefits within the marine seafood economy, existing state programs will likely need to go further. Doing so is consistent with the legislation that established the Maine Climate Council and the prioritization process within that legislation. Support for pilot projects ensures that seafood businesses that are vulnerable to shifts in the marine environment receive early benefits of a transition to a clean energy economy, as well as helping the fisheries and aquaculture sector adapt to climate change.

Specifically MSBC will:

- **Identify key industry partners** for piloting replicable renewable and efficiency upgrades to their marine seafood businesses
- **Ensure adequate technical assistance for the implementation** of such programs. Many of the roadblocks, and strategies for avoiding barriers to decarbonization and efficiency in rural coastal communities, have been identified in the Bridging the Rural Efficiency Gap report produced by the Island Institute, and include lack of access to programs or information about programs due to lack of broadband service. Particularly as the fisheries grapple with other significant regulatory and market changes, assistance in implementation will be essential.
- **Advocate for financial support and subsidies** going beyond what is necessary to achieve the State's overall mitigation goals. The industry's use of energy efficiency and renewable investments to date has been limited, and the pandemic coupled with significant regulatory uncertainty in multiple different fisheries makes planning for these investments at the current level of support more difficult. Prioritizing early action within the sector to ensure the best returns from adaptation funding will allow businesses to move forward with long-term investments that are climate informed.
- **Coordinate with state government agencies** to create incentives to integrate renewable energy into marine seafood businesses.
- **Share success stories and best practices** with the marine and other natural resource-dependent sectors.

Strategy 3 - Blue Carbon Optimization: Enhance mitigation by conserving and restoring coastal habitats that naturally store carbon.

1. Recommended strategy and how it addresses Maine's climate resiliency and mitigation goals

Coastal Blue Carbon is a term that refers to the carbon that is sequestered by coastal ecosystems like salt marshes and seagrass beds. Protecting, restoring and managing coastal blue carbon ecosystems contributes to Maine's mitigation goals by enhancing carbon sequestration in the state. These actions will contribute to resilience goals by reducing the impacts of storm events and sea level rise while also improving health and resilience of the coastal ecosystems on which Maine's coastal fisheries and tourism depend.

Blue carbon ecosystems are an order of magnitude more efficient at burying carbon per unit area than forests, yet when they are degraded, flooded with freshwater, or drained, they can become sources of carbon dioxide and other greenhouse gases (GHGs), including methane. This strategy focuses on the ability of healthy coastal and marine areas to provide vital benefits to the community, ecosystem, and economy, while performing long term carbon storage and sequestration of GHGs and ameliorating coastal acidification. Essential strategy components include inventorying Maine's blue carbon resources to inform baseline estimates of current storage and sequestration, tracking changes in sequestration/emissions over time, and increasing conservation and restoration of coastal ecosystems to optimize carbon burial and obtain climate mitigation benefits.

Globally, blue carbon ecosystems are responsible for approximately 20% of the total carbon that gets buried [1]. The diverse geological features and vast length of Maine's coastline provide abundant natural opportunities to sequester GHGs both from the atmosphere and nearshore marine waters. Coastal habitats including tidal marshes and eelgrass (seagrass) beds comprise Maine's coastal blue carbon resources. Through photosynthesis, marsh plants and eelgrass utilize and store carbon dioxide in plant tissues, thus removing carbon dioxide from the surrounding environment and locally reducing impacts of coastal acidification. The majority of plant carbon is shunted directly into roots and rhizomes where it is effectively buried in saturated and oxygen-poor soils, and removed from the atmosphere for centuries to millennia. Intertidal and subtidal seaweed (macroalgae) may also provide opportunities for long term carbon sequestration provided the biomass gets buried in marine sediments. An active area of current research addresses the degree to which seaweed tissue is exported from the nearshore environment to the deep ocean, thus contributing to carbon burial [2].

Blue carbon management projects reduce GHG emissions and provide quantifiable climate mitigation benefits through conservation, restoration, and creation of coastal blue carbon ecosystems and implementation of land use practices that prevent stormwater run-off and eutrophication. Potential projects include a) removing undersized culverts to restore tidal flow and reduce methane emissions in marshes, b) enhancing environmental conditions to promote plant growth in eelgrass beds, salt marshes, and seaweed (e.g., improve water quality, increase sediment supply, revegetate, etc), c) creating or restoring salt marsh and eelgrass habitat to historic extents, where conditions remain or can be made suitable, d) quantifying the extent to which carbon sequestration through seaweed aquaculture can be optimized, and e) conserving marsh and coastal rivers/streams buffers to protect coastal water quality including the uptake of nutrient runoff, and

to protect fish and wildlife habitat. Collectively, these projects would protect or restore important ecosystem functions that benefit coastal commercial activity, landowners, and municipalities.

Using estimates of existing blue carbon stocks and emissions, the State would be able to address climate change mitigation goals in coastal areas by a) prioritizing and implementing conservation to protect critical habitat and critical habitat buffers, including marsh migration spaces, b) identifying and implementing enhancement, restoration, and cultivation, and c) leveraging and mobilizing funds to the most appropriate actions. Achieving long-term carbon storage requires careful management of tidal marshes, eelgrass and seaweeds through conservation, restoration and protection. These actions will also produce the suite of services to communities, the ecosystem, and the economy outlined below.

a. For adaptation strategies, what climate impacts does it address? How will this strategy reduce the vulnerability of Mainers to the impacts of climate change?

Coastal and marine blue carbon *mitigation* strategies will have significant, direct, and quantifiable *adaptation* benefits that should not be underestimated, particularly in Maine where both the coastal length and coastal length-to-state area ratio are among the top ten in the United States[1]. Coastal and marine ecosystems are subject to and already experience a disproportionate level of impacts as a result of climate change as compared to other natural systems. Protecting, restoring, and managing these natural systems through Blue Carbon Optimization will inherently leverage *adaptation* by advancing ecosystem services that address multiple Maine Climate Council adaptation strategies, including "Foster the value of the State's natural resources and natural resource industries and their ability to support resilience". Ecosystem services benefits are outlined in more detail below in section 5.

b. List any site-specific geographies where the strategy would be applied.

The strategy's inventory, conservation and restoration actions would be applied across a swath of Maine's coastline at the location of existing and suitable habitat for salt marsh plants, eelgrass, and seaweed. Suitable sites for Blue Carbon Optimization are found statewide, but depend on local geography. Science-based conservation plans for tidal marshes and marsh migration opportunities have been developed by federal, local and regional organizations and partnerships at different landscape scales. Recognition of and leveraging of these initiatives will provide important "on-the-ground" support, take advantage of applied resources, and tap direct knowledge for implementation within those specific geographies. Similar statewide assessments of management and restoration of seagrasses and seaweeds are not yet available, and will depend on enhanced mapping of intertidal and shallow subtidal resources.

2. What is your measurable outcome for this strategy, assuming all recommended actions to implement the strategy are achieved?

Measurable outcomes are 1) protected and restored acreage of salt marshes, eelgrass and seaweeds to facilitate carbon burial (Gg CO2 equiv/yr), 2) prevention of carbon release from organic wetland soils (marsh peat), 3) support for strategic siting of seaweed aquaculture leases and sector-based seaweed harvest management practices to best preserve and enhance coastal habitats and

[1] According to the Congressional Research Service and NOAA.

water quality, and 4) maintenance and enhancement of ecosystem services provided by healthy, abundant salt marsh plants, eelgrass and seaweeds.

a. For mitigation strategies:

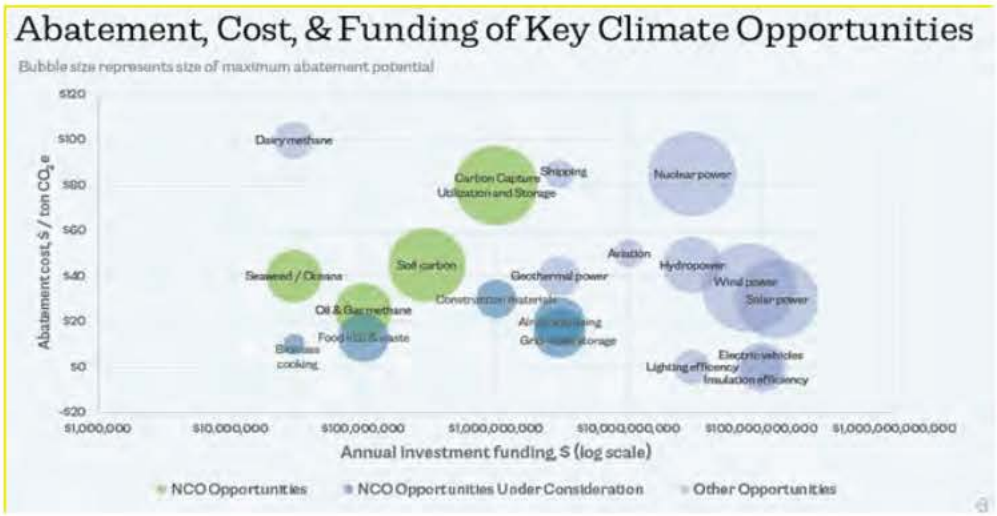
i. What is the estimated CO2e savings (metric tons) by 2025, 2030, 2050?

Estimated carbon stocks and long term burial rates for salt marsh, eelgrass, and intertidal rockweed (production rates only) were provided to ERG for the "cost of doing nothing" analysis included in the Appendices of this document, and at: https://docs.google.com/spreadsheets/d/1do00hZMmgDnYS6a-j4JvoMzMfDDuPx6A19RnZ968XnY/edit#gid=1434701238 (see tabs for "All Strategy Summary", "Blue Carbon Tables", "Salt Marsh C Data", "Eelgrass C Data", and "Seaweed C Data"). The salt marsh calculations also provided a range of GHG emissions factors. Ranges of burial rates were based on literature values for salt marshes [3] and seagrass [1]. It is anticipated that the information provided to ERG can be used to generate projected CO2 savings over time.

Recent mitigation potential estimates for 2025 for tidal wetland (marshes) and seagrass restoration in the United States are projected to be 6.7 (0.8-12.6) Mg Ce ha^{-1} yr^{-1} and 0.89 (0.37-1.41) Mg Ce ha^{-1} yr^{-1}, respectively [4]. Fargione *et al.* (2018) additionally valued seagrass losses at 89 (36-142) Mg Ce ha^{-1}, and established uncertainty of restoration potential and marginal abatement costs for tidal wetlands and seagrass.

ii. What is the cost effectiveness of those reductions (cost per ton of CO2e reduced) and the total cost?

As provided in Fargione *et al.* (2018) [4] and in section 5. below for Benefits and Costs, quantitative estimates of inventory, conservation, restoration and monitoring of mitigation success to realize CO2 reductions vary widely based on habitat type (marsh, eelgrass, seaweed) and scale. Notably, beyond the cost per ton of CO2 reduced, the co-benefits of Blue Carbon Optimization to the ecosystem cannot be overstated. For general strategy context, the following figure, courtesy of the Grantham Foundation Neglected Climate Opportunities Initiative, illustrates abatement cost vs. annual funds required for carbon capture, utilization and storage, seaweed/oceans, and soil carbon.



b. Are outcomes measurable with current monitoring systems?

Current monitoring systems are not designed to assess carbon sequestration following implementation of Blue Carbon Optimization actions, but they provide a starting point. More specifically, current imagery acquisition and mapping programs do not track mitigation successes, and thus changes in sequestration. Some data on protected or restored tidal marsh and marsh migration area are available through the State's conservation lands database, however existing mapping does not track the extent of protected tidal marsh (especially on the seaward edge) with the accuracy needed. Both greater accuracy in existing data and additional data collection to track ecosystem condition, carbon storage, and GHG sequestration-to-emission ratios will be needed to quantify outcomes for Maine's resources as specific biogeography and tidal regime may impact those metrics.

Further, there is currently not a funding mechanism for regular mapping of eelgrass beds and change over time, and no mapping strategy or methods for statewide mapping of seaweed beds that would allow for accurate measurements of these habitats' Blue Carbon potential. Without regular resource assessment, the impact of sea level rise and other coastal changes to these resources is unknown.

Measurement of the co-benefits of Blue Carbon Optimization for coastal economies and adaptation also poses challenges under current monitoring programs. Measurement of ecosystem services requires evaluating many metrics, some of which are not available for regional or Maine-specific applications, in part because of limitations on staffing or financial resources. Documenting benefits of seaweed aquaculture to the marine environment and the industry could be achieved through improved communications between scientists and business owners, through a group such as the Maine Coastal and Marine Information Exchange (proposed in a separate strategy from the Coastal and Marine Working Group).

3. What specific actions would be required to implement the strategy, including but not limited to legislation or regulation.

a. Determine blue carbon stocks and mitigation values by:

i. a comprehensive, coast-wide inventory of coastal blue carbon resources, including mapping of tidal marshes, eelgrass and seaweed beds, and measurements of carbon stocks and GHG sequestration. A comprehensive inventory also requires ground-based assessments to verify coastal vegetation extent delineation, species identification, plant metrics and condition, and soil carbon stocks.

ii. quantifying both regional GHG emissions and the mitigation potential of existing blue carbon resources. In addition to understanding local vegetation distribution and plant metrics, inventories require knowledge of rates of carbon accrual and carbon emissions under different human and land use scenarios.

iii. determining the role that strategic management of seaweed aquaculture plays in long term carbon burial and in locally reducing coastal acidification impacts.

b. Achieve mitigation potential by conserving[2]:

[2] See also Section 3.A.i. in "Promote Climate-Adaptive Ecosystem Planning and Management Using Nature-Based Solutions" strategy

i. *tidal marshes* by identifying priorities to secure GHG stores, enabling the opportunity for future sequestration despite sea level rise, and protecting the coastal ecosystem and community resilience to the impacts of climate change. Critical to managing and planning for the effects of sea level rise on tidal marshes is understanding whether current marshes will keep pace by building their elevation through sediment accretion, or will be "drowned" by higher water levels or by erosion of marsh banks. Through mapping and modeling, partners should identify potential habitat changes within tidal systems (e.g. shifts in relative abundance of mudflat, and low, high and brackish marsh) at multiple sites along the coast. Monitoring of marsh elevations must continue and expand in order to determine these trends in Maine's marshes, as accretion and erosion will differ from states to the south, and will vary along Maine's coastline. Targeted conservation of marshes that are building with sea level rise, and facilitation of tidal marsh migration by identifying potential migration space based on best available science, is integral to maintaining and improving salt marsh mitigation and adaptation to sea level rise in Maine. Where migration is the only viable option for a tidal marsh, the State should promote conservation of migration spaces to enable continued adaptation, carbon sequestration, and other important services into the future.

ii. *eelgrass* through protection of current beds and historically-mapped habitat from direct and indirect impacts of shoreline development, commercial harvesting activities, and aquaculture operations through informed lease siting, and by enhancing local and state regulations. As sea level rise occurs, the deep edges of eelgrass beds will migrate landward, necessitating buffer space to allow movement of the shallow edges of eelgrass into suitable habitat, notably Maine's current intertidal and shallow subtidal mudflats. Essential to ensuring maximum possible carbon storage in healthy eelgrass as the sea level rises, is conserving this shoreline currently valued by shellfish and worm harvesters, sought after by aquaculture lease applicants, and desired for dock and pier access by recreational and commercial users. The State must enable prioritization of high value eelgrass beds by supporting coastwide mapping of existing eelgrass to allow determinations of eelgrass with a history of perseverance, to identify development threats to migration, and to clarify the roles that different types, magnitudes and density of aquaculture development serve in sustaining eelgrass. The State should additionally institute measures to minimize impacts of moorings on eelgrass by avoidance of high value beds and use of "conservation moorings".

iii. *seaweed* by managing harvest of subtidal and intertidal species through the DMR. As waters warm and become more saturated with carbon dioxide, each of which can impact physiological processes, the primary productivity rates, photosynthetic efficiencies, growth rates, and reproductive potential of seaweeds can be altered. Critical to predicting how seaweeds contribution to blue carbon potential may wax or wane, is an understanding of species-specific responses. Since there are >250 species of seaweeds on Maine's coast, understanding biological responses of the predominant and commercially important species is integral to making generalizations about seaweed trends.

c. Achieve mitigation potential by restoring:

i. *tidal marshes* along with strategic and collaborative project development. Stable and permanently funded program(s) to coordinate and integrate current approaches under a shared vision is essential to effectively maintain and enhance carbon storage, support ecosystem resiliency and adaptation, and protect biodiversity. Program(s) should build upon existing public and private efforts, such as active research on marsh restoration within New England and the CoastWise Approach, and identify and develop new strategies to address gaps, including intertidal and subtidal planning and coordinated local implementation.

ii. *eelgrass* once informed by comprehensive resource inventory, planning and prioritization. Improve existing water quality where it is a limiting factor for eelgrass persistence. Restore eelgrass by transplanting and/or seeding in suitable locations when controlling factors permit.

iii. *seaweed* through use of aquaculture techniques, husbandry, cryopreservation, and nurseries to restore kelp (large subtidal brown seaweed) populations, particularly in southern Maine and locations affected by marine heatwaves.

d. Enhance mechanisms for conservation and restoration through funding and support for voluntary actions such as:

i. Revise eligibility and scoring of State grant programs (e.g. Lands for Maine's Future, Coastal Community Grants, Maine Outdoor Heritage Fund, Maine Natural Resource Conservation Program) to include a mechanism supporting Blue Carbon monitoring, conservation, and restoration.

ii. Develop new programs that specifically address the knowledge gaps surrounding Maine's Blue Carbon stocks, such as systematic and regular mapping of seaweed stocks.

iii. Changes in rules and regulations that support maintaining or increasing Blue Carbon sequestration, including creating formal carbon sequestration incentives or carbon permit program.

e. Enact legislation and address regulatory changes needed to restrict certain fishing methods in eelgrass beds, reduce impacts on eelgrass from traditional boat moorings, reduce intertidal and shallow subtidal habitat impacts from over- and in-water structures like docks, piers and floats, promote living shorelines in lieu of shoreline armoring, and conserve land adjacent to valuable coastal habitats. Stormwater controls for nitrogen as well as reductions in marine nutrient loading from point sources will be needed to be addressed through legislation and the regulatory process.

Specific actors needed for implementation: staff or faculty from MEGIS, DEP, DACF (MGS, BPL, LUPC, MNAP, Submerged Lands), DMR (MCP, Biomonitoring, Aquaculture Licensing), IFW, Bates College, Bigelow Laboratory for Ocean Sciences, Island Institute, Casco Bay Estuary Partnership, Land Trusts, USFWS, NOAA, Seaweed Fisheries Advisory Council, Maine Aquaculture Association, Maine Seaweed Council, Northeast Coastal Stations Alliance, Kelp Ecosystem Ecology Network, harbormasters

4. What is the timeframe for this strategy?

	Short-term (2022-2027)	Mid-term (2030)	Ongoing Actions
To implement	● Mapping of coastal habitats and measuring carbon stocks and GHG fluxes for blue carbon stock assessment could begin within a year. ● Mapping the extent of eelgrass along Maine's coastline could be completed within five years, but must be repeated on a regular cycle (e.g. every five years) to	● Restore tidal flow to restricted marshes where local infrastructure and community development allow. ● Research the use of farmed seaweed products to mitigate	● Review and revise statutes and regulations such as stormwater and nutrient laws that will improve and protect the health of these habitats. ● Prioritize conservation and restoration projects as well as opportunistic actions. ● Funding source identification underlies

	assess change and document areas of loss or gain. ● With proper funding, restoration of recently identified tidally restricted marshes could begin within one to two years. ● Strategically site aquaculture operations to best foster eelgrass restoration and resilience. ● Develop carbon flux and storage estimates from farmed and natural seaweed beds to develop methods and a carbon and nitrogen accreditation system. ● Compile existing but disparate databases of intertidal and subtidal standing stock seaweed biomass.	greenhouse gas emissions. ● Research species-specific seaweed responses to seawater warming and CO2 enrichment. ● Research uses of seaweed products to maximize CO2 sequestration and mitigation potential.	all conservation and restoration actions, whose implementation will occur over all time scales. ● Develop and refine monitoring strategies that harness existing efforts, consider existing authorities, and collaborate across a network.
	Short-term (2022-2027)	**Mid-term (2030)**	**Long-term (2050-)**
To realize outcomes	● The number of seaweed aquaculture lease applications continues to increase; outcomes based on cultivated seaweeds could be realized very quickly (2-5 years) with strategic planning and siting.	● Initial ecosystem benefits of salt marsh and eelgrass restoration and enhancement will begin being realized with declines in methane emissions.	● Ecosystem benefits of salt marsh and eelgrass restoration and enhancement fully realized with improved carbon burial.

5. Please analyze the Recommended Strategy against the following criteria.

Workforce - Will the strategy create new jobs, prevent job loss, or cost the state jobs?	Coastal blue carbon stock quantification and habitat restoration requires support from the scientific (remote sensing and Geographic Information Systems (GIS) experts, biologists, geologists) and engineering communities, policymakers, agency staff, consultants, construction companies, and offers volunteer opportunities for Maine's youth and citizen scientists. Coastal recreational businesses would be bolstered by healthy and abundant nearshore vegetation. Marine fisheries, including the lobster industry, shellfish aquaculture, and recreational striped bass fishery, will continue to observe nursery benefits for commercial harvest, which provide economic support for fishermen, processors, markets, restaurants, and

	local consumers. Seaweed production and harvest presents a diversification strategy for the working waterfront, new jobs, and additional revenue streams (beyond high-value nutritional, edible products, nutraceuticals, and pharmaceuticals) by removing carbon and nitrogen biomass from the marine environment and selling credits in voluntary markets. Processing and distribution of seaweed for fertilizers, animal feed, biogas production, and biochar represents additional jobs and revenue streams that also have quantifiable impacts on improving water quality and mitigating GHG emissions.
Benefits (non-workforce) - What are the expected co-benefits of this strategy (e.g., improved health, increased economic activity, wildlife habitat connectivity, reduce natural hazard risk, increased recreation, avoided damage)?	Residents of and visitors to coastal communities will benefit from conservation and restoration of coastal habitats. Through the identification of treasured, at-risk salt marshes, especially those that may be tidally restricted, educational opportunities exist to build community surrounding a shared appreciation for Maine's habitats and their values, including the iconic species they support. ***GHG Sequestration*** The beneficial role of blue carbon has been described and enumerated in Maine's Carbon Budget, a fact sheet compiled by several of Maine's scientists. The Maine Climate Council's Scientific and Technical Subcommittee Phase I Working Document reviews coastal and marine habitat roles in carbon capture rates and carbon storage in Appendix 3 (pp 151-153). Importantly, Appendix 3 specifically addresses the potential role of components of the seaweed community in carbon storage, and calculates the sequestration rate contribution of Maine's rockweed population. Similarly, Maine-specific calculations can be completed for salt marsh plants and eelgrass, albeit with many assumptions, limitations and inherent accuracy error until coastal habitats can be more comprehensively inventoried. ***Ecosystem Services*** Globally, ecosystem services values for seagrass/seaweed beds and tidal marsh/mangroves (not found locally) have been estimated at $46,960 and $24,686 per acre per year (1994 USD), respectively [5]. An estimate specific to Southern Maine coastal wetlands assigned a total ecosystem services value of $1,399 per acre per year (2011 USD) [6]. Specific services have also been enumerated, including a coastal wetland protection value of $23.2 billion per year for US coastal storm protection [7]. In addition to the long term carbon storage benefit described by blue carbon, coastal and marine ecosystems that are maintained and restored will achieve their natural capacity to support diverse species assemblages, benefit fisheries, improve water quality, bolster wave attenuation on coastal properties, provide vital flood storage and erosion abatement, and enhance recreational services (kayaking, boating, hunting, hiking, birdwatching). Healthy coastal and marine ecosystems comprise the viewscape that is so valued by Maine residents and visitors. Ecosystem services addressed through optimization of salt marshes, eelgrass beds, and natural and cultivated seaweed beds include: 1. protection of water quality by removal of excess carbon, nutrients, and suspended solids from the water column. These habitats filter either groundwater (saltmarshes and eelgrass) or bulk seawater (eelgrass and seaweed) and remove excess nitrogen and phosphorus, thereby preventing growth of algae. By filtering nitrate, these habitats essentially provide tertiary treatment for no cost. Seaweed cultivation and eelgrass restoration

	techniques allow for targeted placement of permitted farms and beds, respectively, at wastewater outflows or where non-point source nutrient loading is prevalent. These habitats also contribute to the coastal food web by exporting partially decayed plant matter and moving nutrients from marshes into coastal waters, thus acting as the "breadbasket" that helps support commercial and recreational fisheries. 2. protection of existing natural shorelines through wave attenuation, and facilitation of sediment transport and landward migration. 3. production that rivals that of agricultural systems. 4. maintenance of habitat and food availability to support the base of Maine's nearshore marine ecosystem. Unique to tidal marshes are the: 1. accumulation of peat, which stores carbon and elevates shorelines, a first defense against rising sea levels. 2. ability to provide co-benefits to neighboring habitat. Research in Waquoit Bay, Massachusetts, provided compelling evidence that salt marshes help nearby eelgrass beds thrive. Areas of the bay that featured large salt marshes tended to have large eelgrass beds while areas with less salt marsh had smaller eelgrass beds. By removing nitrogen, the salt marshes reduced growth of blooming phytoplankton and seaweed, which block the sunlight needed by eelgrass. Unique to eelgrass and seaweed are the: 1. Essential Fish Habitat (EFH) and Habitat of Particular Concern designations under the Magnuson-Stevens Fishery Conservation and Management Act in 1996. A provision was added to the Northeast U.S. region in 2018 recognizing kelp forests as EFH. Eelgrass and seaweed provide nursery grounds and refuge for juvenile fishes, including Atlantic herring that support the lobster industry, and commercial groundfish species like Atlantic cod and pollock. 2. capacities to locally and seasonally buffer the effects of coastal acidification through consistent primary production.
Costs – What are the estimated fiscal costs and other costs to carry out this program. To the state? To municipalities? What resources do you anticipate needing to inform Mainers about the strategy and the opportunity/costs	• Mapping is most efficiently completed with remote sensing techniques like plane-based aerial imagery, and Light Detection and Ranging (LiDAR) for marshes and intertidal vegetation. Remote sensing conducted by unmanned aerial vehicles (UAVs), such as drones, or underwater techniques including sonar, are useful on small spatial scales and may allow for greater discernment among blue carbon stock types. Free or low-cost satellite remote sensing products provide excellent spatial and historical coverage but at coarser resolution than plane-based or UAV imagery, resulting in less accurate inventories when used in isolation. Many of these methods produce data and products that serve multiple monitoring needs, and therefore costs can be shared among efforts. Of specific note is that many of these methods are also described in the CMWG Monitoring Strategy, and also can provide information necessary for community planning, infrastructure, shoreline change assessment, and other management purposes - costs should be considered duplicative as the

of the strategy? Where would financing likely come from?	efforts can be completed for multiple needs at once and achieved through cost-sharing. o Accurate mapping of coastal blue carbon stocks using aerial photography is estimated to cost approximately $250,000 annually for five years (⅕ of the coastline each year for five subsequent years)(see Maine pending legislation for LD 559 described below). This annual cost includes new DEP staff resources needed to manage the program, groundtruth selected field sites, and generate GIS coverage layers *as they pertain to eelgrass only,* although importantly, imagery could be used to map salt marshes and intertidal seaweeds with additional personnel resources. Groundtruthing of remote sensing products for seaweeds using *in situ* biomass verifications will additionally require limited upfront costs associated with personnel efforts. o Funds to support localized, short term eelgrass mapping efforts (~$50,000) have recently been compiled by the DEP through an existing federal (Environmental Protection Agency) grant, and partnerships between state agencies, the Casco Bay Estuary Partnership (Maine's only National Estuary Program), and environmental non-profits. o Partners throughout the State have recently mobilized to secure funding to collect high resolution coastal LiDAR in Southern Maine that can be used to determine salt marsh elevations. This effort should continue to be supported in the future to collect LiDAR from other portions of the state, and should be repeated on a regular schedule in the future to determine change. o In addition to existing recent low tide aerial imagery for Casco Bay and opportunistic data sets for other coastal segments through the Maine Office of GIS's Orthoimagery Program, cost of inventory of priority coastal habitat restoration locations could be offset by use of the more than 1,000 existing mapped tidal marsh restrictions compiled by the Maine Coastal Program. o The Maine Economic Improvement Fund Small Campus Initiative has dedicated $130,000 to Maine Maritime Academy, Schoodic Institute, and the Bigelow Laboratory for Ocean Sciences to develop UAV tools for surveying rockweed (to complement the existing CRASSH research program). Supplemental funding from the Bigelow Center for Seafood Solutions and the Broad Reach Fund additionally support this work. o Other funding opportunities, like the Blue Natural Capital Financing Facility, offers support to kick-start self-sustaining blue carbon programs. ● Carbon sequestration projects subject to blue carbon and nitrogen credits in voluntary markets must undergo verification and methodology approval processes, performance reviews, and annual monitoring from a third party. One such third party is Gold Standard, an organization that evaluates carbon emission mitigation programs. Gold Standard has been contacted for cost estimates specific to Maine applications. ● Cost estimates for emissions factors depend on the level of precision required and are influenced at least by site location and amount of annual rainfall.

	Emissions factors can be obtained from the literature with a +/- 20-30% degree of uncertainty, and can also use proxies to facilitate general cost estimates. ● For the entire Gulf of Maine, the estimated cost for five years to assess and mitigate impact of sea level rise on salt marshes through conservation of marshes and adjacent buffers would be $12.5 million (see U.S. Gulf of Maine Habitat Restoration and Conservation Plan (2010)). An estimate for Maine only would likely vary from 10's of thousands to more than $1 million per project site, depending on site factors, restoration practice, etc. Funding mechanisms such as transfer tax for coastal properties may help to offset costs. ● Restoration costs for eelgrass vary widely based on many factors including the method and expertise of personnel used, planting or seeding density, site accessibility, as well as monitoring plan, which is generally the most expensive portion of total costs. A total eelgrass restoration cost per acre was calculated at $245,000 (2001 USD) [8] and more recently, at $948,072 (2010 USD) [9]. ● Expanded capacity for the DMR to review aquaculture lease permit applications and coordinate with the Maine Seaweed Council and Seaweed Fisheries Advisory Council is needed to incorporate sector-based management of seaweed resources. ● At a minimum and *in the absence of* conservation of existing coastal blue carbon stocks due to barriers to marsh migration or degradation of nearshore water quality for eelgrass survival, e.g., habitat quality and quantity will decline, leading to loss of existing sequestration capabilities and associated ecosystem services.
Equity - Is this strategy expected to benefit or burden low-income, rural, and vulnerable residents and/or communities? What outreach has been/will be undertaken to understand the impact of the strategy on front-line communities?	● Understanding where to conserve, enhance and restore marine coastal habitats will provide continued and improved enjoyment of Maine's natural resources for all populations, communities and sectors. ● Tidal marsh restoration that focuses on tidal crossings, if done following best management practices for tidal rivers, will protect roadways, access to communities for emergency services, commerce, tourism, and public safety. Poorly designed tidal crossings that do not allow full tidal exchange are subject to flooding in particular during storms, scour and erosion, and poorly prepared for increased flooding due to sea level rise. Many vulnerable communities (low elevation, elderly, low income, non-English speaking, rural) rely on roads that cross tidal streams. See TNC's coastal resiliency viewer and Coastal Risk Explorer at https://maps.coastalresilience.org/maine/ ● Seaweed farming in Maine is a fisheries sector that is ~30% women-owned and has the fastest return on investment of the current aquaculture options in the state. Thus, seaweed aquaculture offers an opportunity for an underrepresented group in fisheries to generate revenue with relatively low capital expenses.
Proven strategy & feasibility – Has this strategy been implemented successfully	* Detailed information on blue carbon calculations including emissions inventory, blue carbon finance, asset generation, and coastal wetland conservation and restoration methods and considerations, are available through the International Blue Carbon Initiative's [10] and Restore America's Estuaries [11] manuals. ***Blue Carbon Leadership***

elsewhere? Is it feasible with today's technology? What barriers to implementation exist (e.g., financial, structural, workforce capacity, public/market acceptability)?	• Bates College faculty and collaborators are in the process of synthesizing statewide carbon density datasets to create maps of salt marsh carbon stocks in Maine. This work is informed by recent mapping efforts by the Maine Coastal Program that identified nearly 1,100 tidal restrictions in coastal marshes, the removal of which will result in significant carbon benefits for the state. • Coastwide eelgrass mapping and long-term monitoring programs exist in New Hampshire (NH), Massachusetts (MA), and the U.S. Pacific Northwest. NH, MA and Washington utilize a number of predictive models to determine site suitability for eelgrass enhancement and restoration. Conservation and mitigation projects, such as those using "conservation moorings", have been employed in Massachusetts. • Currently in development with over thirty Maine partners representing multiple agencies in the State of Maine, federal agencies, academic institutions, and non-governmental organizations, the CoastWise Approach will provide a voluntary set of science-based, field-tested best practices for communities, private road owners, engineers, and other people interested in designing climate-resilient tidal road crossings. With CoastWise, the intent is to steadily reverse centuries of impacts to marshes and other tidal habitats by designing safe, low maintenance crossings scaled to accommodate sea level rise and restore natural tidal flow. Maine Coastal Program and partners have initiated Phase 1 of the CoastWise project: development of tools, decision-making methods, and guidance materials; this phase will be complete in fall 2020. Phase 2 will focus on creating and implementing outreach and training for the approach; trainings are anticipated to begin in 2021. • The Kelp Ecosystem and Ecology Network and Northeastern Coastal Stations Alliance are long-term monitoring groups using traditional observational methods to determine the relative abundance and biomass of intertidal and subtidal seaweed species, respectively, in the Gulf of Maine. Alaska is the only other state whose growth in the seaweed aquaculture industry rivals Maine's; otherwise, we must look to other Nordic and EU nations (e.g., Norway, Faroe Islands, Ireland) to find examples of thriving seaweed farming industries capitalizing on blue carbon potential. • The Coastal Carbon Research Coordination Network, a National Science Foundation-funded initiative, brings together nation-wide blue carbon data and scientists to reduce uncertainty in the science. • The Massachusetts Division of Ecological Restoration (DER) is an example of a growing government office that has partnered to complete more than 100 projects to repair and enhance habitat quality and quantity, including restoration of tidal flow to salt marshes. The DER uses a Blue Carbon Calculator to locally calculate GHG emissions reductions through wetland restoration. ***Specific Project Examples*** • The "Bringing Wetlands to Market" (BWM) program, which is a collaboration funded by NOAA and carried out at the Waquoit Bay National Estuarine Research Reserve (NERR). One of the project's most important assets is the creation of predictive models for determining the suitability of a salt marsh blue carbon project. Partnership with the BWM program has enabled the Herring River Tidal Restoration project on Cape Cod, and informed Alaska's Kachemak

	Bay NERR staff, which assess blue carbon values in the Kenai Lowlands to quantify values and prioritize conservation measures. ● The Snohomish Estuary Restoration project in Washington has been assessed for blue carbon and climate mitigation benefits. ● The Pacific Northwest Blue Carbon Working Group and academic partners measured sequestration rates and capabilities in coastal wetlands, and identified historic and current tidal wetland habitat to inform restoration opportunities. ● The Port of Seattle Blue Carbon project supports a pilot study in Puget Sound to understand seagrass and seaweed contribution to carbon uptake and sequestration and is partially supported by the WA Dept of Natural Resources. ● The Blue Carbon at Elkhorn Slough project in Monterey, CA was partially funded by the CA Dept. of Fish and Game.
Legal authority - Does the strategy require new statutory (legal/legislative) authority?	While the strategy's mitigation value and potential determinations do not require statutory authority, existing and proposed legislation would streamline the accomplishment of prioritized conservation and restoration actions. Specific legislation shown below would facilitate or provide a model for completing Blue Carbon Optimization tasks outlined in 1. above. ***Maine*** ● 38 MRS § 480-Z: The Maine's Natural Resource Protection Act's In Lieu Fee Program collects compensation payments and distributes them through the Maine Natural Resources Conservation Program. A competitive grant program, the compensation fund "must be a fund dedicated to payment of costs and related expenses of restoration, enhancement, preservation and creation projects." An amendment to the In Lieu Fee Instrument would be needed to make coastal habitat mapping, blue carbon inventory, and/or restoration planning actions eligible for funding in any way (e.g. as part of a measurable restoration project). ● 38 MRS §420-D: Stormwater management regulates development disturbing one acre or more of area. The statute directs DEP to develop rules specifying quantity and quality standards for stormwater. Stormwater quality standards for projects with 3 acres or less of impervious surface may address phosphorus, nitrate and suspended solids but may not directly address other dissolved or hazardous materials unless infiltration is proposed. ● LD 559: Addressed during the 129th legislature, 2nd session, this bill would establish a coast-wide mapping program for seagrass, to be managed by the Department of Environmental Protection. With sufficient funding yet to be established, the legislation would implement a program to provide low tide coastal imagery for mapping of seagrass, intertidal seaweed, and salt marsh vegetation. ● LD 923: An Act To Authorize a General Fund Bond Issue To Upgrade Municipal Culverts at Stream Crossings should continue to be funded through bond or state resources in order to support a funding mechanism for replacing tidal road crossings with climate resilient crossings that protect and restore tidal marshes and habitat.

	• LD 1719: Addressed during the 129th legislature, 2nd session, this bill would support the creation of a Geolibrarian and GIS Information Officer as well as annual data acquisition. With sufficient justification, staff and data acquisition activities could support coastal blue carbon quantification and restoration prioritization. ***External to Maine*** • In 2016, California created the Ocean Protection Act through SB 1636, which included a provision to incorporate "consideration of carbon dioxide removal for eelgrass restoration projects during the habitat restoration planning process in order to fully account for the benefits of long-term carbon storage of habitat restoration in addition to the habitat value." A comparable action taken in Maine could achieve the blue carbon optimization goals outlined in this strategy. • HR 1716 and S 778, the Coastal Communities Ocean Acidification Act of 2019, which would allocate funds to the National Oceanic and Atmospheric Administration to conduct a vulnerability assessment, including economic impact on and possible adaptations or local or regional commercial fisheries and recreational opportunities.

6. Rationale/Background Information

Additional research and data are needed to address data gaps related to this strategy:

- Additional research is needed on feasibility of using high resolution satellite imagery and bathymetric LiDAR for submerged aquatic vegetation mapping.
- Poorly understood is the character and magnitude of eelgrass and eelgrass habitat impacts from shallow water wild fisheries and aquaculture operations.
- Methane emissions in tidally-restricted marshes; only a few case studies exist in the state, yet restoring tidal flow to salt marshes is an important avenue towards optimizing blue carbon ecosystems.
- Carbon stocks and accrual rates in tidally-restricted vs not tidally-restricted marshes.
- How to best position Maine to trade blue carbon offsets on carbon markets. Maine has over 900 known tidal restrictions (and an unknown number of marsh impairments due to ditching) that provide restoration opportunity and climate mitigation benefits, providing important trading opportunities.
- Potential changes (decrease in methane release, increase in carbon storage) if the potential marsh restoration projects are all addressed.
- Identify to what degree are seaweed along Maine's coastline contributing to long term carbon sequestration.
- Predictive models of how warming and carbon dioxide fertilization will impact primary productivity of blue carbon contributors.

Citations (.pdf documents available at https://drive.google.com/drive/u/0/folders/141uvh7eCrp2vRphDla_2RmGBoJDAw2NI)

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Strategy 4 - Promote climate-adaptive ecosystem planning and management using nature-based solutions

1. Recommended strategy and how it addresses Maine's climate resiliency and mitigation goals.

This Ecosystem-based Adaptation Strategy identifies actions that leverage a range of tools (regulatory, voluntary, incentive-based, best management practice) which are demonstrated to promote ecosystem resiliency and protect vital functions while adapting to changing environmental conditions, harnessing our natural resources, and protecting communities and biodiversity. The outcomes of this strategy include job creation, improved restoration and conservation utilizing existing regulatory tools and based on current science, new climate-adaptive approaches to land management, technical assistance for municipalities, and land-owner incentives.

Maine's land owners, land managers, marine planners, and municipalities are increasingly recognizing that they not only need to prepare for climate-change related shifts and disturbances to coastal and marine ecosystems (and the services, communities, and economies that depend upon them); but also that there are a range of well-studied, scalable, nature-based solutions that will allow for climate adaptation and result in a suite of co-benefits to communities, ecosystems, and biodiversity alike.

Coastal and marine systems are unique in the complex relationship between land, fresh water, and sea. Perhaps this is best illustrated by the concept of cross-shore ecosystem services. For example, seagrasses and marsh vegetation act as natural barriers to wave action (studies have found that 15 feet of marsh can absorb 50% of wave energy [1]), and are habitat for many coastal and marine fishes and birds, including many State Species of Greatest Conservation Need. Vegetated buffers to streams, freshwater wetlands and coastal marshes slow overland runoff and reduce inputs of sediment and nutrients into those aquatic and estuarine systems. And species move from terrestrial to marsh and ocean to marsh systems daily for feeding, nesting, and protection. Further, marine ecosystems support a large proportion of the Maine economy through fisheries and aquaculture, industries that rely on resilient and robust marine habitat and ecosystems and are directly and indirectly impacted by the "upstream" condition of contributing land and water through marine food webs and impacts on nearshore marine habitat quality (e.g. shellfish harvest closures due to polluted runoff).

This strategy will address several Adaptation goals put forth by the Maine Climate Council and LD1679. Both climate adaptive planning and nature-based solutions are inherently intertwined with thoughtful, science-based protection, restoration, or management of healthy, resilient ecosystems and the biodiversity they support. There is tremendous opportunity for compounded benefits to people, species, habitats, and economies that should not be overlooked.

In particular, this strategy:

1) Highlights climate-adaptive planning in marine, coastal, and inland areas by identifying those climate change related impacts (e.g. more intense storms resulting in increased runoff and flooding, sea level rise and storm surge, increase in sea temperature leading to reduced amount of kelp forests) that impact ecological systems, and the relevant actions that should be taken to adapt to and proactively plan for these changes to reduce or mitigate financial,

social, and biological impacts. Climate-adaptive planning is relevant for regulatory agencies, private developers, engineers, conservation organizations, large landowners, land stewards, municipalities, wildlife managers, and more. It includes adoption of nature-based solutions into the catalog of planning tools, and making these more widely accessible for this suite of planners, regulators, landowners, and resource managers. A coordinated outreach effort is necessary for this integration, such as through a dedicated program in a State Agency (akin to the former State Planning Office) or other existing outreach programs (such as Beginning with Habitat or Coastal Training Program), or other assistance channels for land trusts (in particular for easement term language and management plan development). In addition, training and practices should be channeled through the proposed *Maine Coastal and Marine Information Exchange* (as put forth by the Coastal and Marine Work Group). An approach to planning that incorporates forecasting and responding to climate change impacts will directly address several of the adaptation goals in LD1679 including fostering natural resource functions, encouraging investments that prevent risk (e.g. inland conservation, dune restoration), reliance on most up to date science on predicted impacts from climate change, and encouraging equity by making solutions more widely available, practicable, and supported.

2) Promotes nature-based solutions (also known as natural infrastructure, green infrastructure) for climate change related challenges that are impacting our non-tidal and coastal rivers, shorelines, and coastal and marine habitats (marshes, dunes, beaches, bluffs, and off-shore habitats). In distinct ways, adaptation plans that allow for nature-based solutions harness the functions of ecosystems, are based on the most recent scientific and technical studies for specific systems, build upon existing momentum in the state (e.g. Living Shorelines and green infrastructure for stormwater), foster the value of Maine's natural resources, and proactively mitigate risk for the state's citizens and infrastructure often with less expense. All while continuing to protect biodiversity and ecological resilience; these are inextricably linked.

Because this Strategy includes a focus on land use and actions that will also provide community protections, it is expected that there will be some overlap (and certainly compatibility with) with Strategies put forth by the *Natural and Working Lands Working Group, Community Resilience, Public Health, and Emergency Management Working Group, and Transportation Working Group*.

a. For adaptation strategies, what climate impacts does it address? How will this strategy reduce the vulnerability of Mainers to the impacts of climate change?

Among the key ways to adapt to climate change and bolster resiliency is to identify and adopt nature-based solutions into development, planning, and management practices. The International Union for Conservation of Nature (IUCN) defines nature-based solutions as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". Examples of nature-based solutions include integrating salt marshes into coastal zone hazard mitigation and climate change adaptation policies, as recommended by coastal practitioners [2], or reforestation of riparian areas to protect water quality, cold water fisheries habitat, and floodplain and terrestrial connectivity (and even mitigate GHG emissions through additional carbon sequestration) [3].

In particular, this adaptation strategy **addresses the following climate impacts through planning, using best management practices, and implementing green infrastructure or nature-based solutions**:

- Loss of marine and coastal biodiversity
- Increasing vulnerability of coastal infrastructure including roads and low-lying development
- Beach, dune, salt marsh and other coastal habitat loss that will impact vulnerable species as well as human development, tourism, and recreation
- Changes in marine habitat and species assemblages
- Increased nutrient loading due to more intense and frequent storm events

b. List any site-specific geographies where the strategy would be applied.

The strategy's inventory, conservation and restoration actions would be applied across a swath of Maine's coastline. The geography of the identified actions are at the statewide and local scale. In many cases, statewide actions are needed to implement local on the ground projects. Science-based conservation and restoration guidance and plans have been developed by federal, local and regional organizations and partnerships at different landscape scales. Recognition of and leveraging of these initiatives will provide important "on-the-ground" support, take advantage of applied resources, and tap direct knowledge for implementation within those specific geographies. Maine's relatively rural and undeveloped coastline also provides significant opportunity for nature-based solutions; a recent Manomet study found that "In landscapes that are not yet significantly urbanized, applying a green infrastructure approach to land use planning can reduce long-term infrastructure costs, enhance ecosystem service delivery and support transit oriented development patterns." [4]

2. What is your measurable outcome for this strategy, assuming all recommended actions to implement the strategy are achieved?

The outcomes of this adaptation strategy include:

- Conservation of marine and coastal biodiversity through habitat protection that allows species to shift as needed based on climate forcing and realizes no net loss in habitat type and quality;
- "Climate-ready" coastal infrastructure including roads and low-lying development that is designed and constructed to allow for sea level rise, increased storm surge, and freshwater flooding, while at the same time having lower long-term maintenance costs and protects aquatic passage, in-stream habitat, and the surrounding terrestrial habitat;
- Protection and maintenance of beach, dune, salt marsh and other coastal habitats that will in turn allow support vulnerable species, as well as protect low-lying human development, tourism, and recreation values;
- Reduced nutrient loading due to installed stormwater infrastructure, that is designed and constructed for more frequent and stronger storm events, and better monitoring that determines problem areas; and
- Increased understanding and participation of municipalities, regional entities, and state programs using climate adaptive management and planning practices.

a. For mitigation strategies:

i. What is the estimated CO2e savings (metric tons) by 2025, 2030, 2050?

ii. What is the cost effectiveness of those reductions (cost per ton of CO2e reduced) and the total cost?

While this strategy does not directly have a CO2e savings, there are costs associated with a "do nothing" scenario, for example lost marsh ecosystem services (including carbon sequestration), lost revenue from tourism under beach loss scenarios, and higher costs of emergency infrastructure repair due to washout or flooding. Recent research has attempted to determine both qualitative and quantitative costs and benefits of many of these ecosystem services, adaptive strategies, and the benefits to coastal communities. In *The Economic Contribution of Casco Bay* [5], important community and tourism activities such as boating, beach-going, recreational fishing, and bird/wildlife watching were determined to be negatively impacted by many climate-change issues, such as increased precipitation and water pollution, beach erosion, and shifts or declines in native species (See Table 1). Regarding the cost-effectiveness, an Environmental Defense Fund study [6] found that beach nourishment, vegetated dunes creation, and marsh restoration all showed high confidence in reducing coastal erosion by providing shoreline stabilization, reducing high tide flooding associate with sea level rise, stabilizing shoreline sediment, and reducing the force and height of medium waves and provided cost estimates for these restoration practices based on a comparison of multiple studies (See Table 2).

b. Are outcomes measurable with current monitoring systems?

While there are some existing monitoring systems, they are not designed to assess coastal and marine habitat conservation and restoration, there is a need for better documentation of the current opportunities for projects, tracking of project implementation, and monitoring of projects to document whether restoration projects are achieving their targeted goals. More specifically, current mapping programs do not track mitigation successes, there is not stable funding for mapping programs to both acquire data for the entire coast or on a repeated and regular basis to document change, and on-the-ground monitoring of habitat and water quality needs to be expanded. Without regular resource assessment, the impact of sea level rise and other coastal changes to these resources is unknown.

Measurement of the benefits of planning and management using nature-based solutions requires evaluating many metrics, some of which are not available for regional or Maine-specific applications, in part because of limitations on staffing or financial resources. Some identified research needs are:

- Determining human perception of different conservation and adaptation strategies, including the values placed on ecosystem services, as suggested in a study by Field et al. 2017 [7].
- The Maine Climate Council Scientific and Technical Subcommittee (MCC STS) identified a need for monitoring beach and dune erosion, accretion, and shoreline sediment budgets, and beach nourishment and dune restoration for longevity and efficacy (MCC STS 2020 [8]).
- Researching the public health consequences of coastal flooding and the anticipated amplification of this human health hazard due to climate change, a critical need as noted by a recent study into the linkages between the oceans and human health [9].
- Additional monitoring to measure nitrogen levels in stormwater.

- Determining how construction of "living shorelines" will function in coastal Maine where sea ice can interact with the built or restored environment (MCC STS 2020 [8]).
- Enhancing efforts to define coastal and marine habitat descriptions and map these habitats to better anticipate how to manage these resources for the future. There is an intense need to know where our coastal habitats are located as we try to model, manage and plan for the effects of climate change on marine species assemblages, trends, habitat use, and habitat quality.

3. What specific actions would be required to implement the strategy, including but not limited to legislation or regulation.

A. Ecosystem Conservation and Restoration - *to Protect and Restore Ecological Functions and Adapt to Climate Change*

i. Conserve and restore ecosystems to foster resiliency, *and* for the full suite of values, including the biodiversity-related, ecosystem service, and nature-based solutions they provide. Climate change is one of the largest threats to biodiversity everywhere in the world. Loss of habitat (conversion) and invasive species are also primary threats. Protecting ecosystems and restoring degraded habitats directly benefits biodiversity, rare species, and species most vulnerable to climate change, with transcending values for communities, socio-economic systems, and human health and wellness. Outreach and promotion for conservation and restoration actions should highlight not only the values for species and habitats but also the opportunity for such action to foster ecosystem services, including the nature-based solutions they are already "quietly" providing which will save tax-payer dollars and reduce risk.

Actions include:

- ***Conservation and/or targeted restoration*** *of eelgrass beds, salt marshes, streams and rivers, riparian and coastal wetland buffers, sand dunes, and beaches**.** All of these natural communities are linked as systems and therefore the actions identified here are meant to be integrative and more holistic, to protect and restore functions at meaningful scales.*
- ***The continued support for or development of new, stable funding mechanisms and the concurrent development and mainstreaming of incentives*** *(such as payment for ecosystem services) and other means of voluntarily restoring/conserving natural systems. This would allow for increased opportunity and proactive ability for property owners, municipalities, and conservation organizations to adapt to coastal flooding, manage increased stormwater flows, and maintain ecosystem functions through habitat restoration and protection. Climate change science and adaptation planning should be integrated into current funding program scoring criteria on land conservation and restoration projects (e.g. Land for Maine's Future, Maine Natural Resources Conservation Program, Maine Outdoor Heritage Fund) and any new climate financing tools.*
- ***Develop and promote best practices, management tools, and integration of the latest science on climate change adaptation and resiliency strategies into easement and management plans, to protect biodiversity and ecosystem function****. Management guidelines (and technical support for implementation) will guide and*

inform easement language by Maine land trusts, public land managers, and municipal open space planners and management planning on fee-owned lands. For example, include increased forested and vegetative buffers as a management recommendation on conservation lands and/or private lands management, fostering carbon storage, maintaining water temperatures, buffering storm surges and sea level rise, and filtering runoff.

ii. Restore hydrological connectivity in coastal watershed freshwater streams and tidal systems: Coastal marshes and tidal streams need the full ebb and flow of the tides to remain healthy enough to provide benefits important to public well-being, healthy ecosystems, and species movement. The health and connectivity of non-tidal streams is also of significant importance for their role supporting nearshore coastal ecosystems, and for the tremendous wildlife, human, and biological values they provide in and of themselves. In sum, in-stream and riparian corridor connectivity and healthy habitat are critical for a suite of plants and animals including most of Maine's invertebrates, coastal and marine fishes, tidal wading birds and waterfowl, and should be considered on a functional scale of river, stream, and tidal marsh networks that extend from tidal outlets to above head of tide.

Maine has two key initiatives that can help guide this effort of protecting connectivity, stream health, and function, and properly restoring those attributes in both tidal and non-tidal streams *with climate change in mind.* Since 2011 Stream Smart, a program led by Maine Audubon and other partners, has led trainings and workshops statewide on the value of "letting a stream be a stream" and voluntary guidance on how to design more stream-friendly road crossings. A statewide field survey has found that "...up to 90 percent of Maine culvert crossings make movement difficult or impossible for wildlife at least part of the year" [10] which includes fish, mammals, and other aquatic organisms. The Stream Smart approach protects natural connectivity and aquatic organism passage, and is a valuable way to support those downstream and nearshore coastal ecosystems especially as part of a more 'holistic' approach to freshwater stream network/river/watershed restoration. The CoastWise Approach led by the Maine Coastal Program and other partners, is currently developing guidelines to mediate or remove tidal restrictions while providing safe, low-maintenance, climate-resilient crossings. The resulting CoastWise Approach will be voluntary, standardized (yet adaptive), efficient, climate-tuned, and useful to both road owners and restoration practitioners. At over 900 locations in Maine (over 90% of all tidal crossings), tidal flow is hindered and sometimes completely blocked by man-made structures like culverts, bridges and dams. These tidal restrictions are most often caused by road crossings often traditionally designed in a way that does not take into account the need for marsh health and stream connectivity. Commonly, road crossings are undersized and perched above the marsh creek channel so they cannot adequately accommodate present or projected tidal flows and block the movements of fish and wildlife through the crossing for some or all of the tidal cycle. Tidal restrictions change the physical, chemical, and biological characteristics of a marsh. Depending on the degree of tidal restriction, impacts can include rapid, complete tidal marsh loss, reduced tidal sedimentation (preventing marshes to keep pace with sea level rise), and upstream methane and greenhouse gas emissions.

Both freshwater and tidal restrictions impede or block fish passage, yet sea run fish that travel from the ocean to the freshwater as part of their life cycle require these critical connections between habitats along the coast. With increasing rainfall and sea level rise, these traditional gray infrastructure crossings are also at greater risk of damage or failure since many have not been designed to withstand these changing conditions.

Actions include:

- ***Creating incentives*** *for coastal road owners, including municipalities and private owners, to replace crossings with correctly sized spans that allow for aquatic organism passage, maintain or improve surrounding habitats, including salt marsh, and allow for increased flooding due to climate change, including freshwater flooding from more frequent and intense storm events and tidal flooding due to sea level rise and storm surge. These incentives could include scoring mechanisms on State and private grants, mandating that Comprehensive Plans identify vulnerable crossings and at-risk coastal habitat to be eligible for funding*
- ***Providing no-cost trainings and materials*** *through the Stream Smart and Coast Wise workshops with the sustained support of State and partner resources*
- ***Increased funding towards climate-adaptive upgrades to road crossing infrastructure*** *following the practices of Stream Smart (freshwater non-tidal) and Coast Wise (tidal) will significantly improve our climate adaptation and benefit communities, habitats, and animal life.*
- ***Aquatic and marsh ecosystems should be managed in a way that also protects the surrounding riparian areas.*** *This more holistic approach will also limit excess freshwater input and nutrient pollution and provide necessary habitat for many species that use marsh, stream, and adjacent riparian systems - especially in fragmented landscapes and as atmospheric temperatures rise (climate refugia). Examples include maintaining buffer areas around wetlands, streams, and other aquatic habitat and incentivizing long-term land protection around wetland and riparian areas.*

iii. Protect and restore beaches and sand dunes: Like coastal marshes, beaches and dunes will need to migrate inland with sea level rise in order to persist and continue to support both biodiversity and community resilience. As a result, conservation of inland areas is critical to providing that migration space, and barriers to inland migration (roads, development, etc.) need to be made more permeable. Furthermore, as Maine's beaches and coastal community development face climate change risks from sea level rise and increased erosion from more frequent, stronger storms and flooding, sand dune management and restoration emerge as critical adaptation measures that can provide protection from these threats. In 38 M.R.S. §480-A, the Legislature stated that the State's coastal sand dunes systems are resources of state significance and that "there is a need to facilitate research, develop management programs and establish sound environmental standards that will prevent the degradation of and encourage the enhancement of these resources".

Actions include:

- *In order to protect valuable coastal sand dune systems, the Maine Department of Environmental Protection should continue* ***to evaluate proposed developments with consideration given to future sea level rise and impose restrictions on the density and location of development and on the size of structures.***

- ***Further work is needed to implement and monitor demonstration projects,*** *and studies of dune restoration to keep up with sea level rise are needed.*
- ***To keep beaches healthy for storm protection, habitat, and recreational uses, Maine should consider the use of selective and/or proactive beach nourishment*** *to help manage coastal erosion while also protecting crucial habitat for rare species such as piping plovers and least terns. This action entails an improved understanding of sand and sediment budgets in beach systems.* [*Note this strategy is more specific to impacts on biodiversity and natural beach ecosystems. It is assumed Coastal Resiliency WG will address beach nourishment for community economies, resilience, and public safety.]*

B. Nature-based Solutions and Climate-Adaptive Planning and Management - ***to include revisions to State and municipal regulations/ordinances and incentives, coastal and marine planning, and funding and support for implementation***

i. Characterize and map marine and coastal habitats to inform climate-adaptive coastal and marine planning and management. This work has implications for determining how food webs and species complexes will adapt or become compromised during the next century in response to climate change, and will inform the siting of renewable energy projects consistent with conservation of high value coastal and marine habitat. It will also inform conservation and restoration priorities for

Actions include:

- ***Identify and map coastal and near-shore and marine habitats*** *that are critical as climate refugia where species can adapt and move, and will provide better working data on the significant intertidal habitats, tidal wetlands, estuarine areas and coastal bays that provide habitat for priority species including nursery grounds for commercially important species, and dozens of at-risk species and migratory species whose ranges will be changing. This Action relates directly to the Blue Carbon Optimization Strategy and Tracking Climate Impacts Strategy proposed by the Coastal and Marine Work Group.*

ii. Provide support for climate adaptive Municipal and Regional Planning: Concrete steps towards adding climate change adaptation and mitigation considerations to the criteria for the development of town comprehensive plans would significantly leverage the inclusion of this information in municipal planning. In addition, the Maine Coastal Program has identified a need for tools to help move discussion at the community level forward from vulnerability assessment to adaptation action including more focus on determination and assumption of risk ([12], MCC STS 2020 [8]). Local stakeholder training on using new data and resiliency tools available for Maine has been identified as a high priority need ([12], MCC STS 2020 [8]). Existing training resources such as the Coastal Training Program (Wells National Estuarine Research Reserve) provide excellent venues for developing training sessions that could be delivered statewide. The Beginning with Habitat Program [13] is also a collaborative program dedicated to community technical assistance and a trusted information resource for planning with consideration for the protection of natural resources, species, and habitat connectivity.

Actions include:

- ***Support municipalities and regional Councils of Government with resource and land use planning in coastal and marine systems.***

- ***Outreach efforts need to be coordinated*** *across federal, state, and regional programs by a central entity (e.g. a State Planning Office or dedicated position/program within another State Agency).*

iii. Promote nature-based solutions (also known as natural infrastructure or green infrastructure) for climate change related challenges that impact non-tidal and coastal rivers, shorelines, and coastal and marine habitats, that foster the value of Maine's natural resources, and proactively mitigate risk for the state's citizens and infrastructure often with less expense. This includes the use of green infrastructure for stormwater management, increased buffering to wetlands and waterways, and "Living Shorelines" (LS) to address coastal erosion issues.

Actions include:

- **Promote the use of "Living Shorelines"** approaches to address coastal erosion issues. Living shoreline (LS) techniques involve recontouring eroding shorelines and installing organic (e.g. woody debris and natural fiber mats), and biologic (e.g. terrestrial planting, establishment of oyster bars, etc.) components as an alternative to more traditionally used rip-rap or sea walls to protect infrastructure. Living shorelines allow for continued sediment transport from uplands to the intertidal thereby helping with natural accretion of tidal wetlands, and do not present as much of a barrier to tidal wetland migration inland with sea level rise. Living shoreline approaches are effective in low energy settings with limited exposure to storm surge and strong open water fetch. Demonstration projects, assessment of community support and/or opposition, and permitting efficiency work is all needed.
- **Green infrastructure stormwater management** should be promoted and further incentivized. To include natural land cover buffers, land use assessments in watersheds, and comprehensive planning technical support.
- **Add nature-based solutions to risk and climate change to the suite of valued benefits of specific conservation practices**, such as protecting or restoring wetland and riparian buffers, protecting tidal marsh migration areas and beaches, and preserving floodplain forests.
- **Prepare outreach tools and additional technical guidance** that can help cross-walk the implementation of nature-based solutions to the suite of co-benefits to people, ecosystems, and biodiversity.

iv. Re-calibrate and strengthen protections of inland natural resources that directly and indirectly influence wetland functions, condition, and climate resiliency. While Shoreland Zoning rules arguably provide meaningful protections within 250-feet of high water and non-forested inland wetlands, these rules were not developed with consideration for the full suite of climate-change related stressors to land and water. Greater protection of streams that flow into tidal waters, and freshwater wetlands associated with those streams (e.g. the headwaters and floodplain as well as large isolated wetlands that detain storm flows and recharge groundwater) will be increasingly important to reduce nearshore nitrification and acidification issues and flooding risks, protect aquifers, and maintain habitat connectivity and climate refugia for plants and animals. Numerous studies have calculated the magnitude of flood mitigation value that wetlands provide. For example, a study of the floodplains and wetlands surrounding Otter Creek, Vermont found that they reduced flood-related damage costs by 84–95% for Tropical Storm Irene and 54–78% averaged across ten

distinct large storm events, underscoring the value of considering ecosystem services and nature-based solutions in land use and development planning [11].
Actions include:

- ***Require all relevant state and municipal plans, permits and regulations to include consideration for climate change,*** *such as measures to reduce stormwater impacts and larger flooding events.*
- ***Review and revise Shoreland Zoning rules,*** *and strengthen or reframe them as climate-adaptive protection of natural resources, beyond the 250' zone, which significantly influences the health and functioning of coastal resources. This specifically includes protections of headwaters, floodplains, and an emphasis on natural floodplain management in order to reduce the impacts of land use on tidal and coastal habitats.*
- ***A similar review of the Natural Resource Protection Act (NRPA) is also needed*** *to better incorporate modern knowledge of climate change impacts, values of buffer protection, and priorities for climate adaptation or mitigation.*

v. Strengthen Stormwater Management Tools: Stormwater runoff carries pollutants, including elevated levels of nitrogen to receiving waters. With increased storm intensities, stormwater loads to key areas for shellfish harvesting and aquaculture can lower the pH and salinity of estuarine waters. Some aquaculture operations already modify their practices in response to this threat. In addition, increased loads of nitrogen have the secondary effect of contributing to coastal acidification, which makes the water more acidic and decreases the calcium carbonate available for shell-building. Elevated nitrogen levels also contribute to nuisance algal blooms, which in turn can lower sediment pH, lower dissolved oxygen levels, and further harm marine life. For example,nuisance blooms can lead to anoxic conditions which smother clams or prevent juvenile clam spat from settling in flats. Maintaining meaningful natural buffers (setbacks) to tidal wetlands, streams and their headwater wetlands provide a lower cost/lower maintenance approach to safeguarding resources from nutrient loading. Doing so helps to prevent stream impairments in the future. This action is aimed at enforcing and strengthening land-based tools to reduce nitrogen and pollutant input, through improved stormwater management, to improve the quality of stormwater runoff and the receiving water downstream.
Actions include:

- ***Strengthen and enforce state laws, rules, and guidance, as well as local ordinances*** *for stormwater and site design to increase the use of low impact development measures. Revise permits issued under the MEPDES program to reduce nitrogen loads from wastewater treatment facilities and stormwater sources where needed based on TMDLs or alternative assessments.*
- ***Develop and implement watershed management plans*** *designed to restore water quality to coastal and marine waters threatened or impaired by nutrient loading.*
- ***Determine whether or not to set numeric criteria for nitrogen*** *in marine waters consistent with a 2007 legislative resolve, focusing initially on greater Portland Harbor.*
- ***Provide technical assistance to municipalities*** *on measures to reduce water quality impacts from development.*
- ***Expand nutrient monitoring and mitigative measures where needed.*** *Expanded monitoring needed to measure concentrations in currently unmeasured sources,*

including loads from urban streams, stormwater outfalls, and combined sewer overflow outfalls. Where significant nitrogen loads are found, determine source(s) and take measures to reduce these loads; e.g. installing green infrastructure, stormwater storage conduits, continued elimination of CSOs, and fertilizer ordinances. The monitoring should include data regarding the health of eelgrass, the presence of nuisance algal blooms, and other indicators of excess nitrogen loadings.

- ***Establish a dedicated fund to support ongoing and expanded water quality monitoring, both in marine and freshwater sources that deliver stormwater and nutrient loads to our marine waters****.*

vi. Improve other regulatory approaches to protect coastal areas from development that will impede marsh migration, impact water quality, and directly or indirectly affect the function and viability of coastal habitats to include impacts from coastal acidification.
Actions include:

- ***Relevant state and municipal plans, permits, and regulations should specifically address climate change impacts to ocean, coastal, and inland areas that influence coastal functions*** *(MCC STS 2020 [8]).*
- ***The regulatory framework of the State should be used to support development and economic growth that will appropriately protect, rather than negatively impact, our coastal and marine environments over the short and long term****. This should include incentives such as density bonuses for developers, and other established tools that reduce fragmentation and cumulative impacts to sensitive natural features.*

4. What is the timeframe for this strategy?

	Short-term (2022-2027)	Mid-term (2030)	Long-term (2050)	Ongoing (starting in short term)
To implement	● Enhancements to Maine's Shoreland Zoning (SLZ) rules and Natural Resource Protection Act rules, with political support. ● Revision of Maine's laws and regulations that address stormwater, nutrient pollution, and sources of bacteria loading. ● Municipal planning, support, and outreach for regulatory guidance and financing, incentives, planning - *need to start in the near term and continue as*	● Living Shorelines regulatory streamlining, further demonstration projects, and outreach (*active now but will continue and be realized over the medium term)* ● Stormwater management improvements incl. enforcement, regulatory anticipation of climate change, promoting low impact development measures, technical assistance, expanded nutrient monitoring ● Develop funding mechanisms or other incentive-based actions		● Conservation of high priority coastal wetlands and eelgrass beds, marsh migration zones, riparian and stream networks, wetlands, floodplains, and dunes and beaches ● Restoration of high priority coastal marshes, eelgrass beds and other subaquatic vegetation, tidal and freshwater streams, associated buffers and

	Action items within this Strategy are developed. ● The full development of the Coast Wise approach and integration into workshops and trainings (with further financial and personnel support)	for land conservation or preservation of ecosystem services ● Coastal and marine habitat characterization and mapping. ● Include climate change considerations and adaptation measures consistently and comprehensively across relevant state and municipal plans, permits, regulations		floodplains, dunes and beaches ● Municipal planning, support, and outreach for regulatory guidance and financing, incentives, planning
	Short-term (2022-2027)	**Mid-term (2030)**	**Long-term (2050)**	**Ongoing (starting in short term)**
To realize outcomes	● Completed workshops and trained practitioners in Coast Wise practices ● Completion of initial round of tidal stream restoration projects ● Climate adaptation and mitigation language and priorities within town Comprehensive Plans ● Revised and strengthened state laws and regulations to reduce sources of pollution that are caused by or exacerbated by the consequences of climate change	● Revised development planning and land use patterns resulting from new Shoreland Zoning rules and NRPA rules. ● Incorporation of updated regulatory guidance into Municipal planning, updated outreach and support materials. ● Reduction in pace, extent of shoreline hardening projects (replaced by green infrastructure approaches) ● Significant improvements to stormwater reductions and monitoring yielding measurable water quality improvements	● Due to tidal barrier removal and marsh restoration efforts, and migration pathway conservation, tidal marshes will be able to migrate in response to sea level rise	● Significant increases in protection of Maine's biodiversity, habitats, and related ecosystem services ● Significant rehabilitation of degraded or impaired coastal marshes, eelgrass beds and other subaquatic vegetation, tidal and freshwater streams, associated buffers and floodplains, dunes and beaches

5. Please analyze the Recommended Strategy against the following criteria.

Workforce - Will the strategy create new jobs, prevent job loss, or cost the state jobs?	Some economic studies show that activities like building nature-based solutions result in job creation far exceeding traditional gray infrastructure development [14]. Restoration supports conservation objectives while providing jobs at highly competitive rates. Restoration projects need skilled construction workers, engineers, landscape architects, project managers, and legal support. Services, materials, and supporting industries are often

	sourced from the community or home state so restoration dollars can stay local. Infrastructure development stimulates the economy, and green infrastructure development leads to co-benefits of preservation of Maine's iconic coastline. Our tourism industry depends on the natural beauty of our coast, and nature-based solutions add value to our coast. Each year, millions of tourists come to Maine to experience its natural beauty, and this beauty is further enhanced by using nature-based solutions where it is feasible. Therefore, in addition to direct job creation through construction, nature-based solutions preserve Maine jobs in the tourism and service industries, a vital sector of our economy. One recent study suggests visitors to Maine beaches alone spent $1.7 billion on goods and services in 2018. This represents nearly 29,000 jobs and approximately $164 million in tax revenue for the state [15]. Loss of Maine's beaches due to erosion, development and shoreline hardening could result in a 16% economic loss to tourism in the state. Finally, greater protections of inland contributing resources will help to minimize job losses resulting from nearshore fisheries decline expected with climate change. Implementation of green infrastructure measures, monitoring, and improved water quality could lead to more open flats for harvesting and cleaner waters for tourism/recreation - particularly bird watching and cold water fisheries. Nationally, wildlife watching contributes nearly $80 billion annually to the U.S. economy; in Maine, wildlife watchers contribute around $800 million annually [16]. According to surveys conducted every ten years by the U.S. Fish and Wildlife Service, 538,000 people participated in wildlife watching in Maine during 2011 [17]. Over half participated in marine mammal or shorebird viewing activities in and offshore from Maine's coastal towns. In addition, freshwater anglers spend $208.8 million annually on fishing-related goods and services, which supports 3,330 full- and part-time jobs providing more than $104.8 million in income and a total economic output of $319.2 million [18]. Maine supports the most extensive distribution of wild eastern brook trout in their U.S. range, but climate change and habitat fragmentation threaten the availability of this species' cool-water stream habitat. Nearly half of Maine's brook trout anglers specifically target these wild populations [19]. Habitat conservation and restoration across freshwater, coastal, and marine habitats will continue to provide high quality wildlife viewing and recreational opportunities that attract both residents and non-residents and support tourism and outdoor recreation-related jobs.
Benefits (non-workforce) - What are the expected co-benefits of this strategy (e.g., improved health, increased economic activity, wildlife habitat connectivity, reduce natural hazard risk, increased	This strategy focuses on two key elements: forward thinking, **climate adaptive management and planning**, and **nature-based solutions** that support functioning ecosystems and the myriad services and co-benefits they provide for **community, economic, and biological resiliency**. At the core are ecosystem services, often categorized as provisioning (food, water), regulating (climate and flood regulation), cultural (recreational, aesthetic) and supporting services (photosynthesis and nutrient cycling). The economic significance and societal values placed on ecosystem

recreation, avoided damage)?	services are challenging to quantify, especially the valuation of biodiversity "for biodiversity's sake", however examples of local surveys of people's perception of value and monetization of those values do exist [20, 21]. A Manomet "Valuing Maine's Natural Capital" study [22] found that "*In Maine, there is much potential for the use of an ecosystem services framework given how extensive, diverse and important its ecosystem are...preserving this environmental bounty is key not only to maintaining ecosystem services for residents, but also for helping support and grow Maine's biggest Industry [tourism]. In other words, in Maine, protecting these vital ecosystem services also means promoting long term viability of the economy. It is highly recommended that primary studies be conducted to better quantify the unique tourism, recreation and aesthetic value of Maine's landscape. This information could then be used effectively to lobby for environmental protections and to implement schemes that compensate landowners for those types of protection*." **The co-benefits of this Strategy include:** 1. **<u>The win-win of ecosystem services protection:</u> Protection of tidal marshes, coastal and marine habitats, inland wetlands, and buffers to coastal rivers and marshes yield a suite of benefits.** The benefits of coastal and marine habitat conservation and restoration are well established and include improved air quality, and protection of water quality in fresh and coastal waters which yield healthy aquatic life communities, more productive fisheries, important recreation and tourism opportunities, and even increased property values. Natural stormwater treatment and storage is offered by Maine's freshwater wetlands, connected and well buffered stream networks, and upland forests. Protection of these resources within the coastal zone is a cost-effective approach to providing additional protection and long-term resiliency of receiving tidal waters. <u>Example 1:</u> A white paper on the economic values of ecosystem services in Maine notes that conservation "...fosters investment, encourages recreation and tourism, attracts a skilled labor force, protects watersheds, augments municipal tax revenues, provides habitat for game, and protects traditional natural resource industries, in addition to numerous other benefits." [23] <u>Example 2:</u> A University of Maine study on the value of ecosystem services within conservation land in the Downeast Maine region. This study relied on benefit transfer but found that the region's conserved lands provided $463 million in ecosystem service benefits in 2017, with an average of $653 per acre, per year [24]. <u>Example 3:</u> Estimates of nitrogen removal capacity of Maine and Massachusetts salt marshes found they may filter out between 2.8 and 11.3 grams of nitrogen per meter per year (equivalent to between 25 and 101 pounds of nitrogen per acre per year) [25] which is important for buffering stormwater run-off. <u>Example 4:</u> One controlled study found that salt marsh vegetation helped reduce wave action by up to 60%, and suggests that the storm surge related wave reduction functions of tidal marshes are a valuable part of coastal protection

	schemes, which will help protect coastal land and property owners, infrastructure investments, and public safety. [26] 2. **<u>Biodiversity, and plant species, animal species, and habitat resiliency:</u> Enhanced, strategic protection of intertidal and subtidal habitats, estuaries, coastal rivers (tidal and non-tidal) and the floodplains, wetlands, and buffers to those habitats yield a cascade of benefits for commercially important species, at risk species, and Maine's iconic biodiversity important to the tourism industry.** Climate adaptive conservation strategies benefit both local and state economies in multiple sectors enhancing the resilience of commercially important populations, ensuring that the full suite of Maine's coastal wildlife endures and that residents and visitors continue to enjoy wildlife based recreation along the coast. Importantly, intact, protected corridors and networks of natural land will increase the resiliency of species and their ability to adapt or migrate in response to climate change - this includes marsh migration in response to sea level rise. 3. **<u>Cost savings:</u> Nature-based solutions have reduced upfront capital costs, and reduced maintenance and operational fees.** Thus, they are a less expensive option than many gray infrastructure alternatives. In addition, they can be deployed almost immediately as an adaptation and mitigative measure toward climate change, in many cases faster than other technologies. Finally, they also help avoid future damage/costs by leaving natural areas natural and maintaining ecosystem services. One often cited example is that the true costs to build wetlands or implement other measures for flood control, especially under a future of more frequent or heavier storms and in populated areas, would be on the order of 100 times more expensive (and of questionable permanent value) than the cost of just land protection efforts [27]. 4. **<u>Public Values:</u> Maine citizens have placed a high value in both tangible and "invisible" benefits of environmental and ecosystem service protection.** Though there is no comprehensive evaluation of the monetary value the public would place on the suite of ecosystem service and biodiversity values provided by healthy ecosystems, small pilot and case studies demonstrate significant public support. <u>Example 1:</u> A 2013 survey of residents of Kennebunk, Sanford and Wells, Maine found respondents placed a very high importance on environmental protection, and that the importance placed on "...environmental and ecosystem service protection was greater than that placed on the protection of landowner rights and prevention of tax increases." [28] Furthermore, residents hold considerable value for ecosystem services provided by <u>riparian land</u>, and would be willing to "...pay for improvements in riparian land condition itself, as well as for improvements in the condition of local rivers, recreational fisheries, and swimming safety of local beaches that can result from the restoration of this land".

	5. **<u>Restored habitats and climate-adaptive management compensate for or replace lost functions:</u> Habitat restoration seeks to return impacted systems to conditions that are ecologically, socially, and economically supportive.** Restoration or improved, climate-adaptive management can re-establish healthy fish and wildlife populations, protect communities from storm damage, and promote resilience to climate change. Restoration uses proven, commonsense approaches that yield successful results like any other well-planned construction project. An Ecosystem Services Assessment for the Great Bay, New Hampshire, assigned economic benefits to landowners, tourists, recreational and commercial fishing sectors based on <u>improved management</u> of protected and restored salt marsh, eelgrass, and oyster resources [21].
Costs – What are the estimated fiscal costs and other costs to carry out this program. To the state? To municipalities? What resources do you anticipate needing to inform Mainers about the strategy and the opportunity/costs of the strategy? Where would financing likely come from?	**Ecosystem Conservation and Restoration:** ***Costs associated with specific actions include the following (actual cost estimates included when available)--*** 1) *Promote Ecosystem Conservation and Restoration:* Thousands of parcels along the coast, most of which are privately owned, will be impacted by sea level rise - a scale which will require a robust approach by a range of actors with new climate science-based tools (both regulatory and financial). This figure considers the impacts of sea level rise and storm surge but does not account for those properties that will be affected by flooding, vulnerability of transportation networks and access, erosion, or other hazards related to climate change impacts. Multiple funding sources exist or could be better leveraged for either preservation or restoration, and will play an extremely important role in carrying this action forward. These include programs with tremendous public and/or political support such as a possible new Land for Maine's Future bond, federal Forest Legacy dollars, Maine Outdoor Heritage Fund, Maine Natural Resources Conservation Program, Natural Resources Conservation Service and others. 2) *Restore hydrological connectivity in coastal streams and tidal systems:* Cost of having to maintain structures that are not designed for SLR or replacing more often; people cannot access homes; 3) *Sand dune management, restoration and protection*: Further work is needed to implement demonstration projects, and studies of dune restoration to keep up with sea level rise are needed. 4) *Beach Nourishment:* cost of shorebird conservation (which would increase if we do nothing and we continue to lose habitat) for current and future populations as they shift northward **Nature-based Solutions and Climate-Adaptive Planning and Management:** ***Costs associated with specific actions include the following (actual cost estimates included when available)--*** 1) *Characterize and map marine and coastal habitats:* Aerial surveys for mapping eelgrass distribution using true color and near-infrared imagery were budgeted at approximately $95,000 annually for each of five years (⅕ of the coastline each year from Head of Tide to outer

	coast). Such imagery could be used for inventory of supratidal, intertidal and shallow subtidal habitats (marshes, seagrass, seaweeds), and would be of greater utility for tidally exposed vegetation if collected along with LiDAR. Dedicated staff would be additionally required to manage data acquisition, ground truthing efforts, GIS creation, and habitat classification. Dedicated subtidal multibeam data collection and seafloor sampling provides bathymetry, sediment, biological, and marine habitat and species assemblage information. Annual costs associated with the existing program housed at the Maine Coastal Program and Dept. of Marine Resources is $300k per year with the area depending on depths and project goals. 2) *Promote the use of living shorelines*: More proof of concept projects are needed to demonstrate the efficacy and cost effectiveness of living shorelines projects. Financial incentives are needed to encourage use of living shorelines over shoreline hardening, although the incentive amount is not known at this point. In cases of successful living shorelines projects, cost differentials should be measured and widely communicated. For example, Federal Highway Administration has a document from across the country that presents case studies of costs and cost effectiveness of several effective projects [29]. Also relevant is that in southern New England a landowner must demonstrate that they cannot do a living shoreline project before getting a permit for hardening (this points to the need for a more streamlined regulatory process for living shoreline projects in Maine). 3) *Re-calibrate and strengthen protections of inland natural resources:* Greater inland resource protection may impact the developability of properties. This can be lessened by making other development standards such as minimal lot size more flexible, or by offering transfer of development programs or similar approaches. Also consider non-regulatory incentives for shoreline protection and management. 4) *Improve other regulatory approaches:* There would be costs associated with updating the regulations (local and state). Real estate developers may feel disadvantaged by having greater setbacks from certain resources, but this impact can be minimized by offering other types of flexibility so that overall expectations of density could be maintained. Developers, municipalities might face higher costs for stormwater management. However increased frequency and magnitude of flooding will impact human safety, riverside infrastructure, water quality, erosion, and stormwater runoff (Demaria et al., 2016a in MCC STS 2020 [8]). 5) *Stormwater Management:* expanding nutrient monitoring, Increased enforcement of existing laws, updating of regulations, increased technical assistance, increased monitoring all require funding staff in state agencies. Additional regulation will also increase development costs in some cases. 6) *Municipal and Regional Planning support:* Stable, dedicated funding for staffing support will be needed, which includes salary, program development costs, and administration. For context, current annual

	costs to administer a community planning program (which covers all aspects of wildlife conservation but not specifically climate change) at the Maine Department of Inland Fisheries and Wildlife is $121,000 annually, which includes two staff and administration costs. This program is funded primarily through federal grants and is subject to annual fluctuations in Congressional appropriations. Other state government-administered programs are funded using a similar structure. Stable, dedicated funding is needed to provide predictable staffing levels and to grow programs to include more targeted climate technical assistance support to communities. **Cost of doing nothing estimates** are needed for specific Actions in order to better inform Mainers about the strategy and the opportunity/costs of the strategy. **Examples:** a) *Protection of nearshore and tidal habitats now will help to avoid future damage/costs by leaving natural areas natural, thus maintaining vital (even priceless) ecosystem services, and avoiding future economic exposure that would be incurred by developing in sensitive and vulnerable areas (e.g.* A 2019 First Street Foundation study determined Maine experienced nearly $70 million in lost appreciation value from sea level rise from 2005-2017 [30]). b) Calculate how much stormwater could be intercepted under various stormwater reduction plans and as a result Nitrogen and Phosphorus in runoff. c) Calculate aquaculture closures and lost revenue from commercial and recreational harvests and then calculate a range of positive economic impacts based on different percentages of restored waters/drop in impairments (improved stormwater management) (e.g. Bunganuc clam flats example - 14 acres lost to algal bloom) d) The costs of lost biodiversity are often calculated as losses in ecosystem services. The recovery costs for at-risk species should also be factored in. The Government Accountability Office in a 2006 briefing to Congress reported $15.9 and $1.4 million as the mean and median costs to recover a species listed under the Endangered Species Act [31]. Other estimates suggest a much higher average cost of $104 million over 10 to 50 years to recover a single species [32]. With several coastal and marine species already listed under the ESA (e.g., humpback whales, piping plovers) and many more considered at-risk, the costs of doing nothing to conserve these species could be considerable. **Federal funds are available** for many nature-based solutions projects. See the following link: https://www.eesi.org/papers/view/fact-sheet-federal-resources-for-nature-based-solutions-to-climate-change
Equity - Is this strategy expected to benefit or burden low-income, rural,	*Benefits to low-income, rural, or vulnerable residents and communities:* ● Consistent compliance with (and enforcement of) existing or new standards for development will help defray the real or perceived

and vulnerable residents and/or communities? What outreach has been/will be undertaken to understand the impact of the strategy on front-line communities?	concern that wealthy landowners can afford to ignore certain regulations by paying a fine. There is also a potential for imbalance of economic burden if wealthy waterfront landowners are able to respond to climate change impacts (e.g. increased storms, sea level rise) by retreating inland, rebuilding, or retrofitting - responses that may not be available or affordable by less wealthy coastal property owners. The supported use of incentives, nature-based solutions, and regulations that prohibit "risky" development can help avoid this imbalance and/or provide equal access to mitigating measures across socio-economic groups. ● Nitrogen pollution is an external cost that is not currently born by those creating it. This strategy will require those entities to internalize the cost of mitigating, in cases where those sources can be identified. ● Addressing the value of ecosystem services to communities and even sectors will provide a more complete assessment of the costs and benefits of land use and land conservation decisions [28]. ● Coastal property values are typically out of reach for most Mainers, yet those who can afford these properties are making land use decisions that have impacts far beyond the physical limits of their properties. Increased conservation efforts will not only limit these impacts, but also increase opportunities for coastal public access and recreation. ● Equal access to incentive and technical assistance programs for nature-based solutions will be needed to support communities with fewer planning resources (e.g., access to GIS or an on-staff planner). ● Both restoration and conservation goals need to be considered within the constraints of the community or region. For example, conservation of large habitat blocks may be a viable nature-based solution in more rural communities, while restoration of riparian habitats may be more suitable in urbanized and fragmented landscapes. Promoting multiple approaches is key to ensuring all communities have support for the tools most appropriate to their own setting and vision. ● Technical training for "green jobs" could boost opportunities for people new to the work force, and connect education with career development *We are unaware of outreach efforts specifically taken to understand the Strategy impacts.*
Proven strategy & feasibility – Has this strategy been implemented successfully elsewhere? Is it feasible with today's technology? What barriers to implementation exist (e.g., financial,	● The concept of resilience insurance is being explored as a mechanism for potentially helping to finance nature-based solutions and as a way to help balance tradeoffs of risk transfer (e.g., insurance) and risk reduction (see Natural Capital Project at Stanford University) ● Connecticut Institute for Resilience and Climate Adaptation (CIRCA) out of the University of Connecticut: As part of dealing with inland flooding and water impairments due to stormwater runoff to rivers and the

structural, workforce capacity, public/market acceptability)?	Sound there is a new MS4 General Permit to disconnect 1% of impervious surfaces a year down to 12% by municipality. • California Marine Protected Areas [33] • Nitrogen standards exist for Long Island Sound and Chesapeake Bay. • See The Nature Conservancy, 2017. *Lands of Opportunity Unleashing the full potential of natural climate solutions*. [34]
Legal authority - Does the strategy require new statutory (legal/legislative) authority?	<u>Living Shorelines</u> 1. Nationwide Permit 54 "living shorelines NWP 2016" Army Corps of Engineers. https://www.nao.usace.army.mil/Portals/31/docs/regulatory/nationwidepermits/Nationwide%20Permit%2054.pdf 2. Maryland Living Shorelines Protection Act 2008 https://dnr.maryland.gov/ccs/Documents/ls/2008_LSPA.pdf The Bill is very simple, and richer information will come from further interpretation of how the 2008 Bill affected living shorelines efforts for individual property owners and for municipalities. 3. Challenges with permitting process: https://www.coastalreview.org/2017/01/corps-eases-living-shoreline-permit-process/ with links to NOAA and Army Corps guides. <u>Coastal Protections</u> 1. Coastal habitat squeeze: A review of adaptation solutions for saltmarsh, mangrove and beach habitats. [35] <u>Recalibrate and Strengthen Protection of Inland Natural Resources</u> 1. Changes needed in the Natural Resources Protection Act and Shoreland Zoning rules <u>Stormwater Rules</u> 1. Strengthen to require monitoring and mitigation for nitrogen export. Legislation could provide funding for additional monitoring. Also, MA DEP is updating their stormwater rules to meet NOAA 2015 and updated rainfall predictions, with implications on mapping floodplains (current rule making).

6. Background Information and References

Table 1: Original table from *The Economic Contribution of Casco Bay* (2017) [4]. For each negative directional indicator, the table has been annotated with gray boxes to identify the part of the Strategy that can help improve the feature (i.e., which Action is will help with mitigation or adaptation).

Activity	Features Sensitive to Climate Change (Likely Directional Effect on Demand or Supply)	Proposed Action items that help mitigate or adapt to Features negatively affected (-) by Climate Change, below:
Boating	Temperature (+)	
	Sunshine (+)	
	Precipitation (-)	← Improve stormwater rules and inland natural resource protection (buffering)
	Water pollution from urban runoff (-)	
	Extreme weather events (-)	← Improve coastal wetland conservation, promote living shorelines, protect floodplains and riparian buffers (flood and wave attenuation)
Beach-going	Temperature (+)	
	Sunshine (+)	
	Precipitation (-)	
	Beach erosion (-)	← Beach nourishment, sand dune protection, restoration, and management
	Water pollution from urban runoff (-)	
	Extreme weather events (-)	
Recreational Fishing	Temperature (+)	
	Sunshine (+)	
	Water pollution from urban runoff (-)	
	Species availability (-)	← Characterize and map marine and coastal habitats, restore hydrological connectivity in coastal streams and tidal systems, municipal and regional planning support
Bird / Animal Watching	Temperature (+/-)	
	Sunshine (+)	
	Precipitation (-)	
	Species availability (?)	← Improve coastal wetland conservation, protect floodplains and riparian buffers (refugia), beach nourishment, sand dune protection

Source: Adapted from (Shaw & Loomis, 2008).

This strategy was prepared by the Coastal and Marine Working Group for consideration by Maine Climate Council on June 17-18, 2020. More discussion of this strategy with stakeholders is needed to refine the recommended actions for inclusion in the Maine Climate Action Plan.

Table 2: Original table from *Performance of Natural Infrastructure and Nature-based Measures as Coastal Risk Reduction Features* (2015) [6]. Table title: "Natural Infrastructure and Nature-based Measures: Summary of risk reduction performance and engineering guidance, costs, and factors relevant to climate change."

Key - = Low confidence, feature not likely to address + = High confidence, data available ~ = Limited confidence refinement needed Blank = need data			Risk Reduction Performance[1]					Design/O&M Criteria	Costs[2] per linear foot		Other Factors	
			Reduce coastal erosion/ Shoreline Stabilization	Nuisance floods (high tides with sea level rise)	Short wave (<2') attenu-ation (Stabilize Sediment)	Reduce force & height of med. waves (2-5')	Storm Surge (low frequency extreme events)	(for performance areas specific to feature)	Construction	Annual O&M[3]	Mitigates climate change (CO_2 sequest-ration)	Adaptability to sea level rise & changing community needs
Strategy	Structural	Groins	+[4]	-	+			+	$2-5k	$.1-.5k	No	
		Breakwaters	+[4]	-	+	+		+	$5-10k	>$.5k	No	Variable
		Seawall/ Revetments/ Bulkheads	+[4]	+		+	+	+	$5-10k $5-10k $2-5k	>$.5k $.1 -.5k $.1 -.5k	No	
		Surge Barriers	-			+	+	+	>$10k[5]		No	
	Existing Natural	Wetlands	+		+	~	~	N/A	N/A		Yes	Yes
		Mangroves/ coastal forest	+		+	+	+	N/A	N/A		Yes	Yes
		Vegetated Dunes	+		+	+	+	N/A	N/A		~	Yes
	Nature-based	Beach Nourishment	+	+	+	+		+	$2k-5k[6]	$.1k-.5k		Yes
		Vegetated Dune creation	+	+	+	+	+	+	$.03k- 5k[6]	$.1k-.5k	~	Yes
		Barrier Island Restoration	+	+	+	+	+	+	$0.76k - $1.1k[7]			Yes
		Small scale edging and sills (living shorelines)	+	~	+				$1k-2k	<$.1k	Variable	Yes
		Restored Oyster/Shell-fish Reefs	+		+	~	~	Possible, akin to low breakwaters	$.23k - .24k[8]		Yes	Yes
		Restored/ Created Coral Reefs	+		+	~	~	Possible, akin to low breakwaters	$.2k – 508k[9]		~	
		Restored Maritime Forests (including Mangroves)	+	+	+	+	+		$.23k - 216k[10] /ha (mangroves)		Yes	Yes
		Restored Wetlands[11]	+	+	+	~		-	$0.81k-36.4k/ha[12]		Yes	Yes

[1] General coastal risk reduction performance factors include storm intensity, track, forward speed, surrounding local bathymetry and topography
[2] USACE and NOAA (2015) is the source for most costs in this table unless otherwise noted with a footnote. Values not adjusted for inflation.
[3] Based on 50 year project life
[4] While these hardened coastal features can effectively reduce erosion in certain coastal areas, they also often lead to increased or unwanted erosion in other coastal areas.
[5] No data for surge barriers presented by linear foot, but due to size, engineering complexity and more difficult construction conditions, estimated to be greater than $10k/linear foot.
[6] Higher cost is for beach nourishment with vegetated dune creation. Low end estimate based on a NRDA Trustees (2012) for Pensacola Beach.
[7] Day et al. (2005)
[8] Gregalis et al. (2008)
[9] Ferrario et al. (2014)
[10] Gilman and Ellison (2007)
[11] Various methods including sediment diversions or hydrological reconnection
[12] Coastal Resources Management Council's "The Costs of Environmental Restoration Projects"

This strategy was prepared by the Coastal and Marine Working Group for consideration by Maine Climate Council on June 17-18, 2020. More discussion of this strategy with stakeholders is needed to refine the recommended actions for inclusion in the Maine Climate Action Plan.

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Strategy 5 – Manage for resiliency of Maine's marine fisheries and aquaculture industries in the context of climate change adaptation.

1. **Recommended strategy and how it addresses Maine's climate resiliency and mitigation goals.**
   a. **For adaptation strategies, what climate impacts does it address? How will this strategy reduce the vulnerability of Mainers to the impacts of climate change?**

      Climate change is altering the Gulf of Maine in myriad ways, presenting challenges to Maine's commercial fisheries and aquaculture sectors. Preserving the long-standing social, cultural, and economic benefits derived from fisheries and aquaculture will require climate-informed management measures that enhance resilience of these sectors. Commercial marine fisheries and aquaculture provide over $636 million in value of landed catch in Maine, with substantial additional economic value added through secondary activities (economic multiplier ~3x). Aquaculture ventures are gaining in importance throughout the state, and numerous market projections show the potential for growth in Maine's aquaculture sector. Developing and implementing effective climate adaptation and mitigation strategies at municipal, state, and regional levels will be important for sustaining wild fisheries, supporting ongoing growth in the aquaculture sector, and increasing production of seafood in Maine. Management efforts that support marine fisheries and aquaculture in the context of climate change will be essential for aligning mitigation and adaptation efforts with resiliency of Maine's marine economy. This strategy delineates ways in which fishery management information streams need to be strengthened to ensure sustainable fisheries and new opportunities as fisheries adapt to climate change. Further, it highlights market support and business resilience needs, as well as regulatory and policy objectives that are necessary to enable Maine's fisheries and aquaculture operations to remain reliable economic contributors as they adapt to climate change. This strategy relies on and complements the *Maine Information Exchange* and *Maine Seafood Business Council* strategies emerging from the Coastal and Marine Working Group.

   b. **List any site-specific geographies where the strategy would be applied.**

      This strategy will be applied throughout Maine's coastal waters.

2. **What is your measurable outcome for this strategy, assuming all recommended actions to implement the strategy are achieved?**
   a. **For mitigation strategies:**
      i. **What is the estimated CO2e savings (metric tons) by 2025, 2030, 2050?**
      ii. **What is the cost effectiveness of those reductions (cost per ton of CO2e reduced) and the total cost?**
   b. **Are outcomes measurable with current monitoring systems?**

      Outcomes of this strategy can be measured by tracking the future stock conditions, economic contributions, and social importance of marine fisheries and aquaculture in Maine. Existing data systems and indicators are routinely used to evaluate these outcomes. Stock conditions can be

measured through relative abundance, biomass or size indices; stock size relative to reference points established in stock assessments; and spatial distribution of a species (including suitable habitat for farmed species). Economic contributions can be measured through landed value, secondary value, portion of local income or tax revenue derived from fisheries, number of license holders, number and total size of aquaculture leases, diversity of farmed crops, and employment in the fishing and aquaculture sector. Social importance of fisheries and aquaculture can be evaluated through measures of a community's dependence on these industries, as well as numbers of participants departing and entering the industry.

3. What specific actions would be required to implement the strategy, including but not limited to legislation or regulation.

Information support

a. **Enhance (and provide sustainable funding for) marine resource monitoring programs to better detect changes in ecosystem conditions, including the composition and distribution of species and habitats along Maine's coast, as well as socio-economic conditions related to fisheries and aquaculture.** Fishery managers and Maine business owners need access to timely information on changing conditions, habitats, and species along our coast to support decisions that respond constructively to coastal change and to evaluate outcomes of those decisions. This type of information is necessary as a basis for single species fisheries management, ecosystem-based fisheries management, aquaculture siting, and coastal and ocean planning. Sustainable support, coordination, and expansion of these physical, biological, and fishery monitoring programs also will be essential for measuring outcomes associated with this strategy.

b. **Develop stock assessments, ecosystem-based management approaches, risk policies, and harvest strategies that account for ecosystem changes, including shifts in species-environment relationships and in productivity and distribution of species along the coast.** Current approaches for assessing fish stocks and projecting their expected performance in the future rely on assumptions of constant species-environment relationships and multispecies interactions. Climate change is undermining these assumptions and creating new needs for adaptive and ecosystem-based fisheries management approaches that can accommodate changes in distribution, productivity, abundance, and interactions of species. Maine can harness industry observations and insights, academic expertise, and state fishery management roles to advance climate-smart assessment and management strategies.

c. Implement forecasts for key environmental parameters at spatial and temporal scales that are relevant to business planning, operations, and management of Maine's fisheries and aquaculture sectors. Environmental conditions such as temperature, salinity, and pH influence the suitability of coastal and offshore waters for species that are important to fisheries and aquaculture in Maine. As such, prudent operational, planning, and strategic decisions in these industries would be supported by the availability of near-term forecasts and longer-range projections of these environmental conditions. Scientific expertise in climate and ocean modeling in Maine should be harnessed to produce these types of forecasts, working in collaboration with the *Maine Information Exchange* and *Maine Seafood Business Council* to optimize their relevance to business and management decision-making needs.

Market support and business resilience

d. **Evaluate and implement ways to expand local and direct marketing opportunities for sustainably produced Maine seafood.** Promoting Maine seafood products to local consumers can be achieved through collaboration with the *Maine Seafood Business Council*, supporting efforts to increase community awareness of local seafood products and assessing the regulatory environment for opportunities to expand market access to local businesses. Successful implementation of this strategy would result in increased access for fishermen and aquaculturists to local markets while maintaining the standards required to ensure public health.

e. **Support the growing aquaculture sector as a means to increase Maine seafood production, provide important economic opportunities for coastal communities, and harness potential acidification mitigation and other environmental services.** While continuing to support resilient wild fisheries, a variety of measures can be taken to also catalyze growth in the aquaculture sector. These include ensuring regulatory resources and research capacity are scaled to a dynamic and growing industry, and promoting climate change mitigation practices through commercial aquaculture projects.

f. **Develop technical assistance, financing tools, and policy strategies to help fishing and aquaculture businesses plan for and transition activities in a changing ocean ecosystem,** including support for increasing access to resources for which quota allocations and permits are currently limited.

Regulatory and policy objectives

g. **Evaluate and implement ways in which Maine's fishery and aquaculture laws and regulations can provide the opportunity to address environmental change and emerging fisheries while recognizing both the need for regulatory stability.** Wild harvest fisheries, in particular, are susceptible to shifts in species productivity and distribution, which can have an impact on management targets and catch rates for currently harvested species and can create needs for considering new access arrangements for species entering the Gulf of Maine. For the aquaculture industry, changing environmental conditions can impact the suitability and productivity of currently permitted culturing techniques, species cultured, and/or aquaculture sites. Exploring how state regulations and municipal ordinances can simultaneously be flexible to producers; conserve species and habitats; and minimize impacts on rural, low-income, tribal and elderly communities will be necessary to enable fisheries and aquaculture businesses to adapt to a changing environment.

4. What is the timeframe for this strategy?

	Short-term (2022)	Mid-term (2030)	Long-term (2050)	2070 -2100
To implement	X	X		
To realize outcomes		X	X	

Implementation: State agency staff are already actively working on implementing many elements of this strategy in many fisheries and aquaculture sectors. However, advancing all elements will depend on

availability and stability of funding and the ability to motivate shifts towards climate-informed stock assessment and quota allocation strategies in regional fishery management bodies. Effectiveness of this strategy will rely on ongoing maintenance and updating of information streams, market support, and regulations and policies into the mid-term.

Outcome realization: The outcomes of this strategy will be realized on the scale of years to decades. Outcomes will be reflected in the measurement of indicators described in 2b and in the general ability of the state fishery and aquaculture management systems to respond to changing conditions in the Gulf of Maine.

5. Please analyze the Recommended Strategy against the following criteria.

Workforce - Will the strategy create new jobs, prevent job loss, or cost the state jobs?	The successful implementation and development of these objectives will both maintain thousands of commercial fishery and aquaculture jobs and create employment opportunities through the development of new commercial and recreational fisheries and the expansion of aquaculture.
Benefits (non-workforce) - What are the expected co-benefits of this strategy (e.g., improved health, increased economic activity, wildlife habitat connectivity, reduce natural hazard risk, increased recreation, avoided damage)?	These actions will support the long-term viability of multiple fisheries and aquaculture businesses, associated industries that rely on commercial fishery products (supply chain, tourism, etc), and the coastal communities in which these businesses exist and participants live. This strategy will support existing and new commercial fisheries and aquaculture enterprises, provide access to species as they enter the Gulf of Maine, and create a greater volume and diversity of farm-raised crops.
Costs – What are the estimated fiscal costs and other costs to carry out this program. To the state? To municipalities? What resources do you anticipate needing to inform Mainers about the strategy and the opportunity/costs of the strategy? Where would financing likely come from?	Maine Department of Marine Resources is already addressing this strategy through active participation in regional management bodies. The costs of monitoring and assessment need to be sustainable long term and reflective of changes in cost of living. As a result, a funding base to support this strategy partially exists. However, fully achieving the elements of this strategy will require reconsidering priorities for existing funds or increased investments. The state, industry, business, and research communities may all be able to play roles in advancing and obtaining funding to support specific elements of this strategy. In addition, complementary funding needs will be shared with the *Maine Information Exchange* and *Maine Marine Business Council*.
Equity - Is this strategy expected to benefit or burden low-income, rural, and vulnerable residents and/or communities? What outreach has been/will be undertaken to understand the impact of the strategy on front-line communities?	As with any fisheries issue, access and allocation are always some of the most challenging issues. Maine's multiple co-managed and diverse fisheries require special attention to ensure that impacts to individuals and businesses in rural, low income, elderly and tribal communities are minimized and that these groups have access to new opportunities in fisheries and aquaculture. As fisheries rebound in the region, more people want to participate. However, long-standing fishermen who feel that they have sacrificed and worked to rebuild the stock and made investments in harvest opportunities want to recoup the benefits of those efforts. If fisheries shift or opportunities for aquaculture expand,

	the conversations are no less tricky. For example, fishermen in the Mid-Atlantic hold limited access permits for fisheries that have historically been prosecuted in their region. As those species show up in Maine, fishermen here would like to be able to take advantage of those new opportunities, especially as other species that Maine fishermen have historically depended on for diversification, such as shrimp, have been depleted or their distribution has also shifted away from Maine waters. The ability to access those stocks is limited by constraints on the numbers or cost of permits and by quota allocation procedures that distribute allotments of catch to states based on their historical participation in the fishery. Future access and allocation systems will need to be designed to accommodate climate-related species shifts and to ensure the potential for equitable access across diverse users. The successful development and implementation of this strategy will promote and sustain small businesses in economically-vulnerable Maine coastal communities, and will ensure that aquaculture remains a viable sector for new entrants. The objectives proposed in this strategy will include and provide benefits to all socio-economic groups in these coastal economies.
Proven strategy & feasibility – Has this strategy been implemented successfully elsewhere? Is it feasible with today's technology? What barriers to implementation exist (e.g., financial, structural, workforce capacity, public/market acceptability)?	Implementation of this strategy is feasible with existing technology, and many other states are already considering and implementing similar objectives. Barriers include the need for expanded and stable funding for monitoring and forecasting of species dynamics and ecosystem change; technical and financial support for fishery and aquaculture business planning, transitions, and adaptation; and movement within regional fishery management bodies to adopt more climate-informed approaches for fisheries management, including in stock assessments, catch limits, and quota and permit allocations.
Legal authority - Does the strategy require new statutory (legal/legislative) authority?	These objectives, and the strategy as a whole, can be successfully achieved through existing policy and legal frameworks and continued support of the relevant state agencies.

6. Rationale/Background Information

The Maine-New Hampshire Inshore Trawl Survey is an example of a biophysical monitoring state monitoring program that provides consistent, high quality datasets to members of the public and fishery managers. This survey is intended to complement similar surveys conducted by the National Marine Fisheries Service in the outer waters of the Gulf of Maine and one conducted by the State of Massachusetts in their inshore waters. Prior to this survey, no fishery independent information has been available for approximately 80% of the U.S. Gulf of Maine's inshore waters. This survey is currently federally funded on an annual basis. It is crucial to the success of future fisheries management efforts to identify stable support for programs of this nature.

Example Uses of Survey Data

American lobster: Inshore trawl survey data became a key component of the recent American lobster stock assessment model. Analysis of the MENH Survey data together with those of the National Marine Fisheries Service Gulf of Maine survey revealed that Gulf of Maine lobsters consists of two discrete populations; one in the inshore waters where 80% of the lobsters are caught and the other consisting of older individuals in deeper outer waters (Chen et al. 2006). This finding has important relevance to lobster management and stock assessments. As a result, the 2009 ASMFC lobster assessment incorporated the MENH Survey data to reach a different conclusion than would otherwise have been reached using NMFS offshore trawl data alone. MENH survey data were used in the 2015 lobster assessment and the upcoming 2020 assessment.

Atlantic herring: Each year, as herring quotas are set, MENH Survey data are requested to validate and enhance data from other sources such as the NMFS, the Canadian Department of Fisheries and Oceans trawl, and herring acoustic surveys. Specifically, requests are for stratified mean abundance and length frequency information from our inshore survey. Data were provided for the herring assessment SARC 54 in 2012 and yearly thereafter to the Plan Development Team of the New England Fisheries Management Council.

Groundfish: Fisheries independent abundance indices for 10 species of groundfish were provided to the NMFS NEFSC for the Northeast Groundfish Stock Updates in 2012, 2015, 2017, and 2019. Catch at length data, distribution plots, and biological data were also provided.

American shad: MENH Survey data are used for the American Shad Assessment required by ASMFC. Most data on shad are fisheries dependent data collected during commercial or recreational fishing during the spawning migration. Data collected by the trawl survey are useful since it captures shad which are probably 1-3 year old fish. Little is known about these age classes since they are of minor commercial value and because they migrate long distances (Nova Scotia - Georgia) thus tending to be dispersed over large areas. MENH Survey data are used to pinpoint locations that appear to have some importance to these juvenile fish so that measures may be taken to better manage the resource and/or predict population fluctuations prior to harvests.

Northern shrimp: In this case, commercial shrimp fishermen in Maine requested that MENH Survey data on northern shrimp be provided to ASMFC in 2003. Since then, these data have been used in the stock assessment surplus production model and in the process of setting length and timing of the fishing season for shrimp. Data were provided to the 58th Northeast Regional Stock Assessment Workshop (58th SAW/SARC) on shrimp. The survey indices and catches at length by sex were provided.

Sea scallop: Data were requested in 2016/2017 for sea scallop caught in the survey. These data were used in developing new management measures for scallop in Maine waters, including closed areas and rotational management.

*Haddock:*Data were provided for the stock assessment workshop (SAW/SARC 59) working group data meeting tasked with preparing the assessment working papers of the GOM haddock stock in 2014. Survey indices, catches at length, age, and maturity data collected on haddock were presented from the MENH Survey. Data were provided to an operational assessment in 2017 and 2019.

Monkfish and Pollock: Data were provided for the 50th SAW/SARC on monkfish (goosefish) and pollock in 2010. The survey indices, catches at length, and distribution plots from the MENH Survey were provided. The data were used in the assessment report to characterize the northern monkfish stock but

not in the actual assessment model. Summary plots and tables for pollock were also included in the report. Data were provided again for pollock in 2017 and 2019 for the update assessment.

Butterfish: In 2012, abundance indices for butterfish in the fall MENH Surveys were provided to the Mid-Atlantic Fisheries Management Council for a Science and Statistical Committee meeting on setting Allowable Biological Catch (ABC) limits for the butterfish fishery. Data were provided for the 58th SAW/SARC in 2014 for butterfish. The survey indices, catches at length, and distribution plots from the MENH Survey were provided.

Silver Hake, Red Hake, and Loligo Squid: MENH Survey data were provided for the 51st Northeast Regional Stock Assessment Workshop (51st SAW/SARC) on silver hake, red hake, and *Loligo* squid in 2010. Data provided included survey indices, catches at length, and distribution plots for these species. Data has been provided for an update in 2016 for the hake species as well.

Winter Flounder: Data were presented at the stock assessment workshop (SAW/SARC 52) working group data meeting tasked with preparing the assessment working papers for the Gulf of Maine (GOM) and Southern New England/Mid-Atlantic winter flounder stocks in 2011. Survey indices, catches at length, and maturity data collected on winter flounder were presented from the MENH Survey. Also presented were maturity ogives and preliminary results of winter flounder ageing conducted by MDMR. More recent data were provided in 2017 and 2019 for the assessment update.

Atlantic Cod: Data were presented at the stock assessment workshop (SAW/SARC 55) working group data meeting tasked with preparing the assessment working papers of the GOM and Georges Bank Cod stocks in 2012. Survey indices, catches at length, and maturity data collected on cod were presented from the MENH Survey. Also presented were distribution charts of juvenile and adult cod along the coasts of Maine and New Hampshire. Although the data were not used in the assessment models, the data will be presented in the assessment report to characterize the GOM cod stock. A more recent dataset was supplied in 2017 and 2019 for the operational assessment update. Additionally, our data has been looked at during evaluation of Atlantic cod's stock structure in 2018.

White Hake: MENH Survey data were provided at the stock assessment workshop (SAW/SARC 56) working group data meeting tasked with preparing the assessment working papers of the white hake stock in 2012, including the survey indices, catches at length, and maturity data collected on white hake. Distribution charts of juvenile and adult white hake along the coasts of Maine and New Hampshire were also presented.

Witch Flounder: MENH Survey data were provided at the stock assessment workshop (SAW/SARC 62) working group data meeting tasked with preparing the assessment working papers of the witch flounder stock in 2017, including the survey indices, catches at length, and maturity data collected on witch flounder.

Closed Area Technical Team: Data from the MENH survey were provided to the NEFMC habitat committee's closed area technical team for use in assessing the value of groundfish closed areas.

Northeast Region Ocean Council: Complete set of MENH Inshore Trawl Survey data supplied for the Northeast Ocean Data Portal to be used for ocean planning by the Northeast Regional Planning Body.

Other Uses and Capabilities: Various scientists and managers have requested data collected on many other species including sturgeon, skates, spiny dogfish, *Crangon* shrimp, *Illex* squid, Atlantic lumpfish, rainbow smelt, and river herring. Researchers from NOAA, University of Maine, University of New

Hampshire, Bigelow Laboratory for Ocean Sciences, Gulf of Maine Research Institute, University of Maryland, Woods Hole Oceanographic Institute, and the Wells National Estuarine Research Reserve have utilized this survey as a platform for their investigations. Graduate students, consultants for large projects (e.g. LNG siting), NGOs, and many others have used the survey to collect biological samples for toxic contaminants, stomach contents, genetic studies, invasive species, and ichthyoplankton.

Strategy 6 - Climate-Ready Working Waterfronts: Target specific efforts to assist Maine's working waterfronts in their transition to climate preparedness.

1. Recommended strategy and how it addresses Maine's climate resiliency and mitigation goals.

Background:

Maine's coastal and marine economy, and the cultural and economic identity of its coastal communities, depends in large part on thriving working waterfronts -- small and large, public and private, rural and urban. In this strategy we use *"WWF"* or *"Working Waterfront"* to mean facilities that truly rely on a waterfront location to conduct operations. WWFs provide access and associated facilities for our commercial fishing fleets and aquaculturists, recreational fishing fleets and recreational boaters, marinas and boatyards, boatbuilders, maritime security, marine transportation of seafood and goods, transportation for Maine's islands, maritime tourism, and support for other heritage and emerging industries. Working waterfronts, as part of Maine's cultural fabric, are often located in town and city centers and are thriving and historic places that provide pride for locals and destinations for tourists. Operating as a system, working waterfronts and associated businesses are foundational regional systems on which entire communities rely.

As front-line facilities, WWFs should be prioritized in climate-ready planning, land use planning, infrastructure funding support, and resilience guidance and conservation efforts. The Climate Ready WWF Strategy actions below will assist this sector with adaptation to flooding, storm surge and sea-level rise and help WWF owners and users in the marine sector reduce carbon emissions. Listening to the needs of the WWF sector and incorporating their feedback, removing redundancy and improving existing regulations, and creating incentives for adaptation are necessary components for the success of this strategy. This strategy and the action steps detailed in this template have a high likelihood of success if properly resourced.

Threats: Located adjacent to and over the water, WWFs face critical challenges in a changing climate. Fortunately, there are potentially many opportunities to transition to climate preparedness creating resiliency for industry as well as widespread co-benefits. Sea level rise, flooding, storm surge and waves will effect waterfront infrastructure and facilities and disrupt operations; warmer seas will change the composition of fisheries landings; the melting Arctic will change trade routes and shipping; our need for clean ocean renewable energy to meet Maine's climate goals may require retooling and expansion of our ports and waterfronts, and new uses of the ocean will need to responsibly co-exist with traditional uses. All of these issues, and many more, will impact the economies and people that depend on working waterfronts and their communities.

Opportunities: Waterfront infrastructure has distinct advantages over other forms of non-water-development in adapting to existing and future impacts of climate change: marine infrastructure is often designed to be wet and retrofitting is achievable (albeit expensive) for many ports and harbors and their attendant docks, sheds, shops, and yards. With increased flood damage and ongoing

risks, there may be opportunities for redevelopment of non-water dependent shoreline residential and commercial properties into water-dependent uses and associated businesses that tend to suffer less damage from periodic flooding.

Ocean Energy presents additional opportunities. Facilities can grow and prosper if part of a regional system to support a new ocean-based renewable energy sector. New technologies in boats and marine engines, use of best management practices in the cruise ship industry and increases in the use of solar energy will further reduce the carbon footprint of the marine sector.

We recommend the following **Climate-Ready Working Waterfronts (WWF) Strategy**, with seven interrelated and co-dependent components:

1. Implement Creative Funding Solutions --Create an Infrastructure Trust Fund, Revolving Loan Fund, or similar mechanism to provide funding for small to medium sized wharf and pier owners to plan for and install resilient infrastructure.
2. Improve Guidance and Technical Assistance for municipalities and business owners regarding how to conduct a vulnerability assessment for WWF facilities, feasibility and design of resiliency measures, and information on funding sources. Produce toolkits and guides and funding resources for technical assistance.
3. Protect the state's investment in WWFs by requiring state funding programs to consider waterfront resiliency when making funding decisions; explore whether priorities should be developed for state funding programs.
4. Reform and improve regulatory and non-regulatory approaches to development and redevelopment of WWFs to:
    a. reduce redundant and confusing statutes and rules,
    b. address challenges associated with increased flood insurance costs,
    c. address sea-level rise, flooding, and storm surge as part of municipal comprehensive plans and simplified, but effective state and local regulations.
    d. Explore common applications and alignment of standards between overlapping ordinances including NRPA, Shoreland Zoning, and Floodplain Management.
5. Publicize case studies of successful examples of mitigation and adaptation already happening at Maine's ports and WWFs. Incentivize this work through expansion of programs like ME DEP's Environmental Leaders Program, a voluntary certification program based on achieving best practices through a self-guided process.
6. Assess opportunities to reduce marine emissions through continued discussions in summer 2020 and potentially beyond with the Maine Climate Council CMWG's WWF subcommittee and the MCC Transportation Committee, port and ferry managers, harvesters and business owners/managers of small to midsize WWFs, cruise ship representatives, and NGOs. Objectives of collaboration would include understanding what is already happening in Maine and identify best practices (e.g. hybrid diesel ferries, solar panels on fishing co-ops, vulnerability studies of municipal landings, resilient waterfront construction projects), assess the potential to expand the North American Green Marine Program in Maine to showcase resilient waterfronts, and assess the potential for other pilot programs, including assistance to the fishing sector, and

improved understanding of local and regional threats and opportunities and local/regional/state waterfront infrastructure needs.

7. Help reduce other pressures on that affect the economic resiliency of working waterfronts by:
    a. Conducting additional education and outreach about the importance of WWFs to Maine's and culture.
    b. Reducing the tax burden of working waterfronts by:
        - restructuring and reformulating the current use taxation program;
        - providing tax incentives for measured reductions in GHG emissions; and
        - reducing taxable value for improvements made that adapt to future flood scenarios

a. For adaptation strategies, what climate impacts does it address? How will this strategy reduce the vulnerability of Mainers to the impacts of climate change?

Climate impacts addressed:

1. (Adaptation) Impacts, risks, and hazards on Maine's coast and island infrastructure including: king tides, storm surge, and flooding from increased and more severe rain events and increased rates of sea-level rise.
2. (Mitigation) Greenhouse gas emissions from the marine sector and creating the platform for Ocean Energy construction, service, and support.

Reduce vulnerability:

1. Reduces physical vulnerability of essential WWF infrastructure, and helps avoid disruptions in business chains and employment levels
2. Sustains and increases commercial access by providing reliable infrastructure
3. Reduces energy costs for port and waterfront users through pilot projects

b. List any site-specific geographies where the strategy would be applied.

Working waterfronts statewide. Site specific areas could be chosen for pilot projects.

2. What is your measurable outcome for this strategy, assuming all recommended actions to implement the strategy are achieved?

- Number of Maine working waterfronts and individual facilities that implement resiliency measures on an annual basis.

a. For mitigation strategies:

i. What is the estimated CO2e savings (metric tons) by 2025, 2030, 2050?

ii. What is the cost effectiveness of those reductions (cost per ton of CO2e reduced) and the total cost?

b. Are outcomes measurable with current monitoring systems?

Adaptation Measures: No
Mitigation Measures: Partially. ME DEP has a marine emissions monitoring program; its 2020 report includes suggestions for expansion of this program

3. What specific actions would be required to implement the strategy, including but not limited to legislation or regulation.

We recommend the following **Climate-Ready Working Waterfronts (WWF) Strategy**, with the following actions:

1. Pass Legislation to enact a Working Waterfront Infrastructure Trust Fund or Revolving Loan Fund,
2. Develop Guidance and Technical Assistance Materials for municipalities and water-dependent business owners. New funding might be needed for technical assistance providers to deliver these materials.
3. Create and Adopt Guidance to protect the state's investment in WWFs
4. Inventory existing regulation to inform Reforms and Improvements to Regulatory and Non-regulatory approaches to development and redevelopment of WWFs
5. Publicize case studies of successful examples of mitigation and adaptation already happening at Maine's ports and WWFs. Incentivize this work through expansion of programs like ME DEP's Environmental Leaders Program
6. Continue discussions in summer 2020 and potentially beyond with the Maine Climate Council CMWG's WWF and Ports subcommittee and the MCC Transportation Committee, port and ferry managers, harvesters and business owners/managers of small to midsize WWFs, cruise ship representatives and NGOs, with the objective of assessing opportunities for reducing emissions at ports and WWFs and associated industries and increasing participation in the Green Marine Program.
7. Help reduce other stressors that affect the economic resiliency of working waterfronts by reducing the tax burden and building support for working waterfront conservation and protection.

4. What is the timeframe for this strategy?

	Short-term (2022)	**Mid-term (2030)**	**Long-term (2050)**	**2070 -2100**
To implement	X	X		
To realize outcomes	X	X	X	X

5. Please analyze the Recommended Strategy against the following criteria.

Workforce - Will the strategy create new jobs, prevent job loss, or cost the state jobs?	The WW strategy will potentially create new jobs in construction, fishing, tourism, and renewable energy. By providing continued access to working waterfronts *and the associated necessary infrastructure,* It will prevent job loss in Maine's marine economy, including: fishing, aquaculture, offshore businesses and developments, and

This strategy was prepared by the Coastal and Marine Working Group for consideration by Maine Climate Council on June 17-18, 2020. More discussion of this strategy with stakeholders is needed to refine the recommended actions for inclusion in the Maine Climate Action Plan.

	associated secondary industries (for example, fish processing, food, boat building, and coastal tourism, etc.) It will protect a heritage industry and more properly value the contributions of this industry to the state.
Benefits (non-workforce) - What are the expected co-benefits of this strategy (e.g., improved health, increased economic activity, wildlife habitat connectivity, reduce natural hazard risk, increased recreation, avoided damage)?	Co-benefits include: • Streamlined and more efficient infrastructure development, adaptation, and maintenance. • Improved outreach and partnerships between private and public sector • Avoided damage and costs to crucial fishing, tourism, and private residence infrastructure • Preservation and socio-economic enhancement of Maine heritage fishing industries • Increased opportunities for physical and socio-economic diversification of coastal industries • Increased public access to piers and marine recreation • Increased state, federal, municipal, business, and non-government org partnerships for WW projects • Improved ability to service the ocean energy sector
Costs – What are the estimated fiscal costs and other costs to carry out this program. To the state?	A full cost analysis for all the actions in this strategy was not completed. For a Working Waterfront Trust Fund - State costs: A state fund of $1M could likely finance resiliency improvements at two to ten medium-sized working waterfronts.
Equity - Is this strategy expected to benefit or burden low-income, rural, and vulnerable residents and/or communities?	This strategy will benefit low-income, rural, and vulnerable people by protecting waterfront access for multiple uses, and especially commercial uses, as climate change hazards impact infrastructure. It provides ports and WW with the regulatory mobility to adapt quickly to protect economies and the people that depend on them.
Proven strategy & feasibility – Has this strategy been implemented successfully elsewhere? Is it feasible with today's technology? What barriers to implementation exist (e.g., financial,	Existing examples include: • Numerous examples of state revolving loan funds and other forms of financing infrastructure investments. • Some projects may require addition technical assistance (financial barrier and limited bandwidth) • Green Marine Certification Program: o An established nationwide program that encourages marine industry businesses to gradually improve their environmental impacts year after year through self-evaluation and verified by an external entity. o Results show continued improvement in scores and environmental leadership in ports around the country

structural, workforce capacity, public/market acceptability)?	(https://green-marine.org/wp-content/uploads/2019/06/2018Perfo_Report_final_WEB-1.pdf) o Barriers: How to encourage Maine ports/terminals/shipyards/ship operators to participate? Can incentive be offered?
Legal authority - Does the strategy require new statutory (legal/legislative) authority?	Yes, to create a working waterfronts infrastructure improvement fund Yes, to create regulatory reforms to help WWF respond to sea-level rise, storm surge and flooding.

6. Rationale/Background Information

Related reports for WWFs and associated industries:

- Maine Coast Fishermen's Association- Maine's Working Waterfront MCFA 2019 WWF report
- Flood insurance and Maine's preparedness for SLR: Shore Up Maine 2019
- Mapping Maine's Working Waterfront, 2007 Island Institute Report: The Last 20 Miles

Appendix B

Coastal and Marine Working Group List

MCC Coastal and Marine Workgroup Member & Affiliate Contact List - Updated 5.9.20

First Name	Last Name	MCC Role	Affiliation	Email
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Appendix C

Summary of Survey Results

Appendix C
Maine Climate Council Coastal and Marine Working Group (CMWG)
Summary Report on CMWG Survey Results

Drafted by Jessica Reilly-Moman, CMWG technical staff
Reviewed by Kathleen Leyden and Heather Leslie, CMWG co-leads & Laura Singer, CBI

Introduction

In May 2020, the Coastal and Marine Working Group (CWMG) conducted a survey to obtain feedback on their seven proposed strategies in advance of the submission of the strategies to the Maine Climate Council in June 2020. WG staff, Laura Singer (SAMBAS Consulting) and Jessica Reilly-Moman (University of Maine), designed the survey.

Survey Questions

After providing demographic data, the respondents were guided through each of the seven strategies and their associated actions. For each strategy, the survey asked respondents to select the top three actions that were most important in the near term. The survey also asked if any of the actions concerned them and if there was anything missing from the strategies. Finally, the survey respondents were asked to provide feedback on if and how environmental change had impacted their lives or their community, both physically and socially.

Caveats

- The online survey was distributed through working group member networks with a compressed time for response. Although the survey response is not representative, valuable feedback was received and qualitative analysis of the survey illustrated the range of perspectives to the draft strategies and Climate process variety of views.
- Many respondents indicated that selecting which actions were most important and when they should occur was not possible or very difficult without contextual information.
- The survey was lengthy and dense, and difficult for some respondents to navigate. Technical and policy-related language in the draft surveys was a barrier to some respondents and it appeared that CMWG members could respond more easily than some others.
- Approximately two hundred respondents answered an initial version of the survey that omitted one of the seven strategies. The remainder of the respondents responded to a corrected survey.

Methods

The survey was implemented using the Survey Monkey platform, a web platform for online surveys. The CMWG released the survey via email to WG and the Climate Council's Science and Technical Subcommittee members, and a wide array of partners and contacts. The survey was open for 12 days before a nonsystematic qualitative analysis was conducted to present the results to the WG. The survey received 427 total responses during this time period, including 27 WG members. Jessica Reilly-Moman reviewed the 427 responses first individually, then using

an Excel spreadsheet. For analysis, she used visual coding of quotations to note key emergent themes, as well as concerns, first by WG members, then by all respondents.

Results

The results of the survey are presented in two parts.

I) Themes that emerged across all responses in the qualitative analysis. The qualitative analysis performed by CMWG staff was guided by two questions: What themes emerged? What "red flags" or inflammatory language emerged?

II) Quantitative results, presented in charts and include respondents' concerns for each strategy, histograms for demographic information and charts that note the overall respondents' prioritization of actions within each strategy. CMWG survey responses about prioritization were also compared with all other responses.

Please refer back to the caveats section above for qualifications about the nature and appropriate use of these survey results.

I. Themes

Overall, the following themes emerged across all seven strategy areas:

1. Access to information and opportunities to participate. Respondents were concerned about lack of access to coastal/marine data, inclusion in decision-making and concern about outreach to tribal governments and municipalities.

2. Education. Respondents noted that climate change education and outreach should be included as an integral part of all strategies, from K-12 materials as well as information for the general public.

3. Equity and opinions about the CMWG. Respondents were concerned that the CMWG members who developed the strategies were not representative or sufficiently connected to the needs of who would be affected by them. Examples of connections needed were: municipalities, fishermen, tribal groups, and representation from urban and rural areas. Many voiced concerns about how climate change funding would be allocated: by whom, and for whom.

4. Municipal viewpoints. Respondents noted that municipal feedback should guide the development of final strategies. It was noted that funding will likely be a concern of towns and many of the strategies being suggested would be implemented locally.

5. Covid-19 influenced responses from the Fisheries and Working Waterfront Sectors in particular. Survey respondents who alluded to Covid-19 were those responding to the draft fisheries and working waterfronts strategies. These comments related to the need for adaptability, diversified employment and infrastructure, and the need for recommendations that lead to explicit solutions.

6. Use and enhance existing programs. Respondents emphasized that there are existing programs that partially or closely address the draft strategies. Respondents urged that we build on those- and don't reinvent the wheel.

7. Stormwater management, flood insurance, and tourism. Respondents noted that while these three topics are addressed in the strategies, they were not given the prominence anticipated.

8. Feasibility of some nature-based solutions. Some respondents questioned the validity and proof of concept of seeding eelgrass and other nature-based solutions. Whether or not these concerns are supported by literature and practice, this perception may present obstacles--and opportunities for additional pilot projects.

9. Incentivize transition. Many were supportive of incentives that enable people, businesses, and municipalities to transition to climate-ready actions.

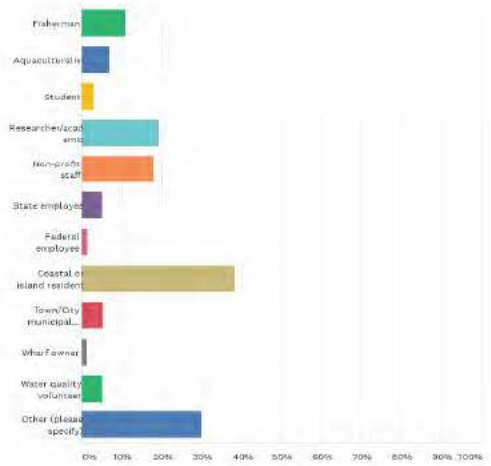
II. Survey Data

See the following section.

CMWG Stakeholder Survey Results

Public and WG member feedback
May 28, 2020

Q6 Organization/Occupation/Affiliation, check all that apply. (Optional)



Who responded?

- 427 people
- 27 WG members
- Older (45+, 65+)
- Male (home stretch push by women)
- Cumberland county 50%, most other represented
- 56% completion rate

Methods & caveats

- Qualitative
- Repeated topics / themes
- Red flags / inflammatory language
- A taste of responses: quotes

- "What concerns you?"
  - Half took to mean "do you care about this?"
- Not representative (as you can tell from the demographics,) but likely still useful
- Respondents progressively lost steam through length of the survey
- Strong opinions from some who IDed as fishermen, municipal officers
- Plenty of "these are all really important…"

OVERARCHING THEMES

1. People are missing - access, outreach, education
2. COVID-19 only referenced in fisheries (corresponds with not enough about people in other strategies)
3. Funding equity: who controls it, who gets it (also applied to management)
4. Stormwater management and nitrification popped up as missing throughout
5. Use what is already out there (tech assistance, monitoring)
6. Municipal involvement / consultation / implementation viewed as lacking throughout
7. Explicit incentives

Blue Carbon: WG concerns

4. Protect and restore current and historically-mapped eelgrass habitat from direct and indirect impacts by improving water quality and promoting transplanting and/or seeding.

5. Manage the harvest of subtidal and intertidal species of seaweed through the DMR and sector-based management developed with the Seaweed Fisheries Advisory Council; use aquaculture techniques to restore kelp.

For each strategy...

- WG member concerns (N = 3+)
- Emergent concerns from all: quotes
- What's missing? from all: quotes

- Focused on constructive feedback
- Although may be strategy specific, worthwhile to reflect on for all strategies as applicable
- WG member concerns aligned with "public"; public had additional insights

Blue Carbon: Concerns

Government overreach

"You guys want to reduce seaweed harvesting and promote farming. Nice."

Community engagement

"None of these particularly list the impact, benefit, or harm to communities living in areas of wetlands."

"A plan to work with communities and their conservation commissions to support better municipal wetland conservation policies and practices. The coastal town that I grew up in does not prioritize conservation of wetlands and needs support or to be incentivized to do so."

Blue Carbon: Concerns

Eelgrass proof of concept

- transplanting unproven / wouldn't work with rising sea temps

"Sea level rise and erosion will undo marsh restoration and seeding of eelgrass often does not work."

"What is missing is the integration of ecological consequences of warming seawater temperatures on eelgrass loss and on causing coastal/marshland erosion. Warming seawater temperatures (especially warm winters) mean more green crabs. Green crabs are responsible for the loss of eelgrass on for marshland erosion."

Blue Carbon: What's Missing

Education (municipal level)

"Public education: conservation can cut both ways from the view of the locals."

"Providing communities with tools to protect the most important wetlands."

"Municipal programs that assist communities in planning & implementing wetlands conservation & integrating wetlands into land use/ zoning ordinances."

"For people to care and support conservation they have to understand why and how, so i think connecting with the stakeholders and the public is important."

Blue Carbon: What's Missing

Conservation of land / anticipate SLR

"Identify and protect land areas into which marshes can migrate as sea level rises."

"Actually mapping out areas to put into conservation protection districts, and then doing that."

"Because it seems not to take into consideration the impact of warming ocean temperatures on eelgrass loss or marsh erosion. Seeding and transplanting eelgrass will be a waste of time/effort/expense with ocean temperatures remaining high."

"This sounds really nice... seaweed/wetlands saving everything. How about preventing development of stores, parking lots, etc."

Blue Carbon: What's Missing

Partnerships and inclusion (with industry, tribes)

"Potential impact on aquaculture siting and site management in the future."

"An effort that is not just coastal. It should include upland reaches to be as proactive and wide as possible."

"The management of aquaculture and seaweed harvesting should have input from a broader range of stakeholders, other than DMR and industry groups. Also funding for that process is needed."

Hydrology

"Specificity regarding restoring tidal flows to wetlands. Restored hydrology should be highlighted."

Blue Carbon: What's Missing

Understandable language

"I don't know. I guess you have to dumb it down for me."

Tracking Coastal and Ocean Impacts: Concerns

Perceptions

"Once again it will be you uninformed making decisions that affect us people who work around these areas day after day."

"In my opinion, it appears that you are just looking to create jobs and funding for yourselves."

Equity

"How are social impacts measured and how are equity, access, and representation built into recommendations?"

Tracking Coastal and Ocean Impacts: WG concerns

2. Expand coastal water quality monitoring, including nutrients and acidification.

6. Map the extent, track, and model future changes of intertidal habitats and beaches including tidal marshes, mudflats, dunes, and beaches.

Tracking Coastal and Ocean Impacts: What's missing

Specifics

"Rocky Intertidal has been omitted. Contrary to popular belief, rocky coasts are not permanent; subject to erosion especially with SLR, and increased precipitation."

"Regulatory review of storm water and agricultural runoff (excess N & P)"

"I don't see anything about the impacts of storm events, but this might be included in #6. Impacts of increased freshwater input during storm events?"

Tracking Coastal and Ocean Impacts: What's Missing

Broader scale
Ecological analyses, looking not just at species or parameter changes but how this changes the system."

"Better understanding of socioecological interactions (integrating #5 with the other natural systems research.)"

"Develop regional monitoring and modelling networks that recognize that Maine's changes are part of larger system."

Tracking Coastal and Ocean Impacts: What's missing

Capturing existing / historical knowledge
"Local historical observations."

"What is missing is applying what is already known about the impacts of climate change (which is now primarily manifesting as increased ocean temperatures)."

Tracking Coastal and Ocean Impacts: What's missing

People: access, use, education, citizen science
"Plan to support access and usability of data (incl for rural areas), including scaling for many uses, visualization and access tools, decision support tools, etc."

"Summary, synthesis, and communication of monitoring data and impacts."

"Coastal community involvement, buy-in and education."

"Actively involve our fishing and coastal communities in monitoring."

C & M Information Exchange: WG concerns

1. Establish an oversight panel of experts from the private, nonprofit, and public sectors to serve as an advisory board and raise dedicated funds to support implementation.

C & M Information Exchange: Concerns

Inclusion

"Such meetings should also include interested public, unless they are considered stakeholders. A measure of success of such meeting needs to be developed."

"would want to be very sure there was buy-in and commitment for use before creating another web tool."

"Stakeholder groups are often tilted well away from businesses and people earning a living from the water."

"State advisory councils have not always been that fair or representative and have a lot of concerning power structure embedded within…"

C & M Information Exchange: Concerns

Implementation / Use Existing Platforms

"I am less concerned, but just cognizant that the creation of new information platforms can duplicate existing info sharing efforts, requires ongoing labor to keep it up to date, and would need an intensive awareness raising campaign in order for people to actually use it."

"Who is responsible for verifying data (if public input is part of the puzzle)"

"Much of this could be implemented in cooperation with UMaine who already does this on a smaller scale."

C & M Information Exchange: Concerns

Who are the "experts"?

"In item 1., what is the definition of expert? Don't have the panel limited to the "same old gang"."

"A good platform already exists (ESIP) and should be adapted to future needs."

"Given expense, limiting adaptation decisions to elites is [a] bad idea."

"Decisions for who is on oversight panels always alarms me. Too often 'for profit' voices are too powerful on these panels."

C & M Information Exchange: What's Missing

Equity / inclusion

"Explicit provisions for equity considerations and plans for increasing capacity for communities to incorporate decision support tools into existing planning/ building processes."

"Incentives for locally owned worker cooperatives or town level cooperatives to fill the roles."

"social media strategy/ presence - nontraditional, far-reaching SciComm efforts"

C & M Information Exchange: What's Missing

Focus on the users / learning across sectors and scales

"Start with asking what information (not data) is needed and wanted by people, and how it can best be provided. Then work backwards to figure out the data and tools needed. Start with the end users. Don't start with the data and scientists (I say this as a science-oriented person)."

"Involve high schools and higher ed. Institutions"

"Ongoing stakeholder meetings held at different coastal communities to improve two way communication from the public."

"Explicit language about information exchange with other coastal states to learn from each other."

Resilient Fisheries and Aquaculture: Concerns

Aquaculture

"Pollution from aquaculture."

"The push for aquaculture privatizes more ocean resources and ultimately will leave out many Mainers who have made their living on the ocean for generations. However, because fisheries are limited entry, aquaculture is the only way for young Mainers to continue their coastal livelihoods. But the promotion of aquaculture for aquaculture's sake will largely benefit large corporations, not individual working class Mainers."

Resilient Fisheries and Aquaculture: WG Concerns

2. Relevant forecasting: implement forecasts for key environmental parameters at spatial and temporal scales that are relevant to business planning, operations, and management of Maine's fisheries and aquaculture sectors.

Resilient Fisheries and Aquaculture: Concerns

Industry issues and management

"Seem like items from an industry wish list; climate connection unclear."

"Every fisheries management plan over the last 100 years has been a disaster. why would this be different?"

"Management of fisheries in the past has not protected species like urchin, elvers and maine shrimp, what would be different?"

Resilient Fisheries and Aquaculture: Concerns

The stakeholder / management dichotomy

"You guys should get [a] job in the private sector...."

"Letting the ACTUAL stakeholders resolve it. More regulation is the enemy of good management."

"Equity considerations should be explicitly included; communication and access to monitoring data should be part of this plan."

Resilient Fisheries and Aquaculture: What's Missing

Use existing data and programs

"Regarding #1, to the extent possible, utilize existing fishery-dependent data (and opportunities for self-reported data), rather than creating new programs to collect data that may already be existing or accessible from fishermen and harvesters."

Incentives

"Payments for ecosystem services (shellfish aquaculture & eelgrass restoration)"

Resilient Fisheries and Aquaculture: What's Missing

Getting beyond (commercially-valuable) species

"No focus on protection or restoration of deteriorated habitats or living resources."

"Missing opportunity to shift fisheries management to ecosystem approach in the context of rapid change. This would include aquaculture in ecosystem approach. Old approaches of assessment and simple species plans are not the best approach in this context."

"Integration of the ecological consequences of warming ocean temperatures on increasing predation rates through mild winters, increasing optimal feeding time, and speeding up of predators metabolism."

Resilient Fisheries and Aquaculture: What's Missing

Help in hard times / covid-19

"I've seen no discussion regarding import/export vs. regional and types of market as part of sustainability. Covid is showing us that weakness."

"Funding and new ways to market seafood during bad times like pandemics."

"Access to capital for initiatives/trials to address potential climate-change related pivots."

"Subsidies for those changing their catch to accommodate new restrictions."

Maine Marine Business Council: WG Concerns

4. Support the growing aquaculture sector: increase Maine seafood production, provide important economic opportunities for coastal communities, and harness potential acidification mitigation and other environmental services through targeted industry support.

Maine Marine Business Council: Concerns

Make it more broad
"Almost ALL small businesses need these types of supports, especially those dedicated to fisheries."

Already existing efforts
"Number 1 is awkwardly worded (info translation for what?) Is the Maine Marine Alliance being considered as an essential entity working on many of these strategies?"

Maine Marine Business Council: Concerns

History of Stakeholder Engagement
"I love the idea of this, but when it comes down to rubber hitting the road - this really translates into a whole lot of nothing for the actual business people, harvesters, & fishermen. Trust me I have spent many hours and many days going to meetings across the state as a "stakeholder". It feels warm & fuzzy being there at the table, but when all is said and done, we go home to our businesses and have to grind out a paycheck all alone. Meanwhile these wonderful NGOs and organizations keep getting funded to do wonderful things and the staff always gets paid. This is just a weird translation. Once again, the shit you've outlined above sounds really rosy and enthusiastic. There is a HUGE disconnect between private enterprise and organizations such as this Maine Marine Business Council. Its junk when it comes to actually helping the working men and women on the Maine Coast."

"Would this group provide climate adaption advice for the industry? Or for the State? What if the best thing for the industry is bad for coastal communities?"

Maine Marine Business Council: What's Missing

Covid-19 considerations
"What's missing is that we're now in the middle of a pandemic that is decimating the seafood industry - have to start with a different baseline."

Entire sectors omitted
"Recreational marine businesses. Marinas, recreational fisherman, tackle shops."

"No mention of tourism."

Maine Marine Business Council

Specific Tools

"Develop business tools/plans for stakeholders/fishers who must change how they make a living."

"Clinate business labeling much like sustainable seafood labeling."

"Ways to invest in aquaculture start ups!"

Don't do it

"No council is needed. State and federal agencies & private sector already do this work."

Climate Ready Working Waterfronts: WG concerns

Missing flood insurance

"Will this survey never end.....I was just trying to help out"

Climate Ready Working Waterfronts: Concerns

Maine / community owned access

"Communities in Maine, and only communities in Maine, should own the working waterfront"
"The wealthy own Maine's coast. Buying them out or allowing them to rebuild 2nd, 3rd, etc vacation homes after disaster puts further burden on the less fortunate. Never bail out the wealthy. Stop developing lands that are essential to mitigating climate disaster or are in the path of SLR."

"None of these actions address the issue of decreased access due to gentrification of ME's coastline. Wealthy out of staters are buying up coastal land and not allowing clammers to access the intertidal, complaining about working waterfront noises and smells. The state is currently saying that these people "own" the intertidal, and not fighting for access and working waterfronts. This makes climate change adaptation measures even harder to implement!"

"We should always be looking for ways to expand waterfront access for ALL, so keep that in

Climate Ready Working Waterfronts: Concerns

Municipal implementation

"these programs are very difficult to calibrate to municipal boundaries and more difficult to calibrate between municipalities, better to come up with some new mechanisms."

"Ability for very small communities to implement"

"With the current lack of a State Planning Office or other resource to assist towns, a "resiliency" chapter will likely not result in the hoped for result. Towns need assistance with planning for climate change topics."

"Zoning should stay local/Transition shorelines via state incentives, who, what, why is that decided?"

Climate Ready Working Waterfronts: What's Missing

Flood insurance throughout sectors

"Dealing with flood insurance costs and the associated issues with getting a loan; a clear state policy statement that working waterfronts are important."

"Floodplain Insurance relief or funding to mitigate costs of adaptation to comply with FEMA standards."

"climate based insurance options for waterfront owners?"

Climate Ready Working Waterfronts: WG concerns

Where's tourism?

"No acknowledgement of role of tourism, recreational use of waterfronts."

Climate Ready Working Waterfronts: What's Missing

Stormwater / runoff

"What happened to revision of stormwater and nitrogen laws. This is a serious oversight."

People power / education

"implement a train the trainers type program for COGs working on comprehensive plans to incorporate new comp plan guidance for resilient communities"

"MDEP Environmental Leadership Program is a great idea; it should extend beyond tourism."

Climate Ready Working Waterfronts: What's Missing

Funding / equity
"Who is going to pay for this?"
"Funds for land acquisition/ working waterfront trust."

"These programs can be expensive and may inadvertently benefit the wealthy coastal land owners while reducing financing for more vulnerable communities. Still an important priority."

Municipal involvement
"More help to towns for local W/W planning and preservation. Keep this with local decision makers."

Nature based solutions: Concerns

Coastal residents / landowner conflict
"Considerable resistance from developed coastal communities. Lack of capacity for planning in State and RPCs"

(Municipal) implementation
"No consideration of how to coordinate state/municipal planning priorities."

Nature based solutions: WG concerns

(reflected in the comments)

Nature based solutions: Concerns

Proof of concept
"Costly, temporary, and has spillover effects."

"This assumes that living shoreline interventions are viable, long term solutions. That's not clear yet, and more study on viable approaches and structures is needed."

Nature based solutions: What's Missing

Funding

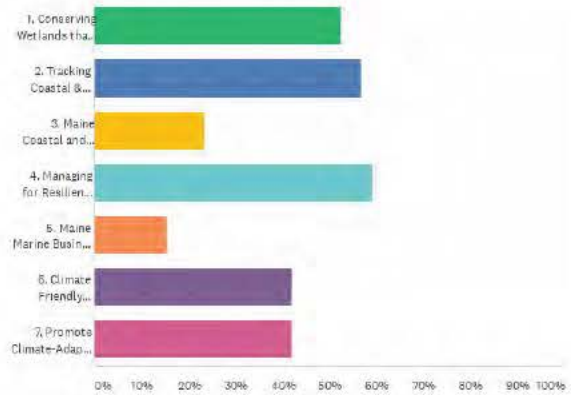
"Nature-based alternatives are costly to implement and no funding mechanism are identified in this section."

"You neither explain what this entails, nor do you quantify costs."

People

"Should include socio-economic information, users, and community dependence on particular areas."

Q35 Please choose the 3 topics that are most important to you.



Nature based solutions: What's Missing

Incentives

"examine existing grant programs for opportunities to include climate resilient considerations into project scoring; give additional points to projects with co-benefits for wildlife and people"

"Incentives for private coastal environmental easements?"

Appendix D

Outreach Efforts

Date	Primary Constituents	CMWG Ambassador (s)	In person or virtual?
1.17.20	Maine Aquaculture Summit: industry members, scientists students	Heather Leslie	In person
1.24.20	Maine Coastal Observing Alliance	Angie Brewer	In person
3.5.20	Maine Coast Heritage Trust's Coastal Resilience Master Class in Topsham and Hancock (remote)	Bev Johnson and Kristen Puryear	In person and virtual
4.09.20	Maine Climate Funders	Ivy Frignoca	Virtual
4.15.20	Casco Bay Regional Shellfish Collaborative	Ivy Frignoca	Virtual
4.23.20	Maine Conservation Voters	Bev Johnson and Kristen Puryear	Virtual
4.30.20	Friends of Casco Bay Members	Ivy Frignoca, Cassaundra Rose	Virtual
5.13.20	Stream Connectivity Work Group	Claire Enterline	Virtial
4.2020	Association of State Wetland Managers (Marla Stelk, Dir)	Heather Leslie	Phone call
6.10.20	Maine GIS Users Group	Claire Enterline (also Tora Johnson from Community Resilience WG)	Virtual
5.27.20	Fishermen and other fisheries experts	Heather Leslie	Virtual
5.2020	Maine Association of Planners/Build Maine/Smart Growth	Kathleen Leyden	Virtual
5.2020	Maine Climate Youth Justice	Kristen Puryear and Bev Johnson	Virtual
5.2020	Maine ports group	Kathleen Leyden	Phone call
Ongoing	DMR staff	Claire Enterline	Virtual
Ongoing	IDFW staff	Amanda Cross	Virtual

Appendix E

Blue Carbon Greenhouse Gas Sequestration Analysis

Blue Carbon Greenhouse Gas Sequestration Analyses

A. Salt Marsh Estimated Carbon (CO2) Sequestration and Methane (CH4) Emissions under Current and Projected Sea Level Rise and Restoration Scenarios

1. Color codes:
   - C Sequestration
   - C Emissions (via Loss of C Sequestration in Tidal Restricted Salt Marsh)
   - C Emissions (via Methanogenesis in Tidal Restricted Salt Marsh)

2. Footnotes about assumptions, limitations, and data sources are referred to in the tables as (*1), (*2), (*3), etc., and explanations provided below the tables

3. These tables provide estimates of the amount of salt and brackish marsh area that is available for carbon sequestration under current conditions and modeled based on sea level rise scenarios. Based on published studies, healthy marshes that receive the full ebb and flow of the tide have carbon sequestration potential of 74-256 gC/m2 per year, however in marshes were tidal flow is limited by a road or other crossing that limits the full tidal flow and cycle, carbon sequestration is significantly reduced. Restricted marshes (<18 PSU salinity) become net methane emitters at a rate of 8.4-41.6 gC/m2 per year. In the tables below, we present scenarios for marsh sequestration for current and sea level rise conditions based on area of healthy marsh and restricted marsh. In all marsh migration scenarios, there is a net loss of marsh area compared to current 2020 conditions under the assumption that no current marshes will keep pace (accrete sediment) with sea level rise. Specific assumptions and methods to determine the area of healthy and restricted marsh under each scenario are provided in the footnotes and supporting documents.

Table 1. Emissions Factors Used in the Carbon Burial Calculations

Emission Factors	Low Estimate	High Estimate
C Sequestration (healthy, unrestricted salt marsh); gC/m2-yr (NEG = SEQUESTRATION) (*1)	-74	-256

Emission Factors	Low Estimate	High Estimate
C Emissions (methanogenosis in tidally restricted marsh, <18 PSU salinity); gC/m2-yr (POS = EMISSIONS) (*2)	8.4	41.6

Table 2. Range of marsh vulnerability as areas of sequestration and potential emissions under current conditions and due to SLR predictions (ft), tidal crossing restrictions (roads, railroads, dams), and modeled marsh migration

Sea Level Rise magnitude (ft)	Baseline Area Salt and Brackish (km2), Low Est. (*3)	Baseline Area Salt and Brackish (km2), High Est. (*4)	Marsh Change due to SLR (km2) (*5)	Total Remaining Marsh Due to SLR (km2), Low Est. (*6)	Total Remaining Marsh Due to SLR (km2), High Est. (*6)	Number of Tidal Marsh Crossing Restrictions (*7)	Low End Area of CH4 Emissions due to Restrictions (km2) (*8)	High End Area of CH4 Emissions to due Restrictions (km2) (*8)	Percent Marsh Area Loss Due to SLR, low	Percent Marsh Area Loss Due to SLR, high	Total Number of Tidal Marsh Crossings - Low End (*7)	Total Number of Tidal Marsh Crossings - High End (*7)	Percent of crossings that are restricting tidal flow at marshes, Low End (*7)	Percent of crossings that are restricting tidal flow at marshes, High End (*7)
0 (Baseline)	73.2	92.4	0	73.2	92.4	336-347	39.1	39.1	-	-	368	368	91.30%	94.30%
1.2	73.2	92.4	-60.7	12.5	31.7	488-514	6	15.2	-82.90%	-65.70%	534	545	91.30%	94.30%
1.6	73.2	92.4	-56.8	16.4	35.6	495-521	7.9	17.1	-77.60%	-61.50%	542	553	91.30%	94.30%
3.9	73.2	92.4	-36.7	36.5	55.7	565-594	17.5	26.7	-50.10%	-39.70%	619	630	91.30%	94.30%

Table 3. Carbon Burial Estimates for Baseline and Sea Level Rise Scenarios (Baseline, 1.2', 1.6' and 3.9' sea level rise) With and Without Tidal Restrictions (*8, *9)

	Low Burial Amount Scenario (Gg CO2 equiv/yr)		High Burial Amount Scenario (Gg CO2 equiv/yr)	
Scenario	*Low Marsh Area*	*High Marsh Area*	*Low Marsh Area*	*High Marsh Area*
Baseline				
C Sequestration Potential (without consideration of Tidal Restrictions) (*8)	-19.83	-25.03	-68.59	-86.58
C Emissions (via Loss of C Sequestration in Tidal Restricted Salt Marsh) (*8,*9)	10.59	10.59	36.64	36.64
C Emissions (via Methanogenesis in Tidal Restricted Salt Marsh) (*8,*9)	1.2	1.2	5.95	5.95
Net C Sequestration (*9) (Gg CO2 equiv/yr)	-8.03	-13.23	-26	-43.99
1.2' SLR				
C Sequestration Potential (without consideration of Tidal Restrictions) (*8)	-3.39	-8.59	-11.71	-29.7
C Emissions (via Loss of C Sequestration in Tidal Restricted Salt Marsh) (*8,*9)	1.63	4.12	5.62	14.26
C Emissions (via Methanogenesis in Tidal Restricted Salt Marsh) (*8,*9)	0.18	0.47	0.91	2.32
Net C Sequestration (*9) (Gg CO2 equiv/yr)	-1.58	-4	-5.18	-13.13
1.6' SLR				
C Sequestration Potential (without consideration of Tidal Restrictions) (*8)	-4.44	-9.64	-15.37	-33.36
C Emissions (via Loss of C Sequestration in Tidal Restricted Salt Marsh) (*8,*9)	2.13	4.63	7.38	16.01
C Emissions (via Methanogenesis in Tidal Restricted Salt Marsh) (*8,*9)	0.24	0.53	1.2	2.6
Net C Sequestration (*9) (Gg CO2 equiv/yr)	-2.07	-4.49	-6.79	-14.74
3.9' SLR				
C Sequestration Potential (without consideration of Tidal Restrictions) (*8)	-9.89	-15.09	-34.2	-52.19
C Emissions (via Loss of C Sequestration in Tidal Restricted Salt Marsh) (*8,*9)	4.75	7.24	16.42	25.05
C Emissions (via Methanogenesis in Tidal Restricted Salt Marsh) (*8,*9)	0.54	0.82	2.67	4.07
Net C Sequestration (*9) (Gg CO2 equiv/yr)	-4.6	-7.02	-15.12	-23.07

Salt Marsh Analysis Assumptions and Limitations:

(*1) CO2 sequestration in tidal salt marshes: Low value from Drake et al., 2015; high value from Roman et al., 1997

(*2) CH4 emissions (in tidal salt marshes with salinity < 18 ppt): low and high values summarized in Kroeger et al., 2017

(*3) Baseline Area Salt and Brackish (km2), Low Est. - this value is based on the Maine Natural Areas Program tidal marsh mapping effort: https://www.maine.gov/dacf/mnap/assistance/tidal_marshes.htm. The values given here represent only salt and brackish marsh (freshwater marsh area is removed from this analysis as it does not have the same CO2/CH4 sequestration and emission potential).

(*4) Baseline Area Salt and Brackish (km2), High Est. - this value is based on the Maine Natural Areas Program (MNAP) salt and brackish marsh areas and additionally adding salt and brackish marshes that were not mapped as part of their effort. The Maine Coastal Program identified additional salt and brackish marsh through desktop analysis of all coastal marshes using the National Wetland Inventory, aerial images, and other GIS tools. The MNAP effort did not attempt to map areas smaller than a certain acreage as well as fringing marshes, while the high estimate includes marshes of all sizes and types.

(*5) Marsh Change due to SLR (km2) - this area calculation is based on the MNAP marsh migration model, with the assumption that no current marshes will keep pace with sea level rise, in other words that no current marshes will accrete sediment at a pace that maintains the elevation of salt marshes relative to the tidal flooding and duration necessary to maintain vegetated communities on the marsh platforms.

(*6) Column F, Total Marsh Due to SLR (km2): These values are based on a "bathtub" GIS model using sea level rise scenarios to predict future areas where elevation could support marsh habitat. These areas assume that no current marsh habitat will keep pace with sea level rise (i.e. assumed they will not accrete enough sediment with sea level rise to maintain vegetation), and only new marsh will be formed at higher elevations. For more information please visit https://www.maine.gov/dacf/mnap/assistance/marsh_migration.htm. Please note this model was not based on SLAMM - it is an elevation only based model. High Est., is based on a "high estimate" for the current extent of tidal marsh (e.g. includes some NWI or aerial imagery interpretation). However the marsh migration scenarios were mapped and calculated based only on the "low estimate" extent for tidal marsh. Therefore there may be some discrepancy in the amount of future marsh calculated under the "high estimate" because the base numbers used for input are not the same.

(*7) Number of Tidal Marsh Crossing Restrictions, Crossings, and Percent of Crossings that are Restrictive - this is the number of crossings at salt and brackish marshes, including culverts, bridges, dams, dikes, causeways, road grades, railroad grades, trails, and dirt roads, that are restricting tidal flow based on a Maine Coastal Program desktop analysis of all tidal crossings. Restriction was assessed based on the presence of upstream or downstream scour, different vegetation community type, or culvert perch. This value has been calculated for present conditions using this desktop analysis. The number of crossings that restrict tidal flow for 1.2', 1.6', and 3.9' sea level rise scenarios are based on the proportion of current tidal marsh crossings that are restrictive compared to the total number of current tidal marsh crossings (91-94%). The total number of future tidal marsh crossings under the 1.2', 1.6', and 3.9' scenarios were determined using the MNAP marsh migration scenarios and modeling where future marsh migration areas and the corridors to those areas would cross roads, railroads, etc.

(*8) Area of CH4 Emissions due to Restrictions (km2) - Using the locations of tidal marsh restrictive crossings, the Maine Coastal Program determined the locations and area of salt and brackish marshes upstream of these crossings currently restricting tidal flow. The total area of all salt and brackish marshes that are not receiving the full ebb and flow of the tide are given for current conditions based on the desktop restriction analysis. The degree of tidal restriction and effect on salinity in each of the marshes has not yet been field verified, and therefore the CH4 emission calculations based on these areas are estimates based on the assumption that the tidal restrictions are causing these restricted marshes to have salinities <18ppt. The areas of future restricted marsh areas are estimated based on the marsh migration scenarios and the assumption that the current proportion of restricted to unrestricted salt and brackish marsh (42-53%) will hold constant in future scenarios.

(*9) Net carbon sequestration estimates based on total potential carbon sequestered (using total area salt and brackish marshes and EF in Table 1), minus loss of carbon sequestered in tidally-restricted areas [using estimated tidal restriction area (*8) and EF in Table 1] minus methane emissions (assuming tidally restricted areas have salinities < 18 PSU and EF in Table 1). In short, a tidally restricted marsh has a double effect on carbon emissions both in losing area that normally sequesters carbon and in releasing methane.

B. Eelgrass Estimated Carbon (CO_2) Sequestration under Current and Projected Sea Level Rise Scenarios

Baseline Condition: Total Eelgrass Area (km2) from -15 ft to 0 ft MLLW 99.89*

*value rounded to 100 km2 for purposes of calculations below

Table 1. Range of eelgrass vulnerability (surrogate for loss) due to SLR predictions (ft) (low and high estimates based on vertical depth uncertainty = 3.28 ft)

Sea Level Rise magnitude (ft)	Area lost (km2) (low estimate)	Area lost (km2) (high estimate)	% of total eelgrass lost (low estimate)	% of total eelgrass lost (upper estimate)
1	2.72	5.56	2.80%	5.80%
2	3.38	7.2	3.50%	7.50%
3	4.28	9.32	4.50%	9.70%
4	5.56	11.99	5.80%	12.50%
5	7.2	15.48	7.50%	16.20%
6	9.32	19.82	9.70%	20.70%
7	11.99	24.9	12.50%	26.00%

Table 2. Range of Carbon Sequestration Rates in Seagrass (+/- 1 SE from the Mean)(values from McLeod et al., 2011)

Low Range (gC/m2/yr)	High Range (gC/m2/yr)
100	176

Table 3. Low and High Carbon Burial Amounts (Gg CO_2 equiv/yr) in Seagrass Under Baseline and Various SLR Scenarios

	Low Burial Amount Scenario (Gg CO_2 equiv/yr)		High Burial Amount Scenario (Gg CO_2 equiv/yr)	
Baseline or SLR Scenario	*Low Eelgrass Loss Estimate*	*High Eelgrass Loss Estimate*	*Low Eelgrass Loss Estimate*	*High Eelgrass Loss Estimate*
Baseline Condition (~2000)	37	37	65	65
SLR from Baseline: 1 ft	35.66	34.62	62.77	60.93
SLR from Baseline: 2 ft	35.42	34.02	62.34	59.88
SLR from Baseline: 3 ft	35.09	33.19	61.76	58.51
SLR from Baseline: 4 ft	34.62	32.26	60.93	56.79
SLR from Baseline: 5 ft	34.02	30.99	59.88	54.53
SLR from Baseline: 6 ft	33.24	29.39	58.51	51.73
SLR from Baseline: 7 ft	32.26	27.53	56.79	48.46

Given Table 3 values, decreased potential for carbon burial over various SLR scenarios can be determined for the cost of doing nothing analysis. For example, under the high burial amount scenario at 5 ft of SLR from baseline, Maine's eelgrass is predicted to lose 8-16% of its capacity to bury carbon if nothing is done to mitigate eelgrass loss.

Eelgrass Analysis Assumptions and Limitations:

1) Baseline eelgrass area calculated from most recent complete Maine dataset, which is Maine DMR 2010 GIS layer. This layer is a composite of multiple survey years such that the entire coast of Maine was surveyed in sections between 2001-2009. More recent eelgrass area calculations are possible for Casco Bay (2018), Belfast Bay/Northport (2019) and the Piscataqua River/Portsmouth Harbor (2019), which demonstrate a cumulative decline in eelgrass by 8.5 sq km (26%) relative to their calculated areas from the 2010 DMR GIS layer. As eelgrass beds are inherently expanding and contracting from year to year due to a multitide of factors (SLR, water quality, light availability, macroalgal competition, invasive species, fouling organisms, ice scour, vessel and mooring impacts), the provided baseline eelgrass area calculation is a best possible estimate of area coastwide.

2) For the purpose of this conservative assessment, the deep edge of Maine eelgrass beds was set at -15 ft MLLW based on 2010 DMR eelgrass layer and the NOAA Coastal Relief Model (CRM) bathymetry raster, which demonstrated that approximately 98% of Maine's eelgrass resides shallower than or at -15 ft MLLW. Since the deep edge of eelgrass is generally controlled by light availability, even a 1 ft increase in SL could decrease light availability and cause beds residing several feet shallower than -15 ft MLLW to recede. Therefore, SLR-caused losses to eelgrass could very possibly be greater than that shown in calculations for nearer term predictions (2030-2050 timeframe).

3) Landward migration of eelgrass into adjacent intertidal habitat is possible unless physical restrictions or disturbance prevent movement or survival (ex. natural hard substrate, shoreline features like bulkheads, docks/piers, moored vessels, aquaculture operations, wild harvest, ice scour). For the purpose of this assessment, landward migration is not permitted since a comprehensive determination of where movement could/could not occur currently cannot be accomplished with reasonable accuracy.

4) Range of loss of eelgrass due to SLR assumes a) equivalent rise across entire Maine coastline, and b) CRM vertical uncertainty of 3.28 ft (1 standard deviation) due to variation in actual water depth. Re: a), SLR calculations may be less accurate along portions of the coastline with steeper as compared to more shallow slopes. Re: b), this magnitude of vertical uncertainty overwhelms the SLR scenarios that are less than 3.28 ft, so instead of providing a single value of loss for each specific SLR scenario, a range of eelgrass areas (and percentage of total) vulnerable to each foot of SLR is provided. With more time to prepare calculations for loss from baseline, vertical uncertainty could be lessened for 6.94% of the coastline by use of the Univ. of New Hampshire's Center for Coastal Ocean Mapping Joint Hydrographic Center and Maine Coastal Program's project-specific high resolution bathymetry.

5) Long term burial rates assumption based on global seagrass estimate, not specific to eelgrass (Zostera marina). Forthcoming publication will address region-specific burial rates for eelgrass: Novak, A, P. Pelletier, P. Colarusso, J. Simpson, N. Gutierrez, A. Ariane-Ortiz, M. Charpentier, P. Masque and P. Valle. Factors influencing carbon stocks and accumulation rates in eelgrass meadows across New England, USA. (accepted in April 2020 to Estuaries and Coasts).

6) Long term burial rates assumption that all eelgrass beds are equally healthy and equally capable of carbon sequestration. In reality, a range of burial rates is needed to include those highly functioning and/or long-present beds vs. those that are more ephemeral and/or provide limited sequestration due to poor eelgrass health.

C. Seaweed Estimated Carbon (CO_2) Sequestration under Current and Projected Scenarios

Baseline Condition: Total Seaweed Biomass (Gg C)	188.54

Table 1. Range of annual biomass production increases from farmed seaweed (values from Island Institute Edible Seaweed Market analysis)

Market Growth Scenario	Relative increase in biomass production 2035	New biomass estimates of farmed seaweed in 2035 (kgs)
Low	8-10%	698,532
Medium	12-15%	1,387,993
High	15-20%	2,705,678

Table 2. Range of Proportion of farmed and natural annual biomass production contributing to Carbon Sequestration in Seaweed (+/- 1 SE from the Mean)(values from Krause-Jensen and Duarte 2016)

Low Range % (gCy-1)	Mid Range % (gCy-1)	High Range % (gCy-1)	
4.3	10.9	18.9	See note 1

Seaweed Analysis Assumptions and Limitations:

1) Assumed suitable habitat for seaweed biomass calculation (Gg C) is just 1m wide along the whole coast, which is an underestimate of actual biomass. Estimate would have improved accuracy given available data about the fraction of the coast that is rocky shoreline.

2) See Table 2 from Krause-Jensen and Duarte 2016. Used 25%, 50%, and 75% for sequestration estimates from uncertainty analyses, and 50% global production from seaweed to generate range of values. It should be noted that these estimates are eventually dependent on a paper published in 1990 (Charpy-Roubaud, C. and Sournia, A., 1990. The comparative estimation of phytoplanktonic, microphytobenthic and macrophytobenthic primary production in the oceans. Marine Microbial Food Webs, 4(1), pp.31-57.) that uses rates from laminarids and fucoids, as well as macrosystis and some tropical algae. If we are in a bind to find production rates (gC m-2 yr-1) we can use this. It is also important to note that Krause Jensen and Duarte assumed a more conservative value of 25% C.

3) There are over 250 species of seaweeds in Maine that will have varying responses to warming and acidification (CO_2 fertilization). The predominant species (by biomass) are the fucoids and kelps, so we use reported change in growth rates from this subset of species to make predictions (Gledhill et al 2015)

4) Assuming seaweed is 45% C, but this value varies by species, life stage, and season

5) Assuming that proportion C of seaweed sequestered is the same for farmed and wild-harvested, and not accounting for a) sinking seaweed purposefully, b) creating biochar, and c) mitigating methane emissions from ruminants with seaweed nutritional supplements