Practical Guidance for Coastal Climate-Smart Conservation Projects in the Northeast

Case Examples for Coastal Impoundments and Living Shorelines

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Credit: Bhaskar Subramanian, MD DNR
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INTRODUCTION

Climate Change along the Coast

Coastal habitats of the northeastern United States vary greatly from the Chesapeake Bay to the Gulf of Maine; however, similar issues plague these systems. Coastal areas are threatened by increasing human populations moving to and building along the shore. New homes, buildings, roads, and other infrastructure translate into a loss of coastal habitats. Human activities also result in excess nutrient runoff, deforestation, over-fishing, invasive species, and wetland destruction and fragmentation (Glick et al., 2008). Climate change is exacerbating these and other ongoing threats to coastal ecosystems.

Changes in the Earth’s climate have been documented for decades. As our climate continues to change, sea levels are expected to rise, and storms will likely become more frequent and increase in strength throughout the Northeast. Air and water temperatures are also expected to continue to increase. Projections for these changes depend on the models and the emission scenarios used. Table 1 provides example projections of temperature changes, precipitation changes, sea-level rise, and storm changes for sub-regions of the Northeast as well as globally.

<table>
<thead>
<tr>
<th></th>
<th>Chesapeake Bay (VA and MD)</th>
<th>Northeast (ME, NH, VT, MA, CT, RI, NY, PA, and NJ)</th>
<th>Delaware Bay</th>
<th>Global</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature</strong></td>
<td>4 to 11°F (2-6 °C) (Pyke et al., 2008)</td>
<td>Winters: 5°F to 12°F; Summers: by 3°F to 14°F (Frumhoff et al., 2007)</td>
<td>2 to 4 °C (Kreeger et al., 2010)</td>
<td>1.8 to 4.0 °C (IPCC, 2007)</td>
</tr>
<tr>
<td><strong>Precipitation</strong></td>
<td>Winter and spring precipitation increase up to 10% (Pyke et al., 2008)</td>
<td>Increase of 10% (with more significant increase in winter precipitation at 20 to 30%) (Frumhoff et al., 2007)</td>
<td>7 to 9% increase (Kreeger et al., 2010)</td>
<td>Increase (as much as 20%) high latitudes; decrease (as much as 20%) subtropical latitudes (IPCC, 2007)</td>
</tr>
<tr>
<td><strong>Sea-level rise</strong></td>
<td>2 to 5 feet (Pyke et al., 2008)</td>
<td>2 to 4.5 feet (Frumhoff et al., 2007)</td>
<td>1.6 to 4.9 feet (Kreeger et al., 2010)</td>
<td>1.6 to 6.6 feet (Rahmstorf, 2007)</td>
</tr>
<tr>
<td><strong>Storm-related changes</strong></td>
<td>More frequent and intense (Pyke et al., 2008)</td>
<td>More frequent (12-13%) and intense (10-15%) (Frumhoff et al., 2007)</td>
<td>More frequent (Kreeger et al., 2010)</td>
<td>More frequent and intense (IPCC, 2007)</td>
</tr>
</tbody>
</table>

Climate change is already occurring and will continue to affect coastal areas in multiple ways, including sea-level rise, increased intensity and frequency of storms, increasing
temperatures, and changing salinity levels. In terms of sea-level rise, coastal areas and human populations along coasts will be significantly affected. Impacts from rising sea levels may include: land and habitats loss from inundation, migration of coastal habitats and landforms (shoreline retreat), loss of wetlands, and increased salinity levels in estuaries and coastal freshwater areas (CCSP, 2009). Linking sea-level rise impacts to coastal processes such as coastal erosion has been difficult to quantify, because various other processes also affect coastal areas, making it harder to isolate impacts from sea-level rise (Guitierrez et al., 2007). Generally, sea-level rise and wave action are the primary long-term or passive processes that drive coastal erosion (Thomas-Blate, 2010). For more information on sea-level rise scenarios and projections for the Northeast, see the sections titled Exposure.

Credit: Bhaskar Subramanian, MD DNR

Storm intensity and frequency are also projected to increase, which will result in an increase in coastal storm surges (CCSP, 2009). Based on various models and scenarios, the International Panel on Climate Change (IPCC) indicates that hurricanes are likely to intensify in terms of wind speeds and precipitation levels. Additionally, winter storms are likely to shift poleward with a possibility of becoming more intense in the North Atlantic (CCSP, 2009; IPCC, 2007). High-energy coastal storms and large waves are the main causes of short-term or active coastal erosion; thus, increasing intensity of storms and related storm surges only exacerbate existing coastal erosion problems (Thomas-Blate, 2010). Although the potential interaction between storm surge and sea-level rise is complex, storm surge can be affected by sea levels. Thus, increasing sea-levels may compound storm surges associated with more intense and frequent storms (CCSP, 2009).

Although other impacts of climate change such as temperature changes and precipitation changes will affect coastal systems, for the purposes of this document the primary impacts considered are sea-level rise and more intense storms.

**Overarching Principles for Climate-Smart Conservation**

The significant climate change impacts on coastal systems means that natural resource managers and others will need to begin to consider how to address climate change as a part of their conservation and restoration efforts. Ideally, managers will work towards making their
projects and efforts climate-smart. There are several overarching principles that are important to consider when thinking about climate-smart conservation and restoration. They apply not only to coastal systems but also to all climate-smart conservation and restoration work. The principles outlined below are based on Restoring the Great Lakes Coastal Future (Glick et al., 2011a).

**Look to the Future While Learning from the Past**

Developing climate-smart coastal conservation and restoration projects will depend upon understanding both current and future potential impacts of climate change on ecosystems where those projects are located. It is also important to understand how the projects will be vulnerable to climate change impacts. To best understand these impacts, one must have a deeper knowledge of how the systems work. Traditionally, natural resource managers have relied on historical ranges and trends in variability of conditions such as erosion rates, temperature regimes, and stream flows to set project goals; however, this is no longer sufficient. Additionally, historical baseline conditions or reference habitats will not remain static (Glick et al., 2011a). Incorporating projections for future conditions will become increasingly important for designing projects that will be effective and successful as the climate changes. Doing so will require addressing two key challenges: 1) obtaining information at the appropriate scale to be useful to project planning and implementation, and 2) identifying the appropriate climate change scenarios to use for planning and implementing projects (Glick et al., 2011a). However, it also is important to recognize that historical information is not irrelevant. Understanding how systems reacted to past climate changes and disturbances can provide information on how they may respond in the future.

**Adopt a Broader, Landscape Approach to Selecting and Managing Restoration Projects**

The extensive reach of climate change impacts requires approaching restoration and conservation from a broader, more landscape-level perspective. Understanding the interactions between climate change and other stressors is important to designing effective conservation and restoration projects. Although management needs are local and often site-specific, planning will need to take place within the context of larger-scale planning to address climate change impacts more effectively. For example, species ranges are likely to shift; thus, when planning projects such as wetlands restoration projects, it may be important to consider whether the restored wetland will support the same type of plant species in 20 or 50 years.

**Emphasize Restoration of Ecological Processes and Dynamic Systems**

In coastal systems, restoration and conservation projects should focus on restoring ecological processes important to system function as opposed to some previous condition. This will make the system more resilient to climate change impacts, allowing it to recover from a disturbance with minimal loss of function. It will be difficult for coastal restoration and conservation projects to achieve a fully “self-sustainable” system as many coastal areas have been significantly altered. However, coastal projects should strive for a level of resiliency. For

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1 By climate-smart we mean conservation/restoration projects that will be resilient and sustainable under climate change.
example, projects can be designed to provide habitat buffer (e.g., remove or prevent hardened barriers along the coast to allow wetlands to migrate inland or allow species migration inland). Additionally, projects should be designed to build resilience in a targeted fashion as habitats or ecosystems may not be able to withstand a broad range of impacts. A system may be resilient to flooding but not drought. It will be important to focus on the most significant threat to the system (Glick et al., 2011a).

![Image](Credit: Bhaskar Subramanian, MD DNR)

**Incorporate Uncertainty**

Uncertainty is something that natural resources managers have always had to address. The inherent nature of climate change means there will always be some level of uncertainty associated with how, when, and where climate change impacts will occur. Managers must incorporate this uncertainty into the way they plan and design projects. It will be important to make projects robust in that they are designed to provide benefits under multiple different scenarios of climate change. Integrating an adaptive management approach also will allow for learning and flexibility throughout the project’s lifespan or management of an area. Addressing uncertainty also will require monitoring of impacts as well as project performance (Glick et al., 2011a).

**Guidance Overview**

The National Wildlife Federation (NWF) is working with the Northeast region’s conservation community on planning for climate change and conducting climate change vulnerability analyses as well as helping plan and implement on-the-ground projects that take climate change into consideration. This document is part of a project designed to generate climate-smart guidance for restoration and management projects to safeguard fish, wildlife, and their habitats from the impacts of climate change. While research, mapping, and vulnerability analyses are all critical as we think about safeguarding fish and wildlife, and will continue, it is important to translate what we have learned into on-the-ground actions. A variety of state fish and wildlife and natural resource agencies have identified the development of such guidance as a high priority to assist them in efforts to translate newly emerging principles for ecosystem-based adaptation into on-the-ground practice. This guidance will provide natural resource managers, planners, and others throughout the Northeast and other coastal regions more detailed
information on the practicalities of responding to climate change for a selection of specific coastal projects.

Project Background

The development of this guidance document is part of a larger NWF and Manomet Center for Conservation (Manomet) project. NWF and Manomet received a two-year grant from the Wildlife Conservation Society in September 2010 to conduct a project that focuses on three high-risk habitats in the Northeast – coastal, freshwater, and forested uplands. The three components of the project include 1) developing habitat specific guidance for climate-smart projects for coastal, freshwater, and forested uplands; 2) working with the region’s fish and wildlife agencies to identify, implement, and showcase three model demonstration projects that embody this guidance for each of the three systems; and 3) producing and distributing a user’s guide and conducting related outreach on the “lessons-learned” from each of these model demonstration projects. This document represents the climate-smart guidance for coastal systems under the first component.

Coastal Climate-Smart Guidance

Over the past few years, interest in the field of climate change adaptation has increased dramatically, particularly within the conservation and natural resource management community. Yet for all of the focus on the emerging discipline of ecosystem-based adaptation, most guidance is still at a fairly high-level and largely conceptual in nature. Because of the general nature of much of this guidance (e.g., reduce existing stressors, increase resilience) there is a danger that the concept of adaptation will be applied so broadly and indiscriminately that it will cease to serve as a meaningful tool for addressing the very real conservation challenges of a changing climate. Additionally, guidance to date has not been at a level of specificity that provides recommendations at a project level. This guidance seeks to provide information on integrating climate change into projects taking place in the coastal environment by examining two specific project types – coastal impoundment and living shoreline projects. However, this guidance is not meant to be technical in nature, rather it provides considerations to managers to take into account as they plan and implement projects.

Guidance Scope

This coastal climate-smart guidance is an initial step to provide wildlife and natural resource managers some practical tools for ensuring that current and future projects are maximizing benefits to ecosystems and critical species. NWF convened an expert panel to develop a process for defining climate-smart conservation for the coastal system and to provide climate-smart options that natural resource managers could consider when planning and implementing projects. The expert panel was made up of a range of members, representing state and federal natural resource agencies and coastal NGOs. The panel members were selected based on their experience with fish and wildlife issues, coastal systems, and climate change. The panel’s charge was to determine the scope for the guidance and develop climate-smart guidance at the project level.

Providing guidance for all the habitat types within the coastal system or all the project types implemented within the coastal system was beyond the scope of this project. The panel
selected two project types in the coastal environment on which to focus. It is important to note that NOAA’s Restoration Center has been working on sea-level rise guidance for tidal wetlands restoration; thus, the panel chose not to focus on coastal wetlands restoration. Coastal impoundments are found along the northeastern coast of the United States, and many are managed by state fish and wildlife agencies. These will be some of the first areas experiencing impacts from climate change such as sea-level rise and impacts from more intense and frequent storms. Living shorelines projects are being implemented throughout the Northeast by both state and federal coastal programs as well as private entities. In choosing these two project types, the panel hoped to address a range of issues relevant to managers and conservationists working along the coast. Many of the considerations outlined could also be applicable to other project types as well. Additionally, the panel chose to focus on the impacts from sea-level rise and changes to storm intensity and frequency.

Finally, the coastal impoundment section of this guidance will be applied to an on-the-ground project in Delaware. The lessons from developing and implementing the guidance will be integrated into a lessons-learned report released in September 2012. This lessons-learned document will include guidance for all three habitat types mentioned in the Project Background Section (coastal, riparian, and upland forests) and information on implementing the guidance at the project-level.

Guidance Framework

To develop this guidance document, the coastal climate-smart expert panel followed a 6-step framework that was originally designed for resource managers in the Great Lakes to make their restoration and conservation projects climate-smart. The framework (provided below) identifies key steps resource managers can take to help ensure conservation and restoration efforts are climate-smart. Extensive information on the framework can be found in Restoring the Great Lakes Coastal Future (Glick et al., 2011a).

![Figure 1. Framework for Making Restoration Projects in the Great Lakes Climate-Smart (Glick et al., 2011a).](image-url)
The panel worked through this framework for both coastal impoundments and living shorelines. Below is general information for each element of the framework that outlines what the panel members considered for each step of the framework.

1. **Identify Goals and Targets:** A first step in any project or strategy development is to identify goals, objectives, and targets. In many cases, goals and targets for coastal conservation and restoration projects are established by local, state, federal, or regional agencies or programs. These goals often have been developed to deal with existing management and conservation issues as well as existing and future threats. Developing guidance that takes climate change into account requires an additional layer of threat analysis to include future changes in rates of sea-level rise, temperature increases, flow regimes, storm surge projections, precipitation changes, species range shifts, and other climate-driven variables. It is the combined effect of these issues that needs to be considered when developing climate-smart projects and actions.

2. **Identify Project Approaches:** The general suite of management, conservation, and restoration project approaches will likely not change significantly for climate-smart projects; however, some of the assumptions that go into project planning and design may need to change. Assessing vulnerability to climate change (Element 3) will help determine which approaches may be necessary to address climate change impacts and where new approaches may be needed.

3. **Assess Vulnerability of Targets/Approaches:** A full vulnerability assessment was outside the scope of the project. The panel members, however, worked through the components of a vulnerability assessment for both coastal impoundment and living shoreline projects to provide a starting point for resource managers. Climate change vulnerability assessments provide an essential tool for informing the development of climate change adaptation plans and strategies. There is no single right approach to vulnerability assessment that applies to all situations. Rather, the design and implementation of an assessment may depend on a host of factors, including availability of already existing information, the level of expertise, time and budget constraints, etc. (Glick et al., 2011a).

   For example, while there are a growing number of models available that can project the impacts of climate change on plant and animal ranges, the availability to conduct more detailed analyses such as modeling the dynamic ecological responses among diverse species within and among ecosystems is still relatively limited. In many cases, focusing quantitative assessments more broadly on habitat changes and then applying qualitative assessments of potential species responses may be the best approach given existing information. Additional studies can then be undertaken as information and resources allow (Glick et al., 2011a).

Vulnerability to climate change, as it is commonly defined, has three principal components: sensitivity is one component, along with exposure and adaptive capacity (Figure 2) (Glick et al., 2011b). Understanding these individual components of vulnerability (whether explicitly or implicitly) is important in that it can help project planners identify more clearly which of your target species, habitats, and/or ecosystems are vulnerable to climate change and, perhaps more importantly, why they are vulnerable.
Figure 2. Framework for Assessing Vulnerability (Glick et al, 2011b).

*Sensitivity:* The sensitivity of a species, habitat, ecosystem, or restoration project approach reflects the degree to which that system is likely to be affected by or responsive to climatic changes (e.g., a species with a narrow temperature tolerance is likely to be more affected by warmer temperatures than a species with a broader temperature tolerance).

*Exposure:* Exposure is a measure of the character, magnitude, and rate of changes a target species, ecosystem or shoreline experiences (e.g., temperature and precipitation, altered streamflows).

*Adaptive Capacity:* Adaptive capacity is a measure of whether a species, an ecosystem, or project approaches are able to accommodate or cope with the impacts of climate change. Adaptive capacity may reflect both internal traits (e.g., species’ mobility) and external conditions (e.g., structural barriers, pre-existing stressors, institutional/financial restrictions).

4. **Identify Climate-Smart Management Options:** Once a resource manager has a sense of how climate change and related impacts will affect conservation goals, targets, and approaches, the next step is to develop a strategy or set of strategies to ensure those goals can be achieved under climate change or reevaluated because of climate change, if necessary. This part of the process is critical as it sets out climate-smart management options and considerations.

5. **Select and Implement Management Options:** After climate-smart management options are identified, managers will likely not be able to implement all options. Managers, thus, will need to consider which management options to select by determining which actions are most applicable and feasible to implement.

6. **Monitor, Review, Revise:** Monitoring may require significant commitment and funding resources, but it is likely to reduce costs stemming from climate change-related surprises. Monitoring allows for testing project assumptions and evaluating effectiveness of project actions (e.g., about how the system in question will respond to climate change, what climate changes might happen, and the effects of particular management actions). In turn, monitoring results allow project managers to refine project goals or actions as needed – a fundamental step in adaptive management.
The primary focus of this guidance is on efforts to *Identify Climate-Smart Management Options*. The expert panel worked together to describe options to integrate climate change into project design and implementation. That section includes general and specific climate change considerations and project climate-smart options. Overall, the degree to which climate change considerations may alter project design and implementation varies. For example, for living shoreline projects, project design will likely not change significantly, while project design and implementation may vary greatly for coastal impoundments when climate change is taken into consideration.
COASTAL IMPOUNDMENT CLIMATE-SMART GUIDANCE

Introduction to Coastal Impoundments

Coastal impoundments are areas of upland or wetland habitats where low level dikes have been constructed to restrict, retain, or exclude water over a selected area. Many coastal impoundments were constructed during the 1600’s and 1700’s to accommodate agriculture production (rice and salt marsh hay) and protect important thoroughfares (Wesleger 1947); however, most impoundments were constructed between 1930 and 1975 to help alleviate pestiferous mosquito breeding in wetlands areas and to attract waterbirds, especially wintering waterfowl (Erwin, 1986). All states along the eastern seaboard have coastal impoundments as do many National Wildlife Refuges (NWR), and many state fish and wildlife agencies integrated coastal impoundments into their wildlife management areas (Erwin, 1986; Ferrigno 1995). Because of the nature of coastal impoundments (interrupting natural water and nutrient flows as well as the ingress/egress of aquatic organisms), concerns arose about fisheries impacts and loss of wetlands. Today many state and federal regulations restrict or prohibit the construction of new impoundments within wetland areas; however, coastal impoundments, if managed properly, provide important functions, especially if water level and salinity management of the impoundments are designed in a way to provide benefits to multiple species (e.g., shorebirds, wading birds, aquatic furbears, juvenile fish, and waterfowl) as well as assisting with invasive species and mosquito vector control (Erwin, 1986). Coastal impoundments also serve as an important place for outdoor recreation such as hunting, birding, and fishing.

Although there is some controversy over how coastal impoundments are used today, they do serve biological and socioeconomic functions that cannot be discounted. Additionally, if properly constructed with improved water control structures and managed to allow tidal exchange, albeit limited, coastal impoundments can actually be managed to enhance estuarine productivity of many aquatic species (i.e., fish nursery habitat) (Meredith 1995). As coastal wetlands continue to experience significant declines and degradation, managed wetlands, such as those associated with coastal impoundments can provide an alternative or complementary habitat for waterbirds and other species (Ma et al., 2008). As such, abandoning coastal impoundments may result in significant biological and ecological functionality being lost. This issue is becoming especially important as climate changes and sea-level rise make coastal wetlands more vulnerable.
Predictions from many scientific bodies indicate that thousands of acres of tidal wetlands will be lost in the next 50 to 100 years as a result of sea-level rise, subsidence, and the inability of tidal marshes to accrete at a rate faster than they become inundated. Moreover, the elevational rise or escarpment along landward margins of many coastlines might prevent the transgression of wetlands inland except as narrow fringes along tidal rivers (DFW, 2010). If these predicted inundations and limited transgressions do occur, managed wetlands might provide some of the remaining significant wetland habitat and be key in maintaining critical coastal habitat for fish and wildlife resources. However, these impoundments are also at risk to climate change and sea-level rise. Some coastal impoundments will be lost, and managers need to start considering what this will mean for the area the impoundments protect and what steps need to be taken to replace the functions and values provided by these managed wetlands. If climate change leads to the higher range of sea-level rise projections, which is looking increasingly likely, important management decisions and planning will need to be made soon to allow for the protection, eventual habitat transition, and long-term planning for the future of coastal impoundments.

**Coastal Impoundments and Climate Change**

Coastal areas and their dependent species, including humans, will be affected by increasing rates of sea-level rise due to climate change. Impacts from rising sea levels may include: lost land and habitats from submergence and coastal erosion, migration of coastal habitats and associated loss of wetland and upland habitats, and increased salinity levels in estuaries and coastal freshwater areas (CCSP, 2009). Increased intensity and frequency of storms will also occur and can exacerbate inundation and coastal erosion. Coastal impoundments are likely to be some of the first areas to be affected by both sea-level rise and impacts from more frequent and severe storms given their proximity to the shoreline and low elevation. Impoundments can become flooded or even completely overtaken by sea water forming large open water areas with associated increased salinities. Additional management problems for coastal impoundments from sea-level rise could include structural damage to the impoundment dikes and water control structures and the inability to remove adequate water during drawdowns. For example, Prime Hook NWR in Delaware has already lost significant acreage of a coastal impoundment to open deep water because of inundation from sea-level rise and the breaching of a barrier dune that served as a dike. This has resulted in a significant number of trees in the upland and forested wetland areas dying due to increased salinities and the conversion of a high quality freshwater wetland into a saline open water habitat with scattered patches salt marsh and sandbar habitats.

As a result of these current and future impacts, both the U.S. Fish and Wildlife Service (USFWS) and state fish and wildlife agencies are beginning to rethink their management of impoundments. As managers become less and less able to manage and restore impoundments to meet management goals, they need to begin considering what the replacement function is for these areas and where lost functions will be replaced. In an effort to begin to work through these questions, a group of NWR mangers from the USFWS Region 5 went through a Structured Decision Making (SDM) process in 2009 to develop a consistent process by which to determine if management of a coastal impoundment on a refuge is feasible to maintain given sea-level rise and climate change (USFWS, 2009). The Delaware Department of Natural Resources and
Environmental Conservation’s Division of Fish and Wildlife (DFW) has also gone through an SDM process to consider management objectives for their impoundments and how sea-level rise will affect their management options, and they are now working to implement pilot projects in response to these evaluations. Questions being asked include: should impoundment water control structures and dikes be altered to accommodate sea-level rise; should some impoundments be abandoned and replaced with new impoundments constructed in more upland habitats; and should impoundments be abandoned all together, and if so what is the strategic retreat and what should be done with these areas?

Climate-Smart Guidance

This section of the guidance document is based significantly on the efforts of Delaware DFW to plan for sea-level rise and implement pilot adaptation projects to address sea-level rise impacts on their coastal impoundments. Input from the panel as they worked to consider how restoration and natural resource managers may need to take climate change impacts, specifically sea-level rise and increased storm intensity and frequency, into account when planning and implementing coastal impoundment management was also key to developing this section of the guidance. The panel recognizes that there are many factors and issues that go into managing a coastal impoundment and that each impoundment has individualized management requirements. This document does not provide technical guidance on impoundment management and is not meant to replace existing protocols and procedures.

1. Identify Goals and Targets

Goals

There are a range of key goals for which coastal impoundments may be managed. The Delaware DFW identified a list of goals as part of their SDM effort relating to managing coastal impoundments, many of which can be applied to any coastal impoundment across the Northeast. Example impoundment management goals include providing for:

- waterfowl habitat
- waterfowl abundance
- waterfowl hunting
- roost habitat for red knots in spring (or other specific bird species)
- autumn shorebird abundance
- breeding shorebirds
- breeding marshbirds
- breeding waterfowl
- foraging habitat for wading birds
- fall and spring shorebird migration
- quality of life vector control (mosquito)
- invasive plant species control
- muskrat control
- non-consumptive wildlife use

Credit: U.S. Fish and Wildlife Service
Connecting Goals Regionally and Nationally

It is important to link project goals and targets to other national, regional, and state plans where applicable (e.g., State Wildlife Action Plans, North American Shorebird Plans, North American Waterfowl Plans, etc.) to help managers identify how their goals fit in with goals at a larger/landscape scale. Linking goals and targets to other plans can also allow for greater support for the action under climate change. For example, if specific species of waterfowl changes its migration timing or pattern because of changes in climate, coastal impoundment managers may want to look to regional plans and work with managers in the region to plan for these changes together. Another example is if you want to create an impoundment to replace salt marsh habitat that might be lost due to sea-level rise, you would want to work with others in the region to consider how the habitat may be affected across a larger area to inform the effort you may take locally.

Reconsidering Goals and Targets in Light of Climate Change

Although as a part of this effort we did not identify how the range of coastal impoundment management goals might change under climate change or how Delaware DFW and other state and federal fish and wildlife agencies might need to change their goals, the expert panel did feel it important to note that coastal impoundment management goals may need to change in light of rising sea levels or other impacts from climate change. This could result in impoundment management approaches (see next section) needing to change to meet existing goals or to accommodate new goals. This is an important aspect for managers to begin considering now. For example, Delaware is predicted to lose a majority of its expansive tidal wetlands/marsh complexes, with anticipated inland migration confined to mostly fringe wetlands. This could affect priorities and choice of activities for different impoundment sites. Managers will need to think about what can be done to ensure management and projects are effective over the long-term.

Examples of how management goals could change:

- Waterfowl related management actions are often primary objectives of a coastal impoundment, but those management actions could change (e.g., timing of drawdown, amount of drawdown, ability to drawdown, etc.), depending on how sea-levels change and affect available habitat (e.g., will temperature shifts cause shifts in populations and how would that affect current management goals).
- Plant species commonly and abundantly found in tidal marshes, such as Spartina, are not usually managed for within impoundments; however, if large areas of tidal marsh are anticipated to be lost outside of impoundments, it may become a species that is actively managed for and protected within impoundments.
- With salinity increases and salt water intrusion, freshwater or brackish coastal impoundments may now need to be managed as salt marsh rather than try to maintain freshwater impoundments.

2. Identify Project Approaches

The primary approach used for managing coastal impoundments is through water level manipulation via control; however, other forms of vegetation and invasive species management often occur as well as ditch and pond creation and maintenance.
Water Flow and Level Control

Water control structures include structures such as levees, tide gates, and other physical or mechanical mechanisms used to control water levels and flow. Impoundments also are managed over different time horizons, e.g., annually or seasonally. Seasonally, managers choose between several actions, such as flushing, drawdown, and flooding. The actions chosen depend on the management goals for the impoundment. Water level management practices can be very species or goal specific. For example, an impoundment may be kept at full pool during the winter and drawn down gradually to provide food in the spring (invertebrates) for migrating waterfowl. During the summer it would be kept low to maximize plant growth and slowly flooded in late summer through the fall to spread food availability (seeds and tubers) for waterfowl over the fall season. On an annual basis these management practices can also vary allowing other management goals to take precedence.

Ditch and Pond Creation

Ditches and shallow ponds can be created and maintained to promote better water circulation and exchange and to create variation in the impoundment topography/bathymetry as well as heterogeneity of plant types. This management practice is particularly important for fish management and mosquito control goals.

Vegetation Management

Vegetation management includes managing for native plants as well as invasive plant species. Native plant species within the impoundment as well as surrounding the impoundment may need to be mowed, disked, replanted, burned, etc. Similarly, depending on the species of invasive plant, they may need to be cut, pulled, sprayed with herbicide, burned, or flooded. Similar to water level control, vegetation management can be very species or goal specific.

3. Assess Vulnerability of Targets and Approaches

Conducting a complete vulnerability assessment for coastal impoundments across the Northeast was beyond the scope of work for the expert panel. However, for this guidance document, the panel decided to walk through a modified version of a vulnerability assessment to provide a starting point and some key considerations for conducting a vulnerability assessment for coastal impoundment work.

For managers wanting to conduct a vulnerability assessment that involves coastal impoundments, they may want to identify larger assessment efforts with which they could coordinate. There are numerous vulnerability assessments underway at the state and regional levels across the Northeast. It will be important to use these tools and place coastal impoundments projects within the context of those tools. The information provided here is meant to show how to think about vulnerability in relation to coastal impoundments in a much-abbreviated fashion.

The first step of a vulnerability assessment (at any level) is to decide on its scope, including what are the goals and objectives, project approaches, timeline, etc. being considered. Much of this is determined in the two steps above. To provide an example of how to evaluate vulnerability for coastal impoundments, we evaluated the vulnerability of the goal – providing
waterbird (i.e., waterfowl, shorebirds, and wading birds) habitat, and the primary project management approach for impoundments – controlling water levels.

**Sensitivity**

**Goal Sensitivity**

*Provide Waterbird Habitat:* Waterfowl, shorebirds, and wading birds will have varying sensitivity to climate change depending on the species. Many species will be sensitive to water levels. If coastal impoundment levels are not able to fluctuate as necessary to provide food sources, habitat, and nesting areas, birds will leave the areas as they may not be able to survive or maintain population numbers. Some waterbirds may benefit if they prefer deeper waters and fish as opposed to vegetation. Waterbirds will likely be sensitive to changes in water temperature and salinity as well.

**Project Approaches**

*Control water levels:* Coastal impoundments will be affected by increased sea levels if current water control structures are not able to remove/ drawdown enough water for management goals. Impoundments also may be completely over taken by sea water from storm surge that could render them non-functional in terms of management goals. Salt water intrusion may also be a problem that cannot be controlled by water control structures.

**Exposure**

Most areas in the Northeast such as the Chesapeake Bay, Delaware, New Jersey, and New England are already experiencing relative sea-level rise both from naturally occurring subsidence as well as climate change induced sea-level rise (NECIA, 2006). Determining how much sea-level rise to plan for is not necessarily a simple task. Projecting how much global sea levels will rise from climate change is complex, and many sea-level rise scenarios exist. When looking at global sea-level rise rates, Glick et al. (2011b) refer to the eustatic rate of sea level or the changes in the volume of seawater (Glick et al., 2011b). However, locally, other factors play into rates of sea-level rise, such as land subsidence, which can make local rates higher than global rates of sea-level rise.

Of the existing sea-level rise scenarios, the ones most commonly used are from the Intergovernmental Panel on Climate Change (IPCC), which estimates 7 to 23 inches of global sea-level rise over the 1990 levels by 2090’s (IPCC, 2007). The IPCC scenarios do not include recent dynamic changes to ice flow in Greenland and Antarctica; thus, the IPCC scenarios underestimate global rates of change. Taking the ice melting into account, Rahmstorf estimates an increase of 30 to 75 inches over 1990 levels by 2100 (Rahmstorf, 2007).

Choosing which sea-level rise scenario to base a vulnerability assessment on will depend upon factors such as the time frame of the project and how much risk one is willing to accept. Using a range of scenarios may be the optimal approach (Glick et al, 2011b). Looking at current rates of relative sea-level rise along the Atlantic Coast, local rates of relative sea-level rise are higher than the current global average generally per year (0.08 – 0.15 inches versus 0.07 inches) (CCSP, 2009). The Climate Change Science Program’s Mid-Atlantic Synthesis and Assessment
Report 4.1 includes a map depicting how much coastal land will be converted to open water with various rates of sea-level rise (Figure 3) (CCSP, 2009).

![Map of coastal land conversion](image)

Figure 3. Projections of wetland habitat change in the Mid-Atlantic under various sea-level rise scenarios in the Climate Change Science Program’s Mid-Atlantic Synthesis and Assessment Report 4.1 on sea-level rise in the Mid-Atlantic (CCSP, 2009).

To provide an example of the exposure of a coastal impoundment to sea-level rise, Figures 4 and 5 depict three sea-level rise projections the Delaware DFW anticipates for the specific coastal impoundments that will be the focus of their climate-smart projects. The figures depict 0.5 meters (green), 1 meter (yellow), and 1.5 meters (red) of predicted sea-level rise for two impoundment areas in Delaware. The numbered areas are impoundments. As the figures show, many impoundments will be affected even with 0.5 meters of sea-level rise.
Adaptive Capacity

By their nature, coastal impoundments have a certain degree of adaptive capacity as their water levels can be controlled. However, if the structures are overwhelmed by too much water, then this adaptive capacity will be lessened. Additionally, coastal impoundments may be modified to deal with the changes in sea-level rise and storm surge in some cases. It is also possible to build new coastal impoundments to try to provide similar function to those that might
be lost. However, some coastal impoundments are already being severely impacted by sea-level rise and have lost their integrity as an impoundment and have converted to open water.

4. Identify Climate-Smart Management Options

For the guidance document, the expert panel developed a suite of considerations that resource managers can use to begin to think about how they may need to integrate climate change into their planning and management of coastal impoundments. In addition to the considerations below, several examples of pilot projects being implemented by Delaware DFW are described. These pilot projects demonstrate options for how to adapt management of coastal impoundments in response to sea-level rise. It is important to note that the examples are projects in specific locations, and they may not be applicable everywhere. However, they do provide context for these considerations.

As noted in the vulnerability assessment section, sea-level rise may result in managers not being able to dewater coastal impoundments as needed and only allow water outflow at the lowest portions of the tide cycle. This limited outflow will require a longer period for a drawdown to occur and in some cases certain levels of drawdowns might not even be possible. This will be an issue for many management goals (e.g., waterfowl, shorebirds, wading bird, etc.) as these impoundments will now function more as open water ponds; thus, it will be important to consider these issues when managing water control structures in a climate-smart way.

Options for Climate-Smart Coastal Impoundments

Water Control Structure Options

1. Add additional or modify existing water control structures with the intent to increase the potential for water outflow. Additional structures could be placed within existing levees or existing structures could be modified to increase their outflow capacity by making outfall pipes larger or more numerous. Both of these options can be relatively expensive. Additionally, the elevation that these outflow pipes are placed is critical, as these elevations will determine structure capabilities.

2. Consider what to do with the dikes/levees. Dikes could be raised and armored for protection or widened and stabilized, both in an attempt to protect from storm surge. Depending on the location, dike construction can be difficult and might require specialized equipment to simply get the construction material on site, such as specialized-track, amphibious equipment, or even offshore dredges.
Another option to stabilize dikes is to create a buffer of habitat on either side of the dike to minimize storm surge. Habitat built in front of the dike could consist of beach habitat extending seaward and upward to dampen storm surge and waves. Behind the dike a buffer of tidal marsh could be created by establishing an internal dike behind the existing dike and reestablishing tidal marsh at the appropriate elevation. The benefit of this latter option is that it prepares for the reestablishment of tidal marsh in the event the front dike fails.

Additional Options

1. Add more sediment to the impoundment as historically coastal impoundments become “sediment starved” as natural sediment accretion is usually diminished in impoundments compared to natural tidal marsh systems. One option for sediment augmentation is using beneficial dredge material to increase the base elevation of the impoundment, thereby helping to prevent it from becoming deep open water habitat. Thin layer application of the sediments should be considered so as not to smother vegetation and limit the creation of upland habitats.

2. Create an upland impoundment in anticipation that the coastal impoundment will eventually be let go. However, a consideration when doing this will be source of water. Depending on the site, it is likely there will be no permanent source of water that will be available for use; thus, a new impoundment will likely depend on precipitation. Given changes in precipitation and timing of snow melt (for certain states) this could prove to be a significant challenge; thus, water supply may be an issue.

3. Create new brackish impoundment in place of current freshwater impoundment.

4. Allow/ assist impoundment in converting to tidal brackish/ salt marsh habitat. Currently, these options are being considered at numerous National Wildlife Refuges across the Northeast, including Prime Hook National Wildlife Refuge in Delaware.

Timing Issues

Planning for coastal impoundment management as sea levels rise has a significant temporal element. When working through possible climate-smart management options, it will be important for natural resource managers to identify examples of different alternatives at different time horizons (short, medium, and long-term). An SDM process can be useful to managers to help make these temporal choices. As mentioned previously, USFWS Region 5 has developed an SDM process to help managers decide how they should treat their impoundments as sea-levels rise. Additionally, the Region 5 document outlines trigger points for when managers may need to start considering alternative options (USFWS, 2009). For example, what are the operational costs and what are the benefits of keeping the impoundment? A trigger point for changing management actions might be when benefits decrease to some point relative or even unrelated to increasing operational costs.

Data Needs

For the design and development of coastal impoundment climate-smart projects the availability of elevation data (LiDAR), vegetation data, soils data, and hydrological data will be
important factors. Elevational surveys may need to be ground truthed to confirm and fine tune established target elevations as LiDAR data might be coarse and not sufficiently detailed. Hydrological data should include volumes of exchange (inflow and outflow) at various water level regimes as well as salinity and dissolved oxygen levels. Additionally measures of impoundment benefits (waterfowl or shorebird numbers, fish abundance, recreational use days, etc.) as well as annual operation costs should also be obtained.

Climate-Smart Pilot Projects

This section describes two pilot projects that the Delaware DFW is planning to implement in an attempt to address the impacts of sea-level rise on their coastal impoundments. These projects and the steps that the Delaware DFW is working through have been included to provide an example of the type of actions a fish and wildlife agency could consider for similar projects. Although the two examples are specific to the coastal impoundments that the Delaware DFW is managing; the panel felt these pilot projects could provide useful insights for other agencies that will need to address sea-level rise impacts on coastal impoundments.

The Delaware DFW has drawn from the experience at Prime Hook NWR where a combination of sea-level rise and coastal storms caused a breach to a coastal impoundment. As mentioned above, the resulting impacts have been significant, causing extensive flooding of the area, converting many formally vegetated areas to open water habitat, causing dramatic salinity increases and associated vegetation die-off, as well as impacting the surrounding uplands, adjacent wetlands, and landscape infrastructure.

Pilot Project 1 - Create a Buffer Wetland to Protect an Existing Impoundment

The first project that Delaware DFW plans to implement is within its Little Creek Impoundment (Figure 6). This 442-acre brackish coastal impoundment has historically had a small strip of protective barrier beach between the impoundment’s easternmost dike and the Delaware Bay. Unfortunately, this barrier beach has gradually eroded away in the last 20 years to the point that even relatively small coastal storms cause damage to the dike system. Delaware DFW will utilize beneficial dredge material to repair the existing dike and enhance the barrier beach in order to maintain the impoundment while also reestablishing an internal dike more landward. Between these dikes, beneficial dredge material will also be utilized to create a tidal marsh. Once this tidal marsh has been successfully established with vegetation and a curvilinear network of tidal channels, the original seaward dike will be allowed to breach, permitting unobstructed tidal exchange into the newly created marsh. It is hoped that this managed landward retreat will: 1) create a protective buffer between the newly formed internal dike and the Delaware Bay thereby protecting the remaining impoundment and 2) allow the reestablishment of a tidal marsh within a portion of the tidal impoundment thereby
preventing it from becoming undesirable open water habitat. This pilot project will allow the Delaware DFW to maintain this impoundment in the short to mid-term, providing them the opportunity to monitor the impacts of sea-level rise, learn from this project, and plan for its other impoundments. The initial steps that Delaware DFW is considering for this project are listed below.

Figure 6. Map developed by Delaware DFW for their pilot project at the Little Creek Impoundments.

Step 1: Build up the existing dike system with beneficial dredge material to restore it to its previous working condition as well as build a new internal dike located landward. Specific details need to be obtained on the source for the beneficial fill, its type, grain size and the delivery mechanism.

Step 2: Thin layer application of beneficial dredge material on to the buffering wetland between the new and existing dike. A detailed elevation survey of the area as well as an adjacent tidal marsh needs to be conducted to determine the quantity of fill required.

Step 3: Encourage salt marsh vegetation growth based on adjacent tidal marsh compositions.

Step 4: Create channels for tidal exchange in the buffer area based on existing and historic channel profiles.
Step 5: Once the buffer area has been successfully established as a tidal marsh, create breaches in the original dike system to promote tidal exchange while allowing the remaining portion of the dike to erode providing a source of sediment accretion.

Step 6: Monitor and provide adaptive management to the project.

Pilot Project 2. Abandon an Existing Impoundment and Create a New Upland Impoundment.

The other pilot project that Delaware is exploring will be to create an adjacent upland impoundment that will allow them to abandon an existing coastal impoundment to sea-level rise when costs of maintaining the impoundment outweigh its benefits. When abandoned, the impoundment may still exist; however, the ability to manage it for existing goals may not be possible or may be significantly reduced. There are a variety of options when abandoning an impoundment: one can abandon the impoundment and take no steps to protect or restore the area or one can actively work to restore the area to a natural wetland. Delaware is looking at the option of both abandoning an existing impoundment while also replacing the lost habitat functions and values by creating a similar impoundment or enhancing wetland habitat in an adjacent upland.

Step 1: Determine if there are suitable uplands available to create a new impoundment. Questions considered include: are they public or private, are they conducive to creating a wetland (e.g., elevation), what current resource values would be lost where the new impoundment will be located, and what resource values are not attainable or limited at the new site? In most cases, in an effort to minimize impacts and maximize benefits this means the conversion of agricultural land into wetland habitat.

Step 2: Determine the source of water (upland flow, groundwater, or tidal exchange) and whether it will be fresh or brackish. Modeling of precipitation potential, freshwater stream input, or tidal inflow will be needed.

Step 3: Determine size and elevation of the new impoundment (LiDAR data would be helpful here). Factors determining size will be based on budget, site limitations, water supply, and resource values needing to be replaced. Delaware is currently evaluating the “duck use days” of its existing brackish impoundments in relation to nearby tidal marshes and freshwater impoundments to quantify the lost duck use values should the impoundments be lost to sea-level rise. In some cases it is feasible that a smaller freshwater impoundment of higher quality could replace many of the resource values of a much larger brackish impoundment.
Step 4: Construct the new impoundment and water conveyance system and then establish appropriate vegetation through both natural revegetation and selective plantings.

Step 5: Monitor and provide adaptive management to the project.

5. Select and Implement Climate-Smart Options

This guidance lays out various considerations that can help natural resource manager consider how to manage coastal impoundments in a climate-smart manner. The considerations are designed to spark new thinking about coastal impoundments in the context of climate change and provide a guide for natural resource specialists and managers to develop more specific options for their sites.

In terms of implementing specific options and actions for coastal impoundments, a manager will need to consider the same factors as when implementing any project. The choice of what to implement will likely depend on a range of factors, depending on need, interests, and resources available. An important issue that also will likely need to be assessed is regulatory permitting requirements and engineering needs. Managers will need to think about the costs of each option in terms of funding, material, and manpower needed to design and implement each option, as well as timelines needed to complete them. Additionally, feasibility and effectiveness of each option should be evaluated.

6. Monitor, Review, Revise

Monitoring and keeping track of the impacts of sea-level rise on coastal impoundments is necessary to help understand how to respond appropriately. Developing a standard monitoring protocol will be important to determine effectiveness of different actions. A monitoring protocol also can help detect early warning signs about climate change, which can provide vital information for federal, state, local, and private interests.

Examples of factors to monitor include: baseline elevation surveys in and out of the impoundment, vegetation response, hydrology changes, and target conditions and species abundance for which the impoundment is being managed for. It will be essential to standardize monitoring protocols between agencies at the state and federal level to make the results comparable and effective. A long-term monitoring commitment will also need to be made.
LIVING SHORELINES CLIMATE-SMART GUIDANCE

Introduction to Living Shorelines

Shoreline erosion is a naturally occurring process that is being exacerbated by significant development and human activity along the coasts (Erdle et al., 2006). Traditionally, residents and land owners along the shore have installed hard or armored structures such as revetments, bulkheads, and sea walls to minimize erosion (Erdle et al., 2006). The impacts of using armored structures, however, can include loss of vital coastal habitats, such as wetlands, and natural shoreline features, interruption of natural coastal processes, and possible increases in local rates of coastal erosion (NRC, 2007). Over the last several decades, in an effort to lessen these impacts, there has been a move to integrate more natural shoreline and habitat elements into stabilization methods (Erdle et al., 2006). These efforts have gained particular attention given the significant added stressors to our coasts from climate change, including accelerating sea-level rise and more intense coastal storms.

The term “living shorelines” applies to a variety of techniques used to minimize shoreline erosion while also providing habitat value. These techniques are most often employed on sheltered coastlines such as estuaries, bays, lagoons, and mudflats where wave energy is less than open beaches (NRC, 2007). Erosion along sheltered shorelines results from processes similar to those on open coastline systems but at significantly smaller scales. Additionally, sheltered shorelines have “irregular configurations” and are more compartmentalized geomorphically, resulting in greater diversity of characteristics and conditions as opposed to a long stretch of open coast. Understanding and responding to shoreline erosion along sheltered shorelines, therefore, is complex and site specific as are living shoreline projects (Erdle et al., 2006; NRC, 2007).

Interest in using living shorelines as a mechanism to minimize erosion while also providing or maintaining habitat is growing; however, the science of living shorelines and the techniques involved are still evolving (Smith, 2006). Definitions of living shoreline also vary. Generally, living shorelines are a set of techniques that can be used to minimize shoreline erosion and maintain coastal processes and habitats. Living shorelines typically include a combination of soft measures such as vegetation to absorb wave energy and minimize erosion in conjunction with hard structures such as rock sills or oyster reef (Castellan and Wall, 2006). Project options can include riparian vegetation restoration and management, tidal

Credit: Bhaskar Subramanian, MD DNR
marsh restoration or enhancement, oyster reef restoration, bank grading, beach nourishment or dune restoration (TNC, 2011). Living shorelines offer various ecosystem benefits such as providing shallow water habitat for a diversity of aquatic species both in the nearshore and offshore, maintaining a link between aquatic and upland habitats, maintaining shoreline dynamics, and improving water quality by filtering pollution and settling sediment (Thomas-Blate, 2010; NOAA OHC, 2011).

**It is important to note, however, that living shorelines are not suitable in all locations.** Private and public entities alike who are considering living shorelines should work with the appropriate person(s) (state agency, consultant, engineer, etc.) to determine site suitability. Various factors will need to be considered, including historical shoreline erosion rate, elevation, location of the site, wave energy, prevailing wind and wave direction, fetch, shoreline exposure (direction facing), shading, etc. (NOAA OHC, 2011).

**Climate Change and Living Shorelines**

Armored shorelines may protect land and property from rising sea levels, at least in the short-term; however, they interrupt natural processes and can harm coastal habitats (CCSP, 2009). Living shorelines are often recommended as a more natural alternative. They help minimize coastal erosion while providing habitat and enabling/enhancing coastal processes. Given that they offer habitat and ecosystem benefits, multiple agencies and organizations also are recommending living shorelines to help protect against the impacts of climate change. For example, the U.S. EPA lists living shorelines as “soft” measures to maintain shorelines in the face of sea-level rise (U.S. EPA, 2009). Maryland’s Comprehensive Strategy for Reducing Maryland’s Vulnerability to Climate Change, Phase II noted that passing the Living Shorelines Protection Act of 2008 (requires the use of living shorelines over hardened structures except in specifically mapped areas) was an important step in protecting shorelines in the face of rising sea levels. It also references living shorelines as an “adaptation stewardship activity” (Boicourt and Johnson, 2011).

Some organizations are also implementing living shorelines with the specific intent of minimizing impacts from sea-level rise and wave surge resulting from storms. For example, the Maryland Department of Natural Resources (in coordination with a grant from the Chesapeake Bay Trust, NOAA, and the Maryland Department of the Environment) are in the process of implementing a living shoreline project at the Gunston School in Centreville, Maryland whose design incorporates the sea-level rise data for Chesapeake Bay. The Nature Conservancy and the U.S. Fish and Wildlife Service have constructed a living shoreline project at the Alligator River National Wildlife Refuge in North Carolina to enhance the resiliency of the marsh to rising sea levels, including installation of an oyster reef to dissipate wave energy and reduce shoreline erosion (Gregg, 2010). The Partnership for the Delaware Estuary implemented a similar project in the Delaware Bay in New Jersey. The group in coordination with Rutgers University constructed intertidal reef made up primarily of mussel beds to stabilize the shorelines of tidal marshes within the estuary. The mussel beds help protect the eroding edges of the marshes, which is the result of a variety of factors with sea-level rise being the primary cause (Partnership, 2008).
Climate-Smart Guidance

This section also follows the six element climate-smart framework described in the Introduction – Guidance Scope.

1. Identify Goals and Targets

For this guidance, the goals outlined below are the primary goals of living shoreline projects.

Goals

Living Shoreline projects have two main goals (1) protect the shorelines from further erosion and (2) provide habitat at the land/water interface and provide habitat connectivity. Living shorelines projects should accomplish both of these goals.

Reconsidering Goals and Targets in Light of Climate Change

Although the goal of a living shorelines project will not change in light of climate change (they will still be used to minimize the impacts of erosion and provide habitat), the expert panel considered how constructing a living shoreline could help meet other adaptation goals. By enhancing or maintaining habitat that might otherwise have been lost or degraded by an artificially hardened structure, a living shoreline may increase the resiliency of coastal system to impacts from sea-level rise or coastal storms by maintaining coastal processes and habitats, making the system healthier and more resilient over all. Also living shorelines could provide space for potential/predicted wetland migration or act as refugia for some coastal species as they migrate northward by providing habitat.

2. Identify Project Approaches

Some of the assumptions that go into project planning and design may change due to climate change, although overall project approaches likely will not. For example, for living shorelines projects the site suitability selection might change. There is currently no common regional set of criteria for selecting a site or calling a site suitable when considering climate change. Several states have developed suitability criteria for projects in their states. Assessing vulnerability to climate change (Element 3) will help determine which approaches may be necessary to address climate change impacts and where new approaches may be needed. How these approaches may need to change to address climate change impacts is addressed in Identify Climate-Smart Management Options.

Example Living Shoreline Project Approaches

- Plant riparian and marsh vegetation (NOAA OHC, 2011).

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2 For example, Maryland has a guide for living shoreline techniques that includes suitability criteria. Available at [http://www.dnr.state.md.us/CoastSmart/pdfs/SE_TheNaturalApproach.pdf](http://www.dnr.state.md.us/CoastSmart/pdfs/SE_TheNaturalApproach.pdf). Virginia Marine Resources Institute also has developed a decision-tree analysis to help guide shoreline management techniques including living shoreline techniques. The guide is available at [http://ccrm.vims.edu/decisiontree/decisiontree_manual.pdf](http://ccrm.vims.edu/decisiontree/decisiontree_manual.pdf).
- Install organic materials such as natural fiber logs (bio-logs) and organic fiber mats to stabilize slopes, minimize erosion, and trap sediment. These also provide substrate for shellfish (Partnership, 2008; NOAA OHC, 2011).
- Place rock sills parallel to the shore to dissipate wave energy and protect the shore from erosion (NOAA OHC, 2011).
- Construct oyster reef or other breakwaters to disperse wave energy that reaches the shorelines (NOAA OHC, 2011).

Credit: Bhaskar Subramanian, MD DNR

3. Assess Vulnerability of Targets and Approaches

Conducting a complete vulnerability assessment for living shorelines across the Northeast was beyond the scope of work for the expert panel. However, for the document, the panel decided to walk through a modified version of a vulnerability assessment to provide a starting point and some key considerations for conducting a vulnerability assessment for living shorelines work.

For managers wanting to conduct a vulnerability assessment that involves living shorelines, they may want to identify larger assessment efforts with which they could coordinate. There are vulnerability assessments underway at the state and regional levels across the Northeast. It will be important to use these tools and place living shoreline projects and other restoration projects within the context of those tools. The information provided here is meant to show how to think about vulnerability in relation to living shorelines in a much-abbreviated fashion.

The first step of a vulnerability assessment (at any level) is to decide on the scope, including what are the goals and objectives, project approaches, timeline, etc. Much of this is determined in the two steps above. To provide an example of how to evaluate vulnerability for living shorelines, we evaluated vulnerability of two of the goals/ objectives stated above (minimizing shoreline erosion and providing habitat) as well as a project approach (planting riparian/ marsh vegetation).
Sensitivity
For the living shorelines sensitivity analysis, we are focusing on sea-level rise and storm surge impacts.

Goal Sensitivity
Minimize Shoreline Retreat and Erosion
Sea-level rise is projected to result in the retreat of coastal shorelines. Additionally, an increase in hurricane intensity may also result in retreat of shorelines (CCSP, 2009). Coastlines also experience varying coastal erosion rates depending on three main factors: (1) geological characteristics of the coastline and nearshore areas; (2) natural factors and physical processes; and (3) human activities (e.g., dredging, dams) (CCSP, 2009). Because these three factors interact, it can be hard to determine how sea-level rise will exactly affect coastal erosion rates (CCSP, 2009). There is consensus that sea-level rise is affecting coastlines and coastal habitats, but there are fewer consensuses on how erosion rates will respond to sea-level rise. However, the increased intensity and frequency of storms predicted to result from climate change will very likely increase shoreline erosion in the future. Therefore the sensitivity of this goal is high, because erosion will continue and potentially worsen as the climate changes.

Credit: Bhaskar Subramanian, MD DNR

Enhance and Restore Habitat
Increasing sea levels and worsening storm surges threaten to inundate living shoreline sites, affecting vegetation species that have been planted at the site. Increasing salinity levels from the inundation also could affect vegetation species, depending on their salinity tolerances.

In addition, where living shoreline projects involve tidal wetlands, the wetlands will also be affected by sea-level rise. If a wetland cannot maintain its vertical elevation relative to sea-level rise through accretion, then it will eventually become submerged land. While many tidal wetlands have kept up with historical rates of sea-level rise, it is unclear whether they will be able to keep up with accelerated rates projected for the future (CCSP, 2009). Some wetlands may be able to migrate inland, but that ability depends on several factors, including accretion rate, slope, and land use of the adjacent landward area.
Project Approach Sensitivity

Plant Riparian and Marsh Vegetation

The vegetation selected for living shorelines may be affected by rising sea levels if they are sensitive to changes in salinity levels and changes in water levels. In addition, vegetation may be sensitive to changes in temperatures and changes in precipitation patterns as well.

Exposure

Generally, for the Northeast coast, most areas such as the Chesapeake Bay, Delaware, New Jersey, and New England are already experiencing sea-level rise both from naturally occurring subsidence as well as climate change induced sea-level rise (NECIA, 2006). Sea-level rise projections from the IPCC estimate 7 to 23 inches of global sea-level rise over the 1990 levels by 2090’s (IPCC, 2007). However, the IPCC scenarios do not include recent dynamic changes to ice flow in Greenland and Antarctica; thus, the IPCC scenarios underestimate global rates of change. Taking the ice melting into account, Rahmstorf estimates an increase of 30 to 75 inches over 1990 levels by 2100 (Rahmstorf, 2007). The frequencies and intensities of floods and droughts are likely to increase over the remainder of this century (NECIA, 2006). NECIA (2006) also predicts that coastal winter storms may shift from earlier to later in the winter and more storms are expected to travel further up the coast and affect the Northeast. Please see the Exposure section the Coastal Impoundment Climate-Smart Guidance Section for additional information on determining exposure.

Adaptive Capacity

The adaptive capacity of living shorelines is relatively high; however, it depends on where the project is located and what the tidal range is. Projects often have a sand fill component that raises the existing shoreline. Each project is designed uniquely to the site where it is placed. New criteria can be integrated into the projects. They also can help build habitat resiliency if designed appropriately to include a habitat restoration component.

4. Identify Climate-Smart Management Options

For this guidance, after the expert panel analyzed Elements 1 through 3, it became apparent that there is currently insufficient data on how living shorelines will respond to climate impacts to issue specific design guidance. While living shorelines offer habitat benefits that traditional armored structures do not, additional research and long-term monitoring is needed to evaluate the effectiveness of living shorelines over time in light of sea-level rise and increased storm surge. In addition, trade-offs in designing for future conditions must be recognized, since designing for future sea-level rise may compromise the near-term habitat benefits of a living shoreline. For example, if you raise the sill height, in general, you increase the footprint of the hardened structure and/or you may decrease the area for available marsh habitat. If you design for all high marsh with the anticipation of future sea-level rise, then you lack the low marsh habitat benefits now. Project managers must consider the planned life of the project when one is established, the management, and maintenance strategy in making design decisions. The considerations listed below are useful to evaluate in planning a living shorelines project, recognizing that project design is site-specific and that living shorelines are not appropriate for all locations.
Determine local rates of sea-level rise

When designing a living shoreline project, it is important to integrate sea-level rise projections into the planning and design of the project. Projected sea-level rise data will help factor elevated tide levels into project design and influence such choices as site elevation, vegetation type, and other parameters (described in more detail below). As mentioned above, when considering sea-level rise projections managers should take into account the life of the project where one is included in the design. If it is less than 20 years, some projections may not be applicable.

Looking at current local rates of sea-level rise for the area of the proposed project is a useful first step. Long-term tide gauge data for sites along the U.S. coast are available at NOAA’s Center for Operational Oceanographic Products and Services (CO-OPS) website (see Appendix A for website information). Examining projected rates of sea-level rise for the future is an important next step. While global predictions of future sea-level rise exist, it is difficult to downscale projections to local levels. However, having an understanding of the range of potential sea-level rise scenarios is useful for planning purposes. Several models and guidance documents exist as listed below:

- State sea-level rise planning guidance (e.g., Rhode Island Sea-level Rise Policy Guidance document, New York State Sea Level Rise Task Force Report to the Legislature, Maryland’s Comprehensive Strategy for Reducing Maryland’s Vulnerability to Climate Change: Phase I Sea-level Rise and Coastal Storms).

Consider Slope and Elevation of Site

The elevation of a site may become more important as sea levels rise. Slope will be an important factor in the ability of the shoreline or wetland to migrate inland. Gradual slopes are generally used in living shoreline projects, and they will be especially important to help shoreline habitats adapt to sea-level rise (Duhring, 2006). If the slope is too steep, shoreline habitats such as tidal wetlands will not be able to migrate inland. However, consideration also needs to be given to structures (i.e., retaining walls, driveways, residential buildings) that are upland of the area and may inhibit migration regardless of slope. Gradual slopes may also allow proliferation of undesirable invasive vegetation (e.g., Phragmites) so the overall ecological goals need to be considered.

Credit: Bhaskar Subramanian, MD DNR

Consider Vegetation Selection

Plant selection will naturally vary by site, depending on location, slope, fetch, salinity levels, etc. However, a mix of native wetland plants, woody trees, and shrubs at higher elevations are often chosen (NOAA OHC, 2011). A variety of factors should be taken into account when thinking about climate change and selecting vegetation for planting at a living shoreline site. Sea-level rise may cause parts of the living shoreline to become submerged periodically or permanently and salinity regimes may change. Marsh habitat may be converted to open water habitat. Choice of plants may need to be reconsidered. Should plants that are more prevalent upland be selected in preparation for inland migration? Should more salt-tolerant species be selected? Should a mix of plants include some that are more tolerant of inundation? These are questions managers will need to consider.

Manage Invasive Species

Invasive species are likely to be affected by changes in temperatures and salinity levels that result from salt-water inundation from sea-level rise. Managers should keep in mind that current invasive species may become more pervasive, less pervasive, or change all together. This may affect the type of native plants managers choose as well as maintenance plans related to invasive species management.

Evaluate Project Site and Design in Context of Larger Landscape of Climate Adaptation Planning

Consider selecting sites that provide conservation value and increase resiliency to climate change. Project planners can reference state, regional, or other landscape level climate adaptation planning initiatives to determine if their project may fit into a larger strategy. The project planner could work with relevant federal, state, local, and/or private partners on the effort and determine how best to design the living shoreline project to help meet larger, landscape-level goals, such as restoring a certain number of wetland acres.

An important factor of any adaptation strategy, living shoreline project or otherwise, is establishing a protocol to reevaluate the project (e.g., determining if the goals being met) at least halfway through the life of the project. Using a framework to integrate new information as the climate changes and impacts are seen will be necessary.

Consider an Easement on the Living Shoreline and Upland Areas

Living shorelines can serve as part of a larger adaptation strategy for the surrounding area of communities. If in the appropriate location, they may allow inland migration of tidal wetlands, as opposed to an artificial non-vegetated structure like a seawall. As such, it may be worth exploring putting an easement on the living shoreline itself as well as upland areas. When living shorelines are put on private property, if the property changes ownership, the new owner might not have the same interests in a living shoreline. An easement could help protect the living shoreline and the ecological values it provides in perpetuity. However, much (approximately 85 percent) of the land around the Chesapeake Bay is private property, and the practical application of this consideration may be difficult.
Develop a Maintenance and Long-Term Management Plan

Contrary to common misconceptions, living shoreline projects are not zero-maintenance projects. Maintenance and long-term management of living shorelines is essential to their continued success and sustainability. Having a plan and schedule in place for maintenance and management of the site will be important because during the life of the project debris may need to be removed, vegetation may need to be replanted, tree limbs may need to be trimmed/pruned, invasive species may need to be removed, etc. This will be especially important as sea levels rise and storms become more frequent and intense. Site maintenance should be considered during the design of the project. If on private lands, the landowner could work with the contractor to set up a long-term maintenance contract.

Hold Workshops on Living Shoreline Projects

Some states currently hold workshops that bring together state and local agencies as well as private landowners, contractors, and engineers. These events provide a venue where technical information can be shared. The first step of these workshops is to provide private landowners information to assist them in understanding the benefits of living shorelines in contrast to bulkheads or ripraps. Efforts also have to be made to educate various stakeholders on how the use of excessive structural components in projects exacerbates shoreline erosion issues. Over time, climate change information and innovative techniques should be integrated into workshop agendas. Additionally, site visits will be important to demonstrate on-the-ground efforts.

Consider Integrating Climate Change into Grant Programs

Various grant programs exist through federal agencies such as NOAA and USFWS, state agencies such as the Maryland Departments of the Environment, and foundations such as the Chesapeake Bay Trust that provide funding for living shorelines. Granting entities may want to consider requiring the integration of climate change adaptation principles as a prerequisite for grant programs and Requests for Proposals. Including the consideration of climate change as a required element to receive a grant would go a long way to help incentivize the use of sea-level rise information and integration of adaptive management into proposed living shoreline designs.

5. Select and Implement Climate-Smart Options

This guidance lays out various considerations that can help restoration specialists, resource managers, private landowners, and others plan, design, and implement living shorelines in a climate-smart manner. The considerations are designed to encourage new thinking about living shorelines in the context of climate change and provide guidance for specialists, managers, and landowners to develop more specific options for their sites.

In terms of implementing climate-smart options for living shorelines, a manager will need to consider the same factors as when implementing any project. The choice of what to implement will likely depend on a range of factors- project needs, interests, resources available, and existing permitting regulations. Managers will need to consider cost of each option in terms of funding, material, and manpower needed to design and implement each option. Timelines will need to be evaluated. Additionally, feasibility and effectiveness of each management option should be evaluated.
6. Monitor, Review, Revise

Monitoring and keeping track of the effectiveness of living shoreline projects is important not only in its own right, but also under a changing climate as well. Being able to document how living shorelines are better able to withstand changes such as sea-level rise and increasing storm intensities will help demonstrate why and where best they should be used. Lessons also can be learned as to what techniques and designs are best able to withstand impacts from sea-level rise and storm events and adapt them in a seamless fashion.

Living shoreline projects have been constructed up and down the coastline for a variety of objectives, including shoreline erosion control, habitat creation, habitat protection, wildlife value, etc. Just as living shoreline definitions and objectives vary, so too do any subsequent monitoring programs. Most living shoreline projects have not been monitored to assess how well the project has met its objectives, much less how the project has responded to climate changes, such as sea-level rise, increased storm surges, or temperature increases. Although some projects have been monitored, there is no standard monitoring protocol for assessing living shorelines.

Developing a standard monitoring protocol will be important to compare between living shorelines projects to determine effectiveness of different actions and designs. Specifically, identifying minimum and consistent monitoring criteria for living shoreline projects will be important. Identification of these criteria could be done through a small, focused technical workshop, potentially in conjunction with the Chesapeake Bay’s living shorelines workgroup (that has representation from various agencies). A monitoring protocol or criteria also could help detect early warning signs about climate change, which can provide vital information for federal, state, local, and private interests. A challenge to a consistent monitoring protocol is that every project is site-specific. Additionally, funding can often be a challenge. The State of Maryland includes a monitoring component in its living shoreline projects, and it has tried to link living shorelines projects to larger projects and to integrate monitoring within the larger project’s monitoring framework.
COASTAL CLIMATE-SMART GUIDANCE CONCLUSION

Coastal Impoundments

Coastal impoundments serve important biological and socioeconomic functions that cannot be discounted. As coastal wetlands continue to decline and are degraded or lost due to sea-level rise and other impacts from climate change, managed wetlands such as impoundments can provide an alternative or complementary habitat for waterbirds and other species. Management of coastal impoundments is complicated, and adding climate change impacts adds another confounding factor; however, there are processes such as through Structured Decision-Making that can assist managers in making important management decisions. The information provided in this document is meant to assist fish and wildlife managers across the Northeast think about the implications climate change may have on coastal impoundments. Additionally, this guidance document provides examples of some options available to managers to plan for and manage coastal impoundments as sea levels rise.

Living Shorelines

The panel endorses the use of living shorelines in appropriate locations as a tool to provide habitat benefits while reducing erosion. This may help build the resiliency of coastlines to sea-level rise and increasing storm surges. Traditional armored structures can destroy coastal habitat, prevent ecosystem functions, and often result in displacing coastal erosion as opposed to minimizing the erosion. As such, as a conservation community, we need to be pro-active in recommending living shorelines in appropriate locations. Monitoring protocols also need to be developed to evaluate the effectiveness of living shorelines at protecting coastal areas over time with respect to climate impacts. Finally, more research should be conducted on how living shorelines could help provide a mechanism for inland migration of wetlands and how to adaptively manage living shorelines over time so they can continue to provide benefits as sea levels rise and storm surges increase.
APPENDIX A: ADDITIONAL RESOURCES

Organizations and Web-Based Resources


- The *Climate Adaptation Knowledge Exchange (CAKE)* website also provides an extensive, searchable selection of climate change information and resources, which is being regularly updated: [www.cakex.org](http://www.cakex.org).

- NOAA’s *Coastal Services Center* has a website dedicated to providing key resources on coastal adaptation, including relevant climate science and impacts: [http://collaborate.csc.noaa.gov/climateadaptation/default.aspx](http://collaborate.csc.noaa.gov/climateadaptation/default.aspx).


- *Georgetown Climate Center* website provides information on various facets of climate change, including a webpage dedicated to adaptation that includes coastal systems: [http://www.georgetownclimatecenter.org](http://www.georgetownclimatecenter.org).


- *NOAA CO-OPS* is a source of tidal hydrodynamics expertise, including proper selection and interpretation of tide station data. [http://tidesandcurrents.noaa.gov/index.shtml](http://tidesandcurrents.noaa.gov/index.shtml).


Climate Change Impact Studies


Relevant workshop resources and proceedings


Additional Resources


- The U.S. Climate Change Science Program (CCSP) has developed a Preliminary Review of Adaptation Options for Climate-sensitive Ecosystems and Resources (2008): http://downloads.climatescience.gov/sap/sap4-4/sap4-4-final-report-all.pdf.
REFERENCES


Delaware Division of Fish and Wildlife (DFW). 2010. Division of Fish and Wildlife’s Adaptive Climate Change and Sea-level Rise Policy White Paper. Dover, DE.


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