Climate Change Vulnerability Assessment & Adaptation Planning for Salt Marsh Habitats of the North Atlantic

Summary report from the virtual training series: *Building Capacity for Climate Adaptation Planning in North Atlantic Coastal and Marine Protected Areas*[1]

Background

Workshop overview

A virtual training series was held on October 6th, 13th, and 20th, 2020, for 22 attendees from the North Atlantic region of the U.S. and Canada. Organized by the Commission for Environmental Cooperation (CEC), in collaboration with EcoAdapt, Parks Canada, and NOAA's Marine Protected Area (MPA) Center, this workshop series provided training on using the CEC's Climate Adaptation Toolkit to help MPA practitioners adapt to the impacts of climate change. The training focused on identifying vulnerabilities of and developing adaptation strategies for salt marsh and eelgrass habitats as well as promoting collaboration and communication on oceans and climate change mitigation and adaptation. For more information about this training series, please see the Workshop Proceedings.[1]

Habitat description

Salt marshes are intertidal estuarine ecosystems dominated by salt-tolerant plants, often grasses such as the smooth cordgrass *Spartina alterniflora*. Along the North American Atlantic, this highly productive carbon-sequestering ecosystem is found in the Gulf of Mexico and from northern Florida through Newfoundland. This ecosystem is under multiple threats including pollution, development, invasive species, and, in southern locations, conversion to mangrove forest. Further, while this ecosystem has been capable of accreting sufficient sediment to keep up with past rises in sea level, unprecedented rates of sea level rise, altered hydrology leading to reduced sediment inflows, and development that prevents landward migration could result in unprecedented rates of salt marsh loss as a result of modern sea level rise.

Salt marshes provide valuable ecosystem services such as coastal protection, carbon sequestration, and nursery habitat for fishery species, among others.

Regional boundary

This assessment considers salt marshes in the North Atlantic, including the Gulf of Maine and environs.

[1] http://ecoadapt.org/workshops/cec-atlantic-canada

Vulnerability assessment results

This vulnerability assessment utilizes a medium-term time scale (next 50 years).

Common climate and non-climate stressors

Altered storm frequency/severity, sea level rise, and increased wave action/coastal erosion were selected as the climate stressors that have the most significant impact on North Atlantic salt marshes.

Table 1. Observed and projected changes in significant climate stressors for North Atlantic salt marshes.

Stressor	Observed change	Projected change
Storm frequency/ severity	Increases in hurricane activity since the 1970s[2] Increased winter storm frequency and intensity since 1950[2], with Nor'easters becoming more of a concern More frequent storm surge, leading to roads being closed more often	Slight decreases in global hurricane frequency[3,4] Likely increase in hurricane intensity (including frequency of very intense storms), size, and precipitation rates[2,3,5] Changes in the frequency and intensity of severe winter storms are largely unknown[2]
Sea level rise	+16-21 cm (7-8 in) of global sea level rise since 1900[6]	+0.3–1.2 m (1.0–3.9 ft) of global sea level rise relative to 2000 (90% probability within this range)[7] Extreme global scenario of 2.5 m (8.2 ft) possible if Antarctic ice sheet collapses[7]

Development/population growth, roads/armoring, sediment inputs, invasive species, and land-source nutrient pollution were identified as the non-climate stressors that have the most significant impact on North Atlantic salt marshes. Through discussion, workshop participants decided that the impacts associated with sediment inputs, development/population growth, and roads/armoring were similar enough that the three could be grouped together.

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[2] Kossin, J. P. *et al.*, in *Climate Science Special Report: Fourth National Climate Assessment, Volume I*, D. J. Wuebbles et al., Eds. (U.S. Global Change Research Program, Washington, DC, 2017), pp. 257–276.
[3] Bacmeister, J. T. *et al.* Projected changes in tropical cyclone activity under future warming scenarios using a high-resolution climate model. *Climatic Change* **146**, 547–560 (2018).
[4] Knutson, T. R. *et al.* Tropical cyclones and climate change. *Nature Geoscience* **3**, 157–163 (2010).
[5] Marsooli, R., Lin, N., Emanuel, K. & Feng, K. Climate change exacerbates hurricane flood hazards along US Atlantic and Gulf Coasts in spatially varying patterns. *Nature Communications* **10**, 3785 (2019).
[6] Sweet, W. V., Horton, R., Kopp, R. E., LeGrande, A. N. & Romanou, A. Sea level rise. in *Climate Science Special Report: Fourth National Climate Assessment, Volume I* (eds. Wuebbles, D. J. et al.) 333–363 (U.S. Global Change Research Program, 2017). doi:10.7930/J0VM49F2.
[7] Sweet, W. V. *et al. Global and regional sea level rise scenarios for the United States*. (2017). NOAA Technical Report NOS CO-OPS 083, National Oceanic and Atmospheric Administration, Silver Spring, MD, 2017.

Summary of anticipated changes to salt marshes from common stressors

Climate stressors[8]

Altered storm frequency/severity could result in altered tidal flows, increased velocities at tidal restrictions and adjacent scour, increased exposure of back marsh systems to wave action and erosion, and changes in habitat suitability for key ecosystem components and/or keystone species. Increased storm frequency or severity could increase nutrient inputs, leading to decay and increasing instability. However, increased storm frequency or severity that leads to higher sediment inputs could be beneficial in sediment-starved systems.

Sea level rise may cause changes to tidal mudflats, flooding of high and low marsh areas, and possible habitat migration. Sea level rise may result in changes in flora and benthos and the loss of flood-sensitive species.

Non-climate stressors

Development, roads/armoring, and sediment inputs affect salt marsh habitats in many ways, including:

- Constricting flow during high tides and storm surge, creating a tunnel of pressure (occurs at Acadia National Park);
- Exacerbating impacts of warming waters due to sedimentation from adjacent human land uses such as agriculture (occurs at Basin Head Marine Protected Area);
- Smothering plants and aquatic organisms as sediments accumulate, although some sediment can be beneficial (e.g., in sediment-starved systems);
- Causing drying and degradation that alter vegetation communities and elevation (subsidence) where marshes have been ditched and diked for salt production (occurs in southern Maine), further complicating restoration and transitions to different marsh communities;
- Preventing marshes from migrating into uplands, which requires the prioritization of undeveloped locations for migration and restoration in order to improve conditions for species;
- Increasing erosion, direct habitat loss (replacement), barriers to migration, loss of carbon sequestration, and pollution; and
- Increasing accessibility to salt marshes (i.e. due to the proximity of roads), which allows recreation activities and sweetgrass harvesting by tribes, though maintenance of road infrastructure over time can cause localized impacts to salt marshes.

Invasive species impact North Atlantic salt marshes by affecting accretion and subsidence, disrupting existing ecology, and displacing native species. Invasive species within the regional boundary include:

- European green crabs (*Carcinus maenas*), which burrow along marsh edges and weaken peat;[9]
- Tunicates (e.g., carpet sea squirt; *Didemnum vexillum*), which smother habitat and infrastructure (in southern Maine, they are more of an issue in subtidal habitats);
- Invasive cattail (*Typha* spp.);
- Common reed (*Phragmites australis*), which increase accretion rates; and

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[8] Due to time constraints, workshop participants were unable to evaluate the impacts of increased wave action/coastal erosion on salt marsh habitats.

[9] One participant observed that crab populations are knocked back by cold, snowy winters, as exposure to spring freshet kills juvenile crabs.

- Blue crabs (*Callinectes sapidus*) and fiddler crabs (*Uca* spp.), which are beginning to expand their range into southern Maine.

Land-source nutrient pollution affects salt marshes in many ways, including:

- Weakening the physical integrity of habitat;
- Altering species composition;
- Reducing below-ground biomass where nitrogen increases, resulting in marsh degradation and subsidence that cause shifts to low marsh and open water; and
- Driving production of macroalgae, which cause dieback by smothering marsh vegetation.

Combined impacts of climate and non-climate stressors

Climate change is likely to exacerbate the impacts of or be exacerbated by all three non-climate stressors on North Atlantic salt marshes. For example:

- Development and roads can serve as a barrier to marsh migration in response to sea level rise, result in habitat "squeeze", and exacerbate or accelerate inundation and/or erosion.
- Invasive crabs can accelerate the impacts of sea level rise by causing subsidence and marsh loss; conversely, invasive phragmites could counteract sea level rise by increasing accretion, though they also cause greater loss of carbon sequestration services due to lower carbon density. Overall, invasive species accelerate the displacement of native species driven by sea level rise.
- Invasive species weaken the physical integrity of salt marshes and increase rates of erosion and marsh loss, exacerbating the impacts of altered storm frequency/severity.
- Altered precipitation patterns (drought vs. extreme precipitation events) are likely to drive differing invasive vegetation impacts.
- Land-based nutrient inputs weaken the physical integrity and cause continued degradation of salt marshes, exacerbating the impacts of altered storm frequency/severity.
- Land-based nutrient pollution may compromise areas that marshes could migrate into in response to sea level rise.

Summary of adaptive capacity

Ecological potential

Overall, the ecological potential (i.e. the adaptive capacity of the habitat itself) of North Atlantic salt marshes was evaluated as moderate. Within the regional boundary, salt marshes have moderate geographic extent, distribution, and connectivity, with biodiversity and keystone and indicator species in good condition. The ecological and societal value and importance of salt marshes was ranked as high however, both the physical diversity of the habitat as well as past evidence of recovery from the impacts of stressors were ranked as poor. Participants noted that data availability, timescale, and threat all influence the ranking for past evidence of recovery. For example, a marine protected area manager from Basin Head noted that their historical data indicates a high ability for salt marshes to recover from the impacts of stressors, whereas other managers noted that they did not have enough historical data to demonstrate the ability of their salt marshes to recover from impacts. Participants identified buffering capacity as an additional important adaptive capacity factor for salt marshes. Buffering capacity was described as the ability of salt marshes to migrate inshore, accrete sediment, and buffer the impacts of storms, and was ranked as in good condition.

Social potential

Overall, the social potential (i.e. the adaptive capacity of the institutions that manage the habitat) of North Atlantic salt marshes was evaluated as moderate. Workshop participants noted that, at the federal level, there is less capacity for improving social potential (e.g., capacity would have to be redirected from other duties) when compared to external partners and stakeholders (e.g., community organizations, academia).

Organizational capacity: Within the regional boundary, staff capacity (e.g., professional training, time) is poor, and workshop participants commented that this is a major constraint in all organizations and agencies. However, responsiveness (i.e., ability to adjust organizational management and structure) was rated as fair. Participants noted that although management to-date tends to be more reactive than proactive (especially within National Parks), there is a willingness to act and mandates actually allow more flexibility than is assumed. Stakeholder relationships and community partner capacity are both considered fair, and participants highlighted the importance of community partner capacity to take action (e.g., stakeholders are relied upon to do monitoring and provide financial/personnel resources). They also noted that consultation with some partners may be required even though there is limited capacity to participate (e.g., tribes), but lack of capacity from these entities does not indicate lack of interest. Stability/longevity of organizations (i.e., ability to follow through with needed actions) is fair.

Management potential: The presence of existing mandates within the regional boundary was rated as fair, while the capacity for monitoring and evaluation and ability to learn/change were both rated as good. As noted above, proactive management within the area is poor. However, partner relationships are good, which facilitates transboundary and/or interagency cooperation on adaptation actions. Science/technology support is also good, and workshop participants noted that, in Canada, more support comes from universities and academics as opposed to federal agencies. They also commented that on-the-ground observations seem to be undervalued despite their critical importance to adaptation.

Overall vulnerability

Climate Stressor	Likelihood	Consequence	Risk	Adaptive Capacity	Vulnerability
Altered storm frequency/ severity	Almost certain	Major-Catastrophic	Extreme	Moderate	High
Sea level rise	Almost certain	Major	Extreme	Moderate	High

Altered storm frequency/severity and sea level rise were ranked as having major-catastrophic and major consequences, respectively, with a high likelihood of these consequences occurring within the 50-year timeframe. Overall, the vulnerability of North Atlantic salt marshes to sea level rise and altered storm frequency/severity was ranked as high, based on extreme risk (likelihood x consequence) and moderate adaptive capacity.

Adaptation strategies

Vulnerability: Altered storm frequency/severity			
Adaptation strategy	**Cost**	**Efficacy**	**Notes**
Develop a framework to facilitate shifts towards a more fluid concept of how managers have done things historically and how they may need to change given the impacts of climate change (e.g., re-evaluating the concept of non-native or invasive; considering cumulative impacts)	L	L	• Would help get agency leaders on board with new ways we need to be dealing with climate impacts, which represents a major shift for agencies • Framework should integrate a two-eyed seeing approach (i.e., see from one eye with the strengths of Indigenous ways of knowing, and see from the other eye with the strengths of Western ways of knowing) • Plan would be put into place at multiple spatial scales (i.e., the framework is developed at larger, regional scales and then local agencies are responsible for implementing and adapting it). • Cost is low compared to other strategies; a better framework of what "invasive" means could also help reduce costs in the future • Relatively low efficacy in terms of directly reducing vulnerability associated with altered storms
Investigate and model potential impacts to natural resources and human communities if dunes are intentionally breached	N/A[10]	N/A	• Look at models of breach management (e.g., Fire Island EIS)
Engage in a range of actions around managed retreat (e.g., from planning to land acquisition)	N/A	N/A	• Possible conflicts with endangered species considerations (e.g., restoration may negatively impact species in areas where they are otherwise doing well, and significant impacts of sea level rise differ depending on the scenario) • Managed retreat only addresses impacts of inundation; although storm impacts are more acute, it may help address the cumulative impact of sea level rise and storm surge
Improve communication with the public around how climate adaptation strategies may change (e.g., shifting from protecting the dunes to now breaching the dunes)	N/A	N/A	• UPEI CLIVE is an example of how to make climate change concrete to the public

[10] Participants did not have sufficient time to assign a ranking for all adaptation actions.

Restore structural complexity (i.e. making sure there is zonation and diversity within the marsh)	M	M	• Could partner with NGOs and universities • Possible conflicts with hunters and other stakeholders if they believe that preferred habitat is being altered • Removal of invasives and increased species diversity would be a co-benefit
Remove surrounding infrastructure and create climate-aware infrastructure	H	M	• Can leverage outside funding; can also be less expensive if done as part of ongoing management planning and/or mitigation, or if natural infrastructure is used • With natural infrastructure, there are multiple ecosystem benefits (e.g., blue carbon, recreation, fisheries) and socioeconomic benefits (e.g., preventing evacuation routes from being blocked). If done well, natural infrastructure is a good long-term solution that only needs to be installed once; nature-based infrastructure can also grow and adapt over time.
Vulnerability: *Sea level rise*			
Adaptation strategy	**Cost**	**Efficacy**	**Notes**
Managed retreat, where possible; where retreat is not possible (e.g., if marsh backs up to a cliff), facilitate species migration and look at potential mitigation options to maintain ecosystem function	H	H	• Cost can be variable, and even very low at some scales; for instance, building this into an existing plan can reduce costs. • Removal of dikes is already occurring • Long-term solution with variable efficacy • Would increase buffering capacities along shoreline, but could alienate communities if there is not initial buy-in • Conflicts with infrastructure, though it could lead to the use of more resilient infrastructure • Potential policy conflicts where retreat must occur outside of established boundary • Allows for more targeted management of species • Potential for the introduction of invasive species as native species are moved to new locations
Augment sediment to increase resistance to sea level rise	H	M	• Increases resilience to storm events and invasive species • Potential damage to other habitats (e.g., eelgrass, oyster beds, etc.)

Implementation plans for priority strategies

Develop a framework to facilitate shifts towards a more fluid concept of how managers have done things historically and how they may need to change given the impacts of climate change (e.g., re-evaluating the concept of non-native or invasive; considering cumulative impacts).

- *Leaders and potential partners:* Local MPA as leader, or could be collaborative group effort. Potential partners include the U.S. Department of Agriculture, federal advisory committees, universities or other academic institutions, Indigenous communities and organizations, watershed groups/associations, and other local knowledge holders
- *Possible funding sources*: Federal agencies, large NGOs, states; potential to leverage funding from academic partners
- *Existing or needed management mechanisms*: Good facilitation, diplomacy, and public communications; more research, modeling, and mapping (e.g., what will be adapted to what); coordination with endangered species conservation efforts; decision support tools to aid in the application of knowledge that has been gained; encouragement for plant nurseries
- *Timeline*: Start research now; build on existing efforts to make it more useful for MPA decision-making (e.g., with regard to invasive species, look at the Regional Invasive Species and Climate Change Network)

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- *Leaders and potential partners:* Refuges that are already working on managed retreat and/or agencies that have been doing active intervention; watershed organizations/associations and partner networks that are already working in other estuaries (may have gained valuable skills); volunteers to help with plantings; The Nature Conservancy and other NGOs (e.g., land trusts) that can do the work or help obtain funding (for example, Maine Coast Heritage Trust has developed acquisition priorities to support marsh migration, which creates opportunities to pair land acquisition with restoration); Tribes and First Nations; National Estuarine Research Reserve (NERR) system; National Fish & Wildlife Foundation (NFWF); local municipalities and state transportation; permitting agencies (need involvement early on to troubleshoot any potential problems); regional planning organizations that work with municipal partners (especially when spanning multiple political boundaries)
- *Possible funding sources*: Local industry partners (e.g., aquaculture industry gives Basin Head MPA free mussels for use in restoration); local municipalities (can offer in-kind contributions and materials); U.S. Natural Resources Conservation Service (NRCS); U.S. Federal Emergency Management Agency (FEMA) and Department of Transportation (FEMA Building Resilient Infrastructure and Communities [BRIC] grants can be used for planning and restoration); federal grant programs for restoration and conservation (e.g., Parks Canada, NOAA); disaster recovery grants; NGO funding sources (Ducks Unlimited); unexpected opportunities (e.g., visitor

experience); Coastal Restoration Funding (available to Indigenous communities); Maine Coastal Fellows, NOAA Coastal Fellows, and Davidson Fellows programs

- *Existing or needed management mechanisms*: Utilize existing advisory committees with representatives from all potential partners (see above) so they can help with development of management plans; existing management plans and permitting (important to have plans in place even without identified funds, since so many opportunities are for "shovel ready" projects); look down the road for potential impediments to implementation; friendly political climate (otherwise resources can be frozen) and long-term funding secured; potential post-disaster compensation for people who choose to not rebuild and allow area to become marsh
- *Timeline*: It takes time to build up the social and political support for this type of strategy. Recommend re-evaluating the strategy over time to determine future course