Climate Change Vulnerability Assessment & Adaptation Planning for Eelgrass 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

Eelgrass occurs in sub-tidal areas, and can tolerate relatively large fluctuations in salinity and temperature. However, these plants require shallow, clear water to photosynthesize and establish healthy, well-developed root systems. The status of eelgrass is variable, but declines in some areas have been linked to excess nutrients (i.e. from land-source nutrient pollution), lack of oxygen, sedimentation (e.g., from extreme storm/flood events), invasive species (e.g., European green crab), and warming conditions. Other non-climate stressors that can impact eelgrass include dredging/anchoring and shellfish production and harvest. Increased eelgrass cover has been observed in most areas of Newfoundland, likely due to warming waters and reduced winter sea ice conditions that have reduced damage.

Eelgrass provides valuable ecosystem services such as erosion control, water purification/quality, and nursery habitat for fish species, among others.

Regional boundary

This assessment considers eelgrass habitats 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

Diminished dissolved oxygen, warmer water temperatures, and increased coastal erosion/wave action were selected as the climate stressors that have the most significant impact on North Atlantic eelgrass habitats.

Table 1. Observed and projected changes in significant climate stressors for North Atlantic eelgrass habitats.

Stressor	Observed change	Projected change
Dissolved oxygen	2% decline in oceanic dissolved oxygen levels globally since 1960[2]	1–7% decline in ocean oxygen concentrations globally by 2100[3]
Water temperature	+0.6°C (2.8°F) in the Northwest Atlantic from 1900–2016[4]	+2.0–3.2°C (3.6–5.8°F) in the Northwest Atlantic by 2080[4]
Coastal erosion/wave action	-0.5m (1.6 ft) average rate of long-term shoreline change for New England and Mid-Atlantic coasts in the U.S., with 65% of transects eroding[5]	~10% increase in extreme significant wave height in high latitudes of the North Atlantic (i.e., within the study region)[6] Significant increase in coastal flooding and associated erosion in the Northwest Atlantic due to a combination of sea level rise, storm surge, and wind-driven waves[7,8]

Land-source nutrient pollution, invasive species, and tourism/recreation (boating) were identified as the non-climate stressors that have the most significant impact on North Atlantic eelgrass habitats.

Summary of anticipated changes to salt marshes from common stressors

Climate stressors

Diminished dissolved oxygen is likely to reduce eelgrass productivity and increase the likelihood and/or severity of hypoxia events. Dissolved oxygen also reduces diversity of fish and invertebrates, increases stress in juvenile fish, and enhances disease risk.

---

[2] S. Schmidtko, L. Stramma, M. Visbeck, *Nature*. **542**, 335–339 (2017).

[3] R. F. Keeling, A. Körtzinger, N. Gruber, *Annual Review of Marine Science*. **2**, 199–229 (2010).

[4] L. Jewett, A. Romanou, 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. 364–392.

[5] Hapke, C. J., Himmelstoss, E. A., Kratzmann, M. G., List, J. H. & Thieler, E. R. *National Assessment of Shoreline Change: Historical Shoreline Change along the New England and Mid-Atlantic Coasts*. (2011).

[6] A. Meucci, I. R. Young, M. Hemer, E. Kirezci, R. Ranasinghe, *Science Advances*. **6** (2020).

[7] E. Kirezci *et al.*, *Scientific Reports*. **10**, 11629 (2020).

[8] R. Marsooli, N. Lin, K. Emanuel, K. Feng, *Nature Communications*. **10**, 3785 (2019).

Increased coastal erosion/wave action may be associated with increased turbidity/reduced light, uprooting and/or burying of eelgrass, dune migration, sediment movement, and loss of habitat.

Warmer water temperatures are likely to impact eelgrass occurrence, as increased maximum summer water temperatures have been linked to the disappearance of eelgrass near the southern distribution limit of the species. Marine heatwaves are likely to cause further losses of eelgrass through direct physiological stress due to damage to photosystems or negative carbon balance.

Non-climate stressors

Land-source nutrient pollution is flushed into marine systems via increased precipitation and/or overland flow, and is strongly associated with human demographics and land use. Land-source nutrient pollution affects eelgrass habitats in many ways, including:

- Increasing turbidity and eutrophication;
- Increasing epiphytic load;
- Diminishing productivity; and
- Increasing algal blooms, which can block sunlight and impact oxygen levels (i.e., by increasing decomposing organic matter).

Invasive species impact North Atlantic eelgrass habitats by:

- Decreasing cover where European green crabs (*Carcinus maenas*) physically remove vegetation;
- Increasing predation due to changes in species; and
- Altered competitive dynamics between eelgrass and invasive seagrasses.

Tourism and recreation (boating) affects eelgrass habitats by:

- Physically damaging habitat;
- Introducing aquatic invasive species; and
- Increasing turbidity.

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 eelgrass habitats. For example:

- While healthy eelgrass beds may be relatively resilient to nutrient loading, climate changes may cause previously healthy beds to reach a threshold beyond which they begin to experience increasingly negative impacts.
- Land-based nutrient sources increase the occurrence of harmful algal blooms, which smother eelgrass and increase hypoxia events that exacerbate existing stress from diminishing dissolved oxygen.
- Increases in harmful algal blooms and associated odours as a result of diminished dissolved oxygen could impact tourism.
- It is more difficult for eelgrass to recover from physical damage (i.e., due to boating and other recreational activities) in a low-oxygen environment.
- Diminished dissolved oxygen will likely exacerbate negative impacts of invasives on eelgrass, although the exact impacts will depend on the species.
- Mechanical impacts of coastal erosion and wave action will likely amplify nutrient-related impacts to eelgrass habitats.
- Coastal erosion and subsequent breaches of dune systems create opportunities for invasion.

Summary of adaptive capacity

Ecological potential

Overall, the ecological potential (i.e. the adaptive capacity of the habitat itself) of North Atlantic eelgrass habitats was evaluated as moderate. Within the regional boundary, eelgrass habitats have moderate geographic extent, distribution, and connectivity. Workshop participants noted a decreasing trend in eelgrass across the region, with habitats outside MPAs in poor or critical condition. The physical diversity of the habitat was ranked as poor, largely due to its dependence on specific conditions (e.g., water depth, sediment type). While the biodiversity of the habitat was ranked as moderate, participants noted the entire system would collapse if its keystone species (i.e. eelgrass) experienced catastrophic impacts. Past evidence of recovery from the impacts of stressors was ranked as fair to good, despite confounding/unknown factors, and participants noted that genetic diversity may confer some resilience. The ecological and societal value and importance of eelgrass habitats was ranked as high due to the ecological significant of eelgrass and the key role this habitat plays within the region.

Social potential

Overall, the social potential (i.e. the adaptive capacity of the institutions that manage the habitat) of North Atlantic eelgrass habitats was evaluated as moderate.

Organizational capacity: Within the regional boundary, staff capacity (e.g., professional training, time) is fair, and workshop participants commented that staff with specific expertise are available, but their presence is variable across the region. Responsiveness (i.e., ability to adjust organizational management and structure) was also rated as fair, as management plans generally allow for adaptive management but managers are not ready to accept habitat losses. Stakeholder relationships are considered good, while stability/longevity of organizations (i.e., ability to follow through with needed actions) was ranked as very high.

Management potential: The presence of existing mandates within the regional boundary was rated as good. The capacity for monitoring and evaluation and the ability to learn/change were both rated as fair because there is always more that can be done, and it also depends on the scale being considered. Workshop participants commented that managers should be using more refined technology, and rated science/technology support in general as poor. Although partner relationships are considered good, proactive management within the area was rated as poor due to a lack of resources and challenges with stakeholders.

Overall vulnerability

Climate Stressor	**Likelihood**	**Consequence**	**Risk**	**Adaptive Capacity**	**Vulnerability**
Diminished dissolved oxygen	Almost certain	Moderate	High	Moderate	Moderate
Increased coastal erosion/wave action	Almost certain	Major	Extreme	Moderate	High

Warmer water temperatures	Almost certain	Catastrophic	Extreme	Moderate	High

Diminished dissolved oxygen, increased coastal erosion/wave action, and warmer water temperatures were ranked as having moderate, major, and catastrophic consequences on eelgrass habitats, respectively, with a high likelihood of these consequences occurring within the 50-year timeframe. Overall, the vulnerability of North Atlantic eelgrass habitats to coastal erosion/wave action and water temperature was ranked as high, based on extreme risk (likelihood x consequence) and moderate adaptive capacity. By contrast, vulnerability to diminished dissolved oxygen was ranked as moderate due to high risk and moderate adaptive capacity.

Adaptation strategies

Vulnerability: *Diminished dissolved oxygen and warmer water temperatures*			
Adaptation strategy	**Cost**	**Efficacy**	**Notes**
Reduce nutrient loading by using voluntary measures to increase buffer zones, and planting trees and shrubs to diminish exposure to high nutrient levels	M	M	• Would benefit adjacent habitats, though conflicts could occur if buffer increases resulted in the loss of agricultural land • Implementation should occur at various scales • May extend outside of MPA, which would require collaboration with other jurisdictions
Work with stakeholders and local land owners to promote best management practices (BMPs) that address nutrient loading	N/A[9]	N/A	• Review existing policy and practices, as well as monitor the effectiveness of BMPs
Increasing productivity of eelgrass habitat by planting more eelgrass, more species, and more diversity of species	H	L	• Could include a range of plant sources (native and novel species), including populations that are well-adapted to the region as well as those that may have different genotypes and be adapted to different temperature ranges • Efficacy depends on whether the strategy focuses on native or novel species • Increases blue carbon storage and creates a seedbank that may have benefits beyond this project
Remove invasive green crabs through trapping, with a focus on controlling adult populations (given that eradication is not possible)	H	L	• Consider choosing particular regions to focus on, and include research and monitoring to help inform future interventions • Could involve stakeholders to increase efficiency

---

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

			• A potential challenge would be finding a use for the captured crabs • Increases resilience of native species that are positively impacted by invasive removal efforts (e.g., native crabs)
Vulnerability: *Increased coastal erosion/wave action*			
Adaptation strategy	**Cost**	**Efficacy**	**Notes**
Use natural infrastructure and "soft engineering" to restore barrier islands (e.g.)	N/A	N/A	• Strategy reduces exposure to wave action and erosion • Examples include Christmas trees (used to restore/stabilize dunes at Prince Edward Island National Park; marram grass) • Consider the use of artificial reefs, though it's important to consider that the introduction of new artificial materials may have deleterious effects
Take no action	N/A	N/A	• As some dunes remain stable and others migrate, then document what happens and share with the public
Develop a regional approach that incorporates sites for protection (e.g., refugia, resilient populations) but allows for some loss in areas where eelgrass is unlikely to persist	L	H	• Identify stressors at each site to inform site selection and project design • Flip the top-down model of site selection for restoration: survey MPA sites and ask which approach (resist, adapt, direct) each site would like to take, then that becomes a natural experiment across the region (more risk-averse sites could become controls) • Ideally, this strategy would allow recolonization from persistent populations • Using a regional approach would leverage resources by taking advantage of what each protected area and agency can do (e.g., some sites may be able to do more than others, but all can work together to monitor and evaluate; sites with fewer resources could serve as controls) • Could be scaled up to go beyond eelgrass (may lose focus) • Requires partnerships, and some stakeholders may not be supportive of losses • Cost and efficacy based on planning stage
Use climate-informed genetic mixing to create more resilient eelgrass populations (e.g., may	L-H	L-M	• Approaches could include ensuring genetic variation (captures individuals adapted to different components of change and reduces necessity to nail down particular adaptations),

include genotypes resilient to higher water temperatures, turbidity/low light, wave action)			and/or using genomics to map genotypes for specific climate stressors (i.e., determine whether populations vary across environmental gradients) • Cost and efficacy are positively correlated • Co-benefits and conflicts depend on scope and scale • Increased genetic diversity generally has benefits that are not tied to specific climate stressors
Facilitate habitat migration by removing barriers and enhancing connectivity with inland/upland habitat (e.g. purchase land, remove roads/infrastructure)	H	H	• Loss of agricultural land and/or access (due to road removal) may cause conflict with stakeholders • May benefit adjacent habitats • May extend outside of MPA, which would require collaboration with other jurisdictions
Modify structures (e.g. armoring) inside and outside of MPA to improve or impede sediment transport	N/A	N/A	• Would require modeling

---

Implementation plans for priority strategies

Develop a regional approach that incorporates sites for protection (e.g., refugia, resilient populations) but allows for some loss in areas where eelgrass is unlikely to persist.

- *Leaders and potential partners:* Working group with representatives from each MPA, NGOs and Indigenous partners, community members, youth, and fishery representatives; use an outside facilitator and have an independent third party conduct a review of options outlined by the working group
- *Possible funding sources*: The working group itself would be low-cost, but funding must be identified to support research, on-site analysis, and implementation of actions (may be piecemeal from individual sites). Funding opportunities could include:
  - Institution-specific streams (e.g., Parks Canada Nature Legacy/Integrated Conservation Planning), which could be leveraged to streamline piecemeal contributions across the region as different agencies contribute to work occurring within their own jurisdiction
  - Academic collaboration (e.g., Natural Sciences and Engineering Research Council) could be used to fund broad analysis
  - State of play reviews could potentially be funded via the CEC
- *Existing or needed management mechanisms*:

    - Defined working group objectives and clearly-articulated values and priorities (e.g., focus on what can be implemented within MPA management, such as nutrient reduction)
    - Action plan with agreed-upon priorities that is also flexible and in line with funding opportunities
    - Robust communication strategy around seascape conservation vs. site conservation so that it is not thought of as a negative/net loss (i.e., goal is bigger than conservation of any one site, must leverage what everyone is doing and take advantage of inherent differences across sites)
- *Timeline*: Would take 6 months to a year for planning and identifying partners; plan out the lifetime of project/scope, set up working group, and find funding to begin site analysis in year 2; action plan anticipated in year 3

Use climate-informed genetic mixing to create more resilient eelgrass populations.

- *Leaders and potential partners:* Regional eelgrass genomics network to coordinate and share info (look at pre-existing models for ideas on information exchange/collaboration); in Atlantic Canada, there is an eelgrass group led by Fisheries and Oceans Canada (DFO) that could be a good platform to promote this type of project; could partner with academic institutions to identify genotypes and/or conduct common garden experiments in a lab (resource-intensive)
- *Possible funding sources*: Potential for big money/novel funding sources (e.g., Google) because of the carbon sequestration potential of eelgrass and the economic importance of this habitat type to fisheries; pitch to funders as being innovative, utilizing a living laboratory, increasing blue carbon
- *Existing or needed management mechanisms*:
    - Regionally-focused research is needed first (e.g., mapping of genetic diversity onto environmental/climate stressor gradients across the North Atlantic); information is then applied at local sites to inform which genotypes to use for restoration projects
    - A feasibility study is necessary before launching into a larger network (proof of concept for the idea that genetic diversity confers greater resilience)
    - Take advantage of plantings already under way to increase understanding of the impact of genetic diversity on success of restoration
    - Try things on a small scale and monitor for efficacy
- *Timeline*: Regional genomics work would be research-intensive for the first couple of years, but there is opportunity to leverage current work/restoration projects to test impact of genetic diversity (i.e., could pilot some work at sites on smaller scales while concurrently researching broader genomic questions at a regional scale)