# Coastal Adaptation in Massachusetts

# Streamlining Permitting for 'Living Shoreline' Strategies

C. Leanne Cowley

A Sustainability Capstone Project for the Degree of Master of Liberal Arts

Harvard University Extension School

May 2018

Response Word Cloud
"What is your opinion regarding the state of living shorelines in Eastern U.S. and New England?"


*Woods Hole Group, Appendix B, 2017.*

<u>Cover photo credits</u>
Center: Ranger Poole/USFWS, in Schottland et al., 2017, p. 124
Upper left: Robin Lubbock/WBUR, in Schottland et al., 2017, p. 122
Lower left: Massachusetts Audubon Society, 2018
Lower right: http://www.itv.com/news/channel/2018-01-03/jersey-sea-wall-collapses/

## Abstract

Sea level rise is accelerating along the northeast coast of the United States at a faster rate than in other parts of the country. More violent storms, flooding, and erosion are impacting the Massachusetts shoreline. As the Commonwealth considers coastal adaptation policies, state agencies declare a preference, where possible, for “green” strategies over “armoring” with hard structures such as seawalls, which can damage coastal ecosystems. One such softer strategy is known as “living shorelines,” techniques that use natural and biotic elements to stabilize the edges of salt marshes and other coastal areas in order to increase their resiliency against erosion. Salt marshes are critical buffer zones between the sea and the communities behind them and provide ecosystem services such as flood control. However, there is little actual action toward implementing these green engineered structures in the Commonwealth compared to some other Eastern states. This is due, in part, to an outdated Massachusetts regulatory framework that makes it difficult to get permits for coastal projects. This study compares the regulatory system in Massachusetts with that of Virginia, which has a progressive policy toward living shorelines. It found that in numbers of completed projects and in facilitative permitting systems, Virginia is more advanced than Massachusetts, and the use of living shorelines is well established. The Virginia policy framework offers a model for Massachusetts to adopt in order to incorporate living shorelines into the state’s coastal adaptation strategies. Specific recommendations are presented for streamlining the Massachusetts permitting system and for installing a central state agency specifically for oversight of coastal protection projects.

Acknowledgments

I thank Dr. Rick Wetzler and Dr. Mark Leighton for their guidance in making this project the best it could be. Thanks also to Marshall Spriggs for support, advice, and editing expertise.

I am grateful to all my fellow capstone students, whose encouraging words and shared efforts helped to keep my spirits up during the challenging process. It has been a privilege to participate in the experience with you and to have the opportunity to view your impressive work.

Finally, my deepest and most heartfelt thanks go to my husband and children. Steven, you are the most wonderful support and friend I could possibly have. Your unfailing encouragement, faith, patience, and counsel have been the foundation of my success and I could not be more fortunate to have you at my side. Thank you. To Emma and Lucas, your confidence in me, advice, and acceptance of my lifelong learning goals have warmed my heart and made me proud of the people you are.

## Table of Contents

List of Figures



List of Tables

# I. Introduction

The impacts of climate change, long supported by data trends and models, have become increasingly evident at the level of everyday experience for citizens living along the Atlantic coastline of the United States. Eroding beaches, higher tides, flooding basements, and storm damage to both infrastructure and natural systems have become commonplace. As sea levels rise, adaptation planning by government agencies is accelerating (Schottland et al., 2017).

Thus far, coastal adaptation approaches have diverged into two camps. The first category is known as armoring: constructing barricades such as sea walls and revetments -- historically the preferred "obvious" fix to protect against ocean forces (Bilkovic et al, 2016). The other approach, broadly known as green infrastructure or soft engineering (NOAA, 2015a), embraces the knowledge that natural ecosystems have adapted to handle the forces of nature efficiently and effectively, without the unintended consequences that can accompany human efforts. As adaptation planning continues, policy makers and coastal specialists are recognizing that both strategies have their place in different circumstances. For example, armoring is best suited to urban areas containing critical infrastructure, while soft-engineered approaches aim to stabilize eroding natural shorelines in places such as salt marshes (National Research Council, 2006).

Among soft engineering strategies, the concept of "living shorelines" has emerged as a coastal preservation tool that helps the shoreline adapt to sea level rise rather than resist it. The technique entails using natural materials to stabilize and build up eroding salt marsh edges with structures that can mitigate wave impacts and assist in the accumulation of sediment. These measures enhance the resiliency of coastal areas impacted by climate change.

Once undervalued, salt marshes now are recognized as a vital part of any healthy shoreline. They provide critical benefits for people and the environment, and they are the first line of defense for the communities behind them. Beyond its inherent beauty and its critical role in providing aquatic habitat, a tidal marsh has value as a buffer zone and as a sponge that absorbs both storm surge and flooding (NOAA, 2011).

Living shoreline techniques are gaining in acceptance, but have been more readily embraced in some areas than others (Bilkovic et al., 2017; Restore America's Estuaries, 2015). Studies have found that in some states a lack of a statewide supporting framework and confusing layers of regulation can impede the progress of implementing living shoreline projects. Proponents find the permitting system to be a barrier to accomplishing coastal protection goals using the more natural techniques (Bilkovic et al., 2017; O'Donnell, 2016; Restore America's Estuaries, 2015; Woods Hole Group, 2017).

The Commonwealth of Massachusetts has been particularly slow to adopt living shorelines as a form of coastal protection and as an aid to restoration (Woods Hole Group, 2017). Other Atlantic states such as Virginia are actively promoting the methods (Bilkovic et al., 2017). While living shoreline projects have proliferated in the Chesapeake Bay and Delaware Bay and are gaining traction on the New Jersey and New York coastlines (Bilkovic et al., 2017), they are rare in Massachusetts. This study examines the differences between Virginia and Massachusetts to discern how and why living shorelines are readily utilized in one state and not the other. Study objectives are to:

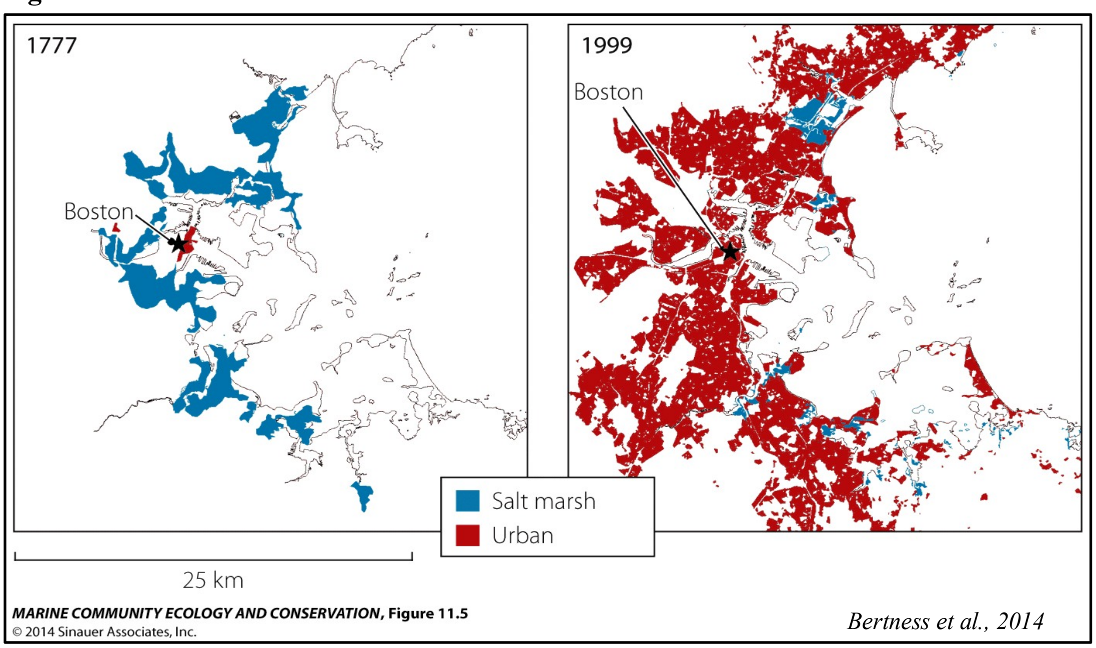
- Examine the current status of living shoreline projects in Massachusetts and in Virginia.
- Compare the permitting system in Massachusetts with that of Virginia.
- Present case studies from Massachusetts and Virginia and compare processes.
- Explore possible reasons for slow adoption of living shorelines in Massachusetts.
- Provide a road map for navigating the current Massachusetts permitting process.
- Lastly, and most importantly, this paper makes recommendations for improvement of the regulatory structure in Massachusetts in order to facilitate adoption of living shoreline techniques that can mitigate the impacts of rising sea levels.

# II. Context and Background

**<u>The Massachusetts Coastal Zone</u>**

The margin between land and sea has always been a dynamic, constantly shifting landscape, responding to impacts from ocean forces, weather, and geomorphic processes. Overlaying these natural changes, in the past four centuries coastal ecological habitats have been deteriorated by development. Wetlands were historically seen as not useful and, in fact, a soggy nuisance; they were considered to be breeding grounds for mosquitos, and improved if filled in, drained or diverted (Bertness, 2007). Thus, for example, the once vast estuary of the Charles, Mystic, Malden, Chelsea, and Bass Rivers now serves as the City of Boston. Since the 1700's, Massachusetts has lost 41% of its coastal salt marshes, 81% in Greater Boston alone (Figure 1). These losses are positively correlated with urban growth (Bromberg & Bertness, 2005).

**Figure 1. Salt Marsh Loss in Greater Boston Between 1777 and 1999**



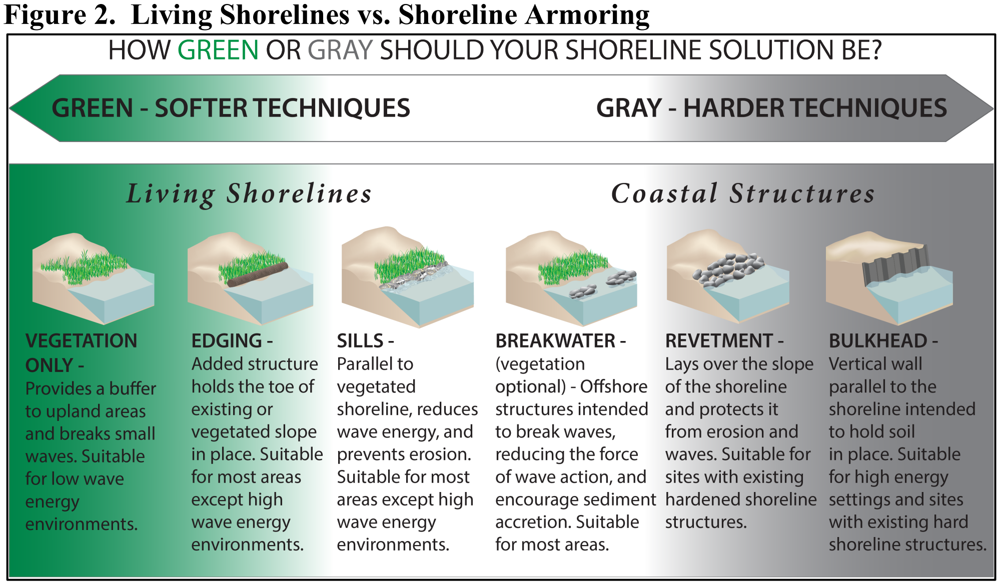

*Bertness et al., 2014*

But in recent years the rate of loss of beaches, dunes and salt marshes has hastened, primarily attributed to climate change (Roman, 2017). The Intergovernmental Panel on Climate Change (IPCC) predicts that "Coasts are projected to be exposed to increasing risks, including coastal erosion, due to climate change and sea level rise. The effect will be exacerbated by increasing human-induced pressures on coastal areas" (IPCC, 2007, p. 48). Sallenger et al. (2012) describe the U.S. Northeast as a "hotspot" of sea level rise (SLR), where levels from Cape Hatteras to Boston rose higher in the past 60 years than any other U.S. coast, and in some areas, three to four times higher than the global average. Sea levels are projected to rise from one to six feet in this century (Anderson & Barnett, 2017); climate change predictive models differ because the exact future concentrations of atmospheric $CO_2$ are as yet unknown.

## **Why Living Shorelines?**

In the face of climate change, new coastal protection strategies are being formulated by government agencies (Commonwealth of Massachusetts, 2011). Armoring in response to sea level rise continues, and the National Oceanic and Atmospheric Administration (NOAA, 2015a) estimates that a third of the U.S. coast will be hardened by the year 2100. But many coastal experts consider soft engineering to be a more sustainable, less damaging, and in the end less costly solution for protecting natural areas (Figure 2) (Bilkovic et al., 2016; CZM, 2011, p. 20).

**Figure 2. Living Shorelines vs. Shoreline Armoring**




https://www.habitatblueprint.noaa.gov/living-shorelines/

Hard structures can cause ecosystem harm over the long term. They interrupt the natural processes of coastal currents, biotic interactions, sediment transport and accumulation, and cause scouring of the seabed in surrounding areas as the water forces its way around a structure (Gittman et al., 2016; Restore America's Estuaries, 2015). Recent studies have demonstrated that the accumulated effects of coastal development and alterations of natural ecosystems can have far-reaching negative impacts to the natural functions and fauna of the shoreline systems, from the localized level to the broader watershed level (Bilkovic et al., 2016; Kornis et al., 2017).

Recognizing the ecologically degrading effects of sea walls has led to increased interest in preserving and restoring natural systems as an alternative (Bilkovic et al., 2017). Working *with* coastal dynamics enables the shoreline to adapt to rising sea levels, build up, and rally against erosive forces. Such efforts also maintain a buffer for the built environment on the landward side of the marsh.

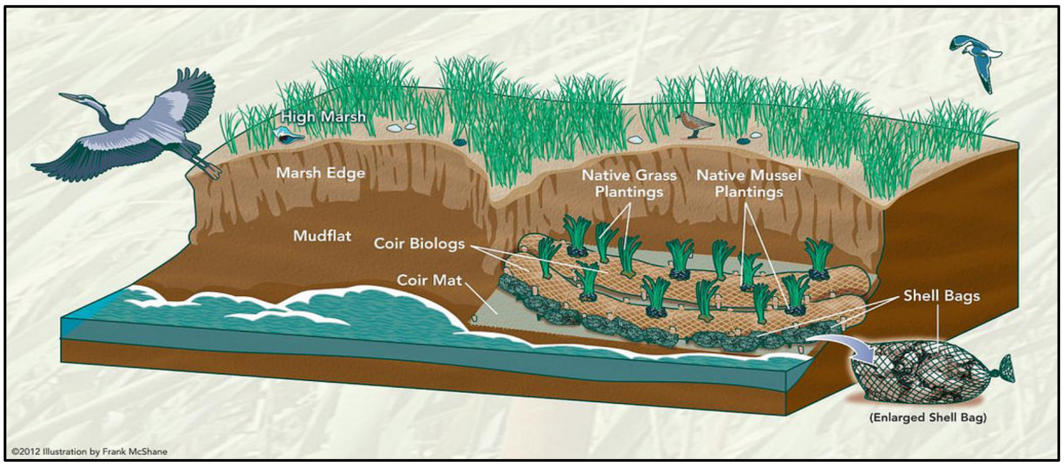
By stabilizing a marsh edge, a living shoreline structure helps a marsh to follow its natural progression of inland migration: as it accumulates sediment brought in by the tide and storms, it rises in elevation and builds layers of peat. New plants establish roots, and the deep root systems bind the layers together strongly, allowing the marsh to withstand greater storm surge. Where there is room to migrate, a marsh will slowly move landward as seas rise. Where there is not, a living shoreline-enhanced marsh can help forestall the worst effects of erosion and storm surge, while absorbing and releasing the more aggressive tides (Bertness, 2007; Roman, 2017).

## Living Shorelines Explained

A living shoreline structure stabilizes, protects, or enhances a marsh by the addition of biodegradable natural fiber rolls or tubes called coir logs, marsh plantings, fiber bags with oyster or mussel shell filler, rocky sills, and sometimes living shellfish. Ribbed mussels *(Geukensia* *demissa),* found in northern and Mid-Atlantic salt marsh edges, are sometimes seeded into a living shoreline (NOAA, 2015; Save the Bay, 2013). An example is shown in Figure 3.

The term covers a variety of categories, goals, and models, but in essence the phrase "living shoreline" conveys that, though humans initially engineer the structure, it will incorporate itself into the landscape over time. Each project is site-specific. Design and placement are determined by the individual location's characteristics, such as wave energy, wind direction, currents, rate of erosion, and sediment transport patterns (Bilkovic et al., 2017).

**Figure 3. Eroding Marsh Edge (left) and Living Shoreline Installation (right).**




*http://dnrec.maps.arcgis.com/apps/MapJournal/index.html?appid=371a244682084370a78d0a54c5edb27a*

Living shorelines also can be called vegetative stabilization or bioengineering (Duhring, 2014). Under the broadest definition, methods also can include beach nourishment, dune restoration, and rocky sills for additional support. A "living breakwater" – an engineered oyster or mussel reef -- is another technique that can be used alone or in tandem with other components (NOAA, 2015a). In Virginia and other states, a distinction is made between installations that are non-structural (focused on vegetation and biodegradable materials) or hybrid (including hard supporting structures) (Duhring, 2014).

Living breakwaters generally consist of live Eastern oyster (*Crassostrea virginica*) or blue mussel (*Mytilus edulis*) reefs, and have multiple benefits. Adult oysters and mussels congregate in beds, attaching to each other or to other hard substrates, creating cement-like masses that effectively deflect wave energy before it hits the shore. As shellfish are efficient water filterers, auxiliary benefits are improved water quality in the reef's perimeter, and sequestration of excess nitrogen from runoff. A reef also provides habitat for invertebrates and fishes (Bertness, 2007).

## Salt Marsh Benefits and Economic Value

The salt marsh environment is complex, with habitat zones determined by how often and to what extent the marsh is covered by the tides. The low marsh, inundated daily at high tides, is more saline; the high marsh is inundated only about twice a month, at the highest tides. Specific salt-tolerant (halophytic) plants typically occupy the zones, each species adapted to differing flood and salinity patterns (Bertness, 2007; NOAA, 2017a).

### Ecosystem Services

The ecosystem services provided by salt marshes are well documented, and summarized in Table 1. Globally, marshes rival coral reefs and tropical forests in their productivity (Bromberg and Bertness, 2005). Coastal wetlands are a rich habitat supporting a biodiverse and complex web of life. Marsh waters are nursery for 75% of finfish and shellfish species worldwide, providing shelter and food for their larval stages (NOAA, 2017b). It has been shown that the abundance and diversity of fish and shellfish increases in coastal wetlands and decreases around hardened shorelines (Kornis et al., 2017). Marshes also perform mitigation functions: NOAA (n.d.b) estimates that one square mile of marsh sequesters 76,000 gallons of $CO_2e$ annually. Marshes also absorb and cycle eutrophication-causing excess nitrogen.

The ability to absorb floodwaters and tides, then slowly release them, may be one of the more critical services that salt marshes provide today. For populated coasts, efficient handling of high volumes of saltwater, rainwater, and runoff has become even more important. Fifteen feet of marsh edge also can absorb up to half the impact of storm wave energy (NOAA, n.d.b).

**Table 1. Salt Marsh Ecosystem Services**

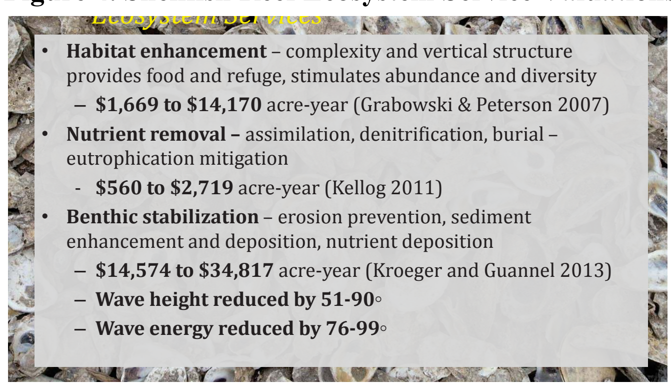
| | |
|---|---|
| Coastal zone buffer | Protects human habitation behind marsh from storm damage |
| Flood control | Absorbs ocean surge and upland stormwater runoff |
| Habitat for biodiversity | Encompasses diverse, complex ecosystem |
| Fisheries support | Provides "nursery" protection & food for larvae and young |
| Improved water quality | Filters and cleans coastal water pollutants |
| Excess nutrient mitigation | Sequesters and metabolizes nitrogen, phosphorus, sulfur |
| Sediment cycling | Maintains natural sediment transport coastal dynamics |
| Climate change mitigation | Sequesters and cycles atmospheric $CO_2$ |
| Waste processing | Soil microbes process organic/inorganic waste |
| Recreation and study | Provides opportunities for fishing, boating, shellfishing, bird watching, and research |

*Bertness, 2007; Woods Hole Group, 2017*

## Economic Value of Salt Marsh Services

Attempts have been made to place a monetary value on these ecosystem services. The U.S. Army Corps of Engineers, for example, calculated that the Charles River wetlands in 2003 provided $40 million worth of flood control. In 2010, New Bedford and Gloucester's commercial fisheries gathered $346 million in profits (Commonwealth of Massachusetts, 2011), thanks in part to estuarine nursery benefits. Almost 30 years ago, Costanza et al. (1989) valued an acre of Louisiana wetlands at between $2,400 and $17,000 (while acknowledging the considerable drawbacks of uncertainties in the valuations). Grabowski et al. (2012) calculated the ecosystem value of oyster reefs at between $10,000 - $99,000 per hectare, per year, not including the values of carbon sequestration and

**Figure 4. Shellfish Reef Ecosystem Service Valuations**




*Brown et al., 2014.*

enhanced biodiversity. Brown et al. (2014), of the Nature Conservancy in Rhode Island, broke this down further, as outlined in Figure 4. Barbier et al. (2011) explore wetlands valuation in great detail.

**Late to the Table**

The Massachusetts government has stated that the inclusion of green infrastructure and habitat restoration are among its goals for coastal adaptation strategies (Commonwealth of Massachusetts, 2011). Yet there has been little action. Public awareness can perhaps be summed up by a 2017 headline in the Everett Independent newspaper: "Wynn Begins Work on Living Shoreline, But What Is a Living Shoreline?" (Daniel, 2017).

A Woods Hole Group (2017) analysis of the state of living shoreline use in New England concluded that one of the factors contributing to the lack of movement is the lack of precedents. Not enough projects have been implemented and monitored for state agencies to assess performance metrics and success rates in the New England environment. This produces a Catch-22 situation: for lack of local long-term scientific studies that demonstrate results and open new areas of study, regulators and practitioners are reluctant to take risks and implement projects, which would enable long-term studies.

Despite challenges, the potential benefits of using green infrastructure to assist marsh resiliency make living shorelines worthy of stronger support by the Commonwealth. Massachusetts must provide a more positive, predictable, and less frustrating regulatory framework, making it easier to get living shoreline projects permitted. Doing so would remove existing barriers and incentivize their use (Bilkovic et al., 2017; Restore America's Estuaries, 2015; O'Donnell, 2016). Coastal resilience is an important component of meeting the challenges posed by climate change along our coast.

# III. Methods

This study required examination of these principle questions:

(1) What is the status of living shoreline practice in Massachusetts? More precisely, how many projects exist or are planned?
(2) What are the regulations and permits required to implement a living shoreline project?
(3) In regard to state of the practice and the regulatory landscape, how does Massachusetts compare to another Atlantic coastal state that strongly supports the use of living shorelines?
(4) What are the main challenges to increasing the implementation of living shoreline strategies in Massachusetts?

All these questions required a clarification of terminology and identification of boundaries, presented below. The first and third questions required that metrics of measurement be established by which to present the status of living shoreline projects, and for a basis of comparison. Research studies, public presentations, and documents containing technical guidance on living shorelines were consulted in order to reveal trends in the practice and current work in the field. Government documents and websites, studies of living shoreline practices, and guidance documents provided regulatory and permitting structures. Conversations with stakeholders filled in gaps in information. Attitudes toward living shorelines in Massachusetts and other states were derived from published documents and personal communications.

The study was developed with the hope of creating a useful document for practitioners in the field and regulators who seek to improve the current regulatory structure in Massachusetts.

## **Definitions and Terminology Used**

Terminology concerning living shorelines varies according to location and source (Pilkey et al., 2012). For this study, the NOAA definition of a living shoreline was used, as follows:

> "Living shoreline is a broad term that encompasses a range of shoreline stabilization techniques along estuaries, bays, tributaries, and other sheltered shorelines.... A living shoreline has a footprint that is made up mostly of native material. It incorporates natural

> vegetation or other living, natural soft elements alone or in combination with some type of harder shoreline structure, like oyster reefs, rock sills, or anchored large wood for added stability. Living shorelines connect the land and water to stabilize the shoreline, reduce erosion, and provide ecosystem services, like valuable habitat, that enhances coastal resilience." (NOAA, n.d.b)

For consistency in this study, three types of living shorelines and their definitions were taken from a study of living shoreline practice in New England, performed by the private consulting firm Woods Hole Group (2017). These are presented below in Table 2, along with the components typically associated with each. Often these three categories overlap in practice.

**Table 2. Living Shoreline Categories Addressed in This Study**

| Category | Typical Components | Typical Goal |
|---|---|---|
| Coastal bank protection | • Coir logs, bags, or blankets of natural biodegradable fabrics<br>• Shells<br>• Native plantings<br>• Rock sill | • Shoreline stabilization<br>• Erosion mitigation<br>• SLR protection |
| Marsh creation/enhancement | • Coir logs, bags, or blankets of natural biodegradable fabrics<br>• Shells<br>• Native plantings<br>• Rock sill<br>• Sediment | • Sedimentation/accretion<br>• Shoreline stabilization<br>• Flood/surge control<br>• Wave energy dissipation<br>• Buffer creation<br>• Habitat enhancement<br>• Water quality enhancement |
| Living breakwater | • Oyster or mussel reef<br>• Reef balls | • Wave energy dissipation<br>• Water quality enhancement<br>• Habitat and biodiversity enhancement |

*Woods Hole Group, 2017*

## <u>Metrics of Measurement and Sources of Data</u>

In this study, a "successful" living shoreline project is one that has been permitted or granted a license by the required regulatory agencies, and either has been constructed or is in the final permitting phases before construction. Therefore the most direct approach to gauge success was to collect data on numbers of permits issued to living shoreline projects. (Although true success for a living shoreline project is perhaps better measured with longevity of the construction and growth of its live components, the dearth of projects in Massachusetts makes such measures unavailable.)

However, aggregate data for living shoreline projects in Massachusetts does not exist. Extensive online searches yielded nothing, and the Massachusetts Department of Environmental Protection's (MassDEP) Office of Permitting confirmed that there is no database or tracking mechanism (K. Kerrigan, personal communication, March 19, 2018). In the absence of numeric data, information was researched from a combination of white papers (e.g. Woods Hole Group, 2017); project funding websites (e.g. NOAA, 2015b); conversations with coastal adaptation specialists from state agencies, nonprofits, and ecological restoration firms; and news articles. The results of this compilation, therefore, can be considered broadly representative of the state of the practice rather than an all-inclusive enumeration.

Comparative data for the state of Virginia was accessible through the Virginia Marine Resources Commission website, which features a comprehensive database of Habitat Management permits (VMRC, 2018b).

Studies on the subject of living shorelines in general, and in Massachusetts and Virginia in particular, provided support for the results and discussion of the data. A review of the contemporary scientific literature on salt marsh studies, living shorelines, and other documents was limited to the years 2005-2018 in order to obtain the most current information.

**State Comparison Methodology**

For the basis of the comparison study, other Atlantic coastal states with which to potentially compare Massachusetts were selected from the literature. Maryland, Virginia, and Delaware were the most-often cited states that are progressive about incorporating living shorelines in their coastal adaptation policy (e.g. Bilkovic et al., 2017; Save the Bay, 2013;

Restore America's Estuaries, 2015). Bilkovic et al., in their comprehensive evaluation of living shoreline development worldwide (*Living Shorelines: The Science and Management of Nature-Based Coastal Protection*, 2017), cite Virginia and Maryland most often as the U.S. states that have gone farthest in developing policy to promote living shorelines. Maryland passed legislation in 2008, the Living Shorelines Protection Act, establishing the state policy that living shorelines and "nonstructural shoreline stabilization measures" are the preferred approach to shoreline protection and erosion control. In 2011, Virginia passed the Living Shoreline Act with similar goals (Bilkovic et al., 2017, p. 46). However, examination of the two states' websites revealed that Virginia has the more centralized and organized repository of information in support of living shoreline use, and a more streamlined permitting process specifically for living shorelines (Maryland Department of the Environment, 2018; VIMS, 2018; VMRC, 2018a). Therefore, Virginia was selected for comparison with the Massachusetts regulatory landscape.

**Limitations to the Data and Boundaries**

Because information was not available for living shoreline projects on private property in Massachusetts, cataloging the number of permitted projects in that state focused on publicly-funded installations. (It is probable, however, that there are more installations on private property than on public property, according to environmental engineering firms that work on living shorelines [E. Leduc, personal communication, February 26, 2018; S. Wilkinson, personal communication, March 18, 2018]). Case studies in both Massachusetts and Virginia were selected from public projects, also because of this limitation to the data.

Areas of habitat focus were constrained to coastal salt marsh environments because they are generally located in sheltered, low wave energy areas that are most suitable for the type of living shoreline strategies considered here (Bilkovic et al., 2016). Dune and beach restoration --

coastal stabilization actions that are sometimes grouped under the umbrella term "living shorelines" -- were excluded from the study for several reasons. Such habitats are not part of the salt marsh environment; do not require the kinds of interventions described in this study; and are not as closely identified with coastal resilience as are salt marshes. Indeed, they have achieved more acceptance in practice and use than the salt marsh and living breakwater categories (S. Wilkinson, personal communication, March 18, 2018), and so may be ill suited to a discussion of regulatory barriers.

Regulatory boundaries encompass three overlapping layers of jurisdiction: local, state, and federal. Local municipalities are responsible for actions in wetlands under the federal Wetlands Protection Act, other environmental protections, local planning, and zoning bylaws. Massachusetts state jurisdiction runs from three miles offshore to mean low water (MLW) in the tidal zone. (In some states the boundary is mean high water.) Federal jurisdiction includes "navigable waters of the U.S.," for which the U.S. Army Corps of Engineers is responsible under the Clean Water Act (Bilkovic et al., 2017: Restore America's Estuaries, 2015).

**Interview Methodology**

Interviews by email or telephone were conducted in order to gain rapid entry to the Massachusetts regulatory landscape. These conversations clarified how some processes work in practice and where further information could be found. Typical interview questions were:

- What role does your agency play in the permitting process for living shorelines?
- What are the steps involved in the process and what is the usual timeline?
- How many projects have you worked on, and are you involved with any currently?
- Where can I find more information about the project/regulation/status?

**Methodology for Selecting Case Studies**

Three sample projects were used to illustrate the differences between the Massachusetts and Virginia regulatory processes, differences in project scale, and timelines from initiation to completion. The case studies also illustrate different elements of site selection and project design. The two Massachusetts projects were self-selected because (a) data on private projects is inaccessible, therefore public projects became the focus, (b) known public projects in the state amounted to three, and (c) the third public project, Wellfleet, does not demonstrate a clear-cut living shoreline design and goal (Flaherty, 2011).

The first case study, the Felix Neck project, is on the island of Martha's Vineyard off the state's southern coast, and was referred to me by a practitioner of a restoration pilot project. It was a worthy case study subject because it is considered to be the largest established living shoreline project in the state (Schoell et al., 2016); additionally it incorporates an ambitious number of goals and components, and is located in an unusually high wave energy zone.

The second subject, Collins Cove in Salem, was referred to me by Coastal Zone Management's North Shore Regional Coordinator. The Coordinator cited it as the only living shoreline project CZM is currently working on in that region. In contrast to the Felix Neck project, it represents a relatively simple design and site, and it therefore provides an alternative set of parameters.

The Virginia sample project was selected by utilizing the permit search function of the Virginia Marine Resources Commission (2018b) and sifting for public projects. To stay within the same general five–year time period of the Massachusetts case studies, the search encompassed January 1, 2013 to March 30, 2018. Of the 273 permitted projects utilizing living shoreline components, 18 were in the public realm. Those that included beach nourishment or hard structures were not included in search criteria. The City of Norfolk Beach Avenue project was selected as closest in intent to that of the Massachusetts sites, with goals of marsh enhancement and erosion protection, and therefore considered comparable. It also is an example of a permit acquired under the state's new streamlined permitting structure, making it particularly appropriate for this study's regulatory focus.

**Regulations and Permitting**

Information about the current regulatory structures for living shorelines in Massachusetts and Virginia was collected from state agency websites, governmental and nongovernmental guidance documents, presentations, and academic sources. Clarification of some points was sometimes sought through communication with employees of the regulatory agencies via email or telephone.

# IV. Results

## Introduction

Gathering data for existing living shoreline projects in Massachusetts was extremely difficult, while data in Virginia was relatively accessible. Thus, while the resulting data does not provide a robust basis for comparison of the two states, it does highlight the significant differences in state-of-the-practice between them. Likewise, straightforward descriptions of the permitting process for living shoreline projects are well documented in Virginia, but are essentially nonexistent in Massachusetts. Key findings are: (1) Since Virginia enacted a Living Shoreline Act in 2011 (Senate Bill 964), and its "Living Shoreline Group 1 General Permit for Certain Living Shoreline Treatments Involving Tidal Wetlands" in 2015 (VMRC, 2015), the number of living shoreline projects has risen in the state. (2) Massachusetts has yet to officially recognize living shorelines as a category of coastal restoration, and the permit process, which applies to any type of project that alters the coastal zone, is complex and time-consuming.

## Number of Living Shorelines Projects in Massachusetts vs. Virginia

### Massachusetts

Web searches and individual interviews yielded only three public living shoreline projects in Massachusetts. These appear in Table 3, along with four privately-funded development projects in the Boston area that have a living shoreline and public space component. Environmental engineers who work on living shorelines reported the existence of many more private projects, but these are difficult to enumerate for privacy reasons and thus are not included in this study (S. Wilkinson, personal communication, March 18, 2018; M. DeRosa, personal communication, March 26, 2018).

**Table 3. Known Public and Private/Public Living Shorelines in Massachusetts**

| | *Public* | *Stage as of March 2018* | *Components* | *Goal* |
|---|---|---|---|---|
| 1 | Wellfleet | Complete, in monitoring and adaptive management | Shellfish reef | Nitrogen mitigation, breakwater |
| 2 | Edgartown | Complete, in monitoring and adaptive management | Coir logs, marsh grass, ribbed mussels | Shoreline erosion mitigation |
| 3 | Salem | In permit process | Coir logs, marsh grass plantings, rocky sill | Erosion mitigation, storm surge protection |
| | *Private/Public* | | | |
| 4 | Boston, Wynn Casino | Permitted, in process | Marsh grass plantings, coir logs, sand fill | Marsh & beach restoration, flood & storm surge protection |
| 5 | E. Boston, Clippership Wharf development | Permitted, in process | Marsh grass plantings, rocky sill | Storm surge protection, flood control, stormwater pollution mitigation |
| 6 | E. Boston, 99 Sumner Street development | Concept | Marsh grass plantings? | Storm surge and flood protection |
| 7 | Dorchester Port Norfolk Park development | Concept | Marsh grass plantings? | Storm surge and flood protection |

It must be noted that the Massachusetts Department of Environmental Protection (MassDEP) website does have a search function for filed Notices of Intent under the Wetlands Protection Act, "Wetlands NOI Projects," which are required filings for living shorelines (Commonwealth of Massachusetts, 2017). However, results are extremely generalized. For example it is not possible to break down a town search result into specific categories of projects, which could entail anything from swimming pools to boat ramps.

Other Sources of Information on Massachusetts Living Shorelines. The paucity of completed projects does not reflect a lack of interest among coastal restoration proponents in New England. Websites and white papers of state and regional NGOs such as Restore American's Estuaries, the Ipswich River Watershed Association, the MassBays Estuary Program, The Nature Conservancy, the National Wildlife Federation, and the Great Marsh Coalition include strong endorsements of living shorelines in salt marsh preservation efforts.

Some Massachusetts state websites reveal potential public coastal restoration projects that have received funding and may lead to living shoreline projects. Massachusetts' Coastal Zone Management Office's "StormSmart" Program provides lists of each year's Coastal Resilience Grants (Commonwealth of Massachusetts, 2018b). The summaries for fiscal years 2017 and 2018 contain a total of 35 funded projects, of which nine are salt marsh related. Ten are related to beach and dune nourishment. Of the marsh-related living shoreline grants, only one, the Salem Collins Cove project, is permitted at this stage. The balance of the grants are for vulnerability studies and assessments of adaptation actions needed in the future.

## Virginia

The website of the Virginia Marine Resources Commission (VMRC) features a comprehensive database of Habitat Management permits, with searchable categories for 16 types of shoreline alteration, including "Living Shorelines," and the ability to search by date (VMRC, 2018b). Each permit record includes the applicant's name, links to the original application, engineering design plans, map location, and all supplemental materials.

A search for "issued" permits for any category containing the words "Living Shorelines" between January 1, 2013 and March 30, 2018 yields 273 results (Table 4). Of the 273, 18 appear to be public projects, the rest on private property. Most are hybrid designs, incorporating both hard structures such as riprap and also biotic elements such as marsh grass and coir logs.

**Table 4. Summary of Virginia Living Shoreline Permits 1/1/13 – 3/30/18**

| | Permitted | Permitted - Refined search | Pending | Denied |
|---|---|---|---|---|
| All Living Shoreline Permits | 273 (18 public) | | 12 | 0 |
| LS + Bio Structure | | 12 | | |
| LS + Breakwater Structure | | 6 | | |
| LS + Coir Structure | | 32 | | |
| LS + Fill Plant Structure | | 62 | | |
| LS + Marsh Toe Structure | | 56 | | |
| LS + Sill | | 149 | | |
| *Public Demonstration Projects* | 16 | | | |

https://webapps.mrc.virginia.gov/public/habitat/

The data can be broken down further. "Pending" permits for living shoreline projects for the five-year period yielded 12 results, all initiated in 2018. Indicating the speed with which the permit process can be negotiated, all permit requests from 2017 were granted within 2-3 months.

Interestingly, and perhaps tellingly as an indicator of an expedited process, a search for denied permits containing the words "Living Shoreline" during the five years yielded 0 results.

A more refined search for permitted "Living Shorelines" with "Bio Structure" yields 12 results. A typical example involved removing a concrete edge, replacing it with a riprap sill, and installing a coir log, sand fill, and marsh grass plantings. Other database search terms that are associated with Living Shoreline include Breakwater Structure, Coir Structure, Fill Plant Structure, Marsh Toe Structure, and Sill. These breakdowns are summarized in Table 4.

The Virginia Institute of Marine Science. VIMS, at the College of William & Mary, has developed 16 Living Shoreline Demonstration Sites throughout the state (as of 2014). These are in addition to other projects in the public sector. Demonstrating living shoreline practices with configurations of elements that are suitable to each site, they are complex installations that are open to the public and include educational programs (VIMS, n.d.). Many of them were funded in part by NOAA's Restoration Center under the Community-Based Restoration Program (NOAA, n.d.a).

Combining the numbers provided by VMRC and VIMS, it can be concluded that there are at least 34 public living shoreline projects in Virginia, and in the last five years about 255 private installations have been permitted.

**Regulatory Structure and Permitting in Massachusetts**

Table 5 below summarizes the regulations, agencies, and permits involved in the approval process for all projects in the Commonwealth's coastal zone. Three levels of jurisdiction apply -- local, state, and federal – and each agency follows its own process. Each agency's application process includes public comment periods and often-lengthy reviews; some timelines overlap.

Starting at the municipal level, it must be determined whether the project site is protected under the Wetlands Protection Act; a Request for Determination (RFD) is filed with the local Conservation Commission. Next, an Environmental Notification Form (ENF) is filed with the state office overseeing the Environmental Protection Act. A Notice of Intent (NOI) goes to the MassDEP. If a permit (the OOC, or Order of Conditions), is issued, the applicant moves on to state and federal applications and reviews. Details are in Table 5 below and Appendix D, p. 47.

In addition, the Massachusetts Office of Coastal Zone Management (CZM), an advisory rather than a permitting agency, performs a Federal Consistency Review to ensure that federal laws are in line with the project. The U.S. Army Corps of Engineers (USACE) also oversees a separate process at the federal level, under the Clean Water Act.

The entire permitting process can take from one to two years. According to a CZM coordinator, simply gathering required filing documents can take months (K. Glenn, personal communication, February 9, 2018). The combined steps of planning, designing, permitting, and executing can take years for a single project of modest size (P. Phippen, personal communication, January 31, 2018).

A graphic of the permitting processes, the "Roadmap," is presented in Appendix D (page 47). It can be used as a visual guideline for practitioners, while illustrating the complexity of what they can expect when seeking permitting for living shorelines in the Commonwealth.

**Table 5. Massachusetts Regulatory Structure for Coastal Projects**

| Governing Regulation | Purpose | Agency(ies) responsible | Form/Permit/Review | Purpose/Intent |
|---|---|---|---|---|
| | | | | |
| **Local and state** | | | | |
| Town regulations and by-laws | | Town Planning Board, Conservation Commission, Zoning Board | | |
| | | | | |
| Massachusetts Wetlands Protection Act (WPA) (MGL c.131 Section 40) | Protects water supplies, land containing shellfish,wildlife and fisheries habitat. Regulates flood control, storm damage prevention, pollution prevention. | Local level: Conservation Commission<br>State Level: MassDEP | 1.Request for Determination of Applicability (RDA),<br>2. Notice of Intent (NOI),<br>3.Order of Conditions (OOC) | 1. To determine whether the project is subject to Wetlands regulations<br>2.To inform ConComm & MassDEP of project<br>3.To permit the activity, usu. with conditions attached |
| Massachusetts Environmental Policy Act (MEPA) 301 CMR 11.00 | Requires all state agencies to minimize damage to the environment | MEPA office and MassDEP | Environmental Notification Form (ENF) | Applies to projects above a certain size or that trigger certain MEPA "thresholds", e.g. aleration of more than 1/2 acre of wetland. Also projects which require "state action," e.g. need permit or receiving state funding. |
| Coastal Zone Management Act | | MA Office of CZM | Federal Consistency Review | To ensure federal permits, if required, align with state policies. |
| Chapter 91 (Mass Public Waterfront Act) | Preserve the Public Trust Doctrine from MLW to 3-mile territorial limit | MassDEP Waterways Regulation Program | Water-dependent license. One or more Applications depending on project details. | Regulates new or change in structures, fill, dredging. |
| **Federal** | | | | |
| Clean Water Act, Section 10/404 | Protects salt marsh wetlands from dredging or filling in navigable U.S. waters, below high tide line | USACE New England regional office | Self-Verification Notification Form (SVNF) **OR** Pre-Construction Notification Form (PCN) in order to qualify for Massachusetts ACE General Permit 7 (Bank and Shoreline Stabilization) **OR** 22 (Habitat Restoration, Establishment and Enhancement Activities) | Construction and maintenance of living shorelines, to maintain land/water continuity, and "retain or enhance shoreline ecological processes." |
| Federal Consistency Review | Ensure project is consistent with federal regulations | MA CZM | No permits required. | If CZM sees issues, comments to other agencies. |
| U.S. Coastal Zone Management Act | Encourages states to adopt state legal actions to enforce coastal zone management policies. | On federal level, overseen by NOAA. State level, see Coastal Zone Management Act above | | Voluntary federal law. Operates through incentives to states. Fed agency agrees to be consistent with state's programs and not override them. |

| | | | | |
|---|---|---|---|---|
| **Regs & Agencies that may possibly apply in certain situations:** | | | | |
| Endangered Species Act, MA Endangered Species Program | Protect endangered species & critical habitat | US Fish and Wildlife Service (USFWS) (under US Dept of Interior) and National Marine Fisheries Service (NMFS) (under NOAA) | | |
| Magnusen-Stevens Act | Protects essential fish habitat | NMFS, NOAA | | |
| Marine Mammal Protection Act | Protects marine mammals of concern | | | |
| National Heritage and Endangered Species Prog. | Protects rare species | MA Division of Fisheries and Wildlife | | |
| National Historic Preservation Act: | Protects historic resources | | | |
| State Historic Preservation Office (SHPO) | | | | |
| Mass. Board of Underwater Archaeol.Resources | | | | |
| Tribal Historic Preservation Officers | | | | |
| | | | | |
| **Advisory roles** | | | | |
| Local Conservation Commission | | | | |
| MA Division of Marine Fisheries | Manages marine fisheries under General Laws of the Commonwealth | | | |
| NOAA | Supporting documentation required if NOAA funding is used. | | | |
| CZM | Supporting documentation required if CZM funding is used. | | | |

*Sources: BeatNews.org, n.d.; Bilkovic et al., 2017; Commonwealth of MA, 2018a; Commonwealth of MA, 2018c; Commonwealth of MA, 2018d; USACE, n.d.; USACE, 2015; USACE, 2017; Massachusetts Office of Coastal Zone Management, 2011; MassDEP website.*

## Regulatory Structure and Permitting in Virginia

The Virginia regulations for living shorelines are condensed in comparison with Massachusetts. Expedited permits are granted on the local/state and federal levels, accessed through joint applications that simultaneously go to local and state agencies as well as the U.S. Army Corps of Engineers (USACE). Enabling legislation, the Living Shorelines Act of 2011 with 2015 amendments, resulted in rapid enactment of regulatory structures for two general categories of living shorelines: those in tidal wetlands alone, and those involving submerged lands, dunes or beaches (VIMS, 2018; VMRC, 2018a).

Of particular interest is the centralization of authority. The Virginia Marine Resources Commission (VMRC) is the primary state agency overseeing permit applications, which are filed with the VMRC and then distributed to the proper agencies. The state also allows use of the USACE recently-completed expedited Nationwide Permit 54 for Living Shorelines,

Table 6 summarizes the Virginia structure.

**Table 6. Virginia Regulatory Structure for Living Shorelines**

| **Governing Regulaton** | **Purpose** | **Agency(ies) responsible** | **Form/Permit/Review** | **Purpose/Intent** | **Notes** |
|---|---|---|---|---|---|
| | | | | | |
| **State Legislation** | | | | | |
| Living Shorelines Act (SB 964) 2011 & 2015 Amendment | Encourage use of LS, provide regulatory structure | Virginia Marine Resources Commission and local wetlands board | Group 1 and Group 2 General Permits | Authorizes use of natural elements, oysters, ribbed mussels as components | |
| **Joint Local, State, Federal Permits** | | | | | |
| Group 1 General Permit Authorization | Provide streamlined process for **LS in tidal wetlands** | Local Wetlands Board, Virginia Marine Resources Commission, Virginia Dept. Environmental Quality, USACE | Joint Permit Application | To qualify applicant for Group 1 General Permit. Submitted to VMRC, which forwards applic to ACE, local wetlands board, and DEQ | "No public interest review or notification of adjoining property owners shall be required and there shall be no application processing fee or permit fee." |
| Group 2 General Permit Authorization | Provide streamlined process for **LS in submerged lands, tidal wetlands, or coastal primary sand dunes and beaches** | same as above | Joint Permit Application | To qualify applicant for Group 2 General Permit. Otherwise same as above. | Requires notification of abutters |
| Chesapeake Bay Preservation Act | Protect Resource Protection Areas of "Tidewater Virginia" | Local government reviews project for compliance with land disturbance/ development guidelines | Local permit | Applies specific local criteria as detemined by town to comply with Bay Act | Utilizes Appendix C of Joint Permit App. Applicant is responsible for contacting local government |
| **Federal** | | | | | |
| Clean Water Act, Section 10/404 | Protects salt marsh wetlands from dredging or filling in navigable U.S. waters, below high tide line | USACE Norfolk District regional office | Nationwide General Permit 54 | Expedited process for Living Shorelines in sheltered waters | Sets conditions for siting and to foster success, avoid adverse outcomes. Defines terms. |
| Clean Water Act, Section 10/404 | same as above | USACE Norfolk District regional office | Nationwide General Permit 13 | Expedited process for Living Shorelines for bank stabilization | same as above |

*Sources: Hardaway et al., 2017; VMRC, 2015; VMRC, 2017; VIMS, 2018; USACE, 2016*

Providing the legal basis for the legislation, the Code of Virginia specifies the legal definition for what living shorelines are and defines the approaches and categories (Duhring, 2014; VIMS, 2018):

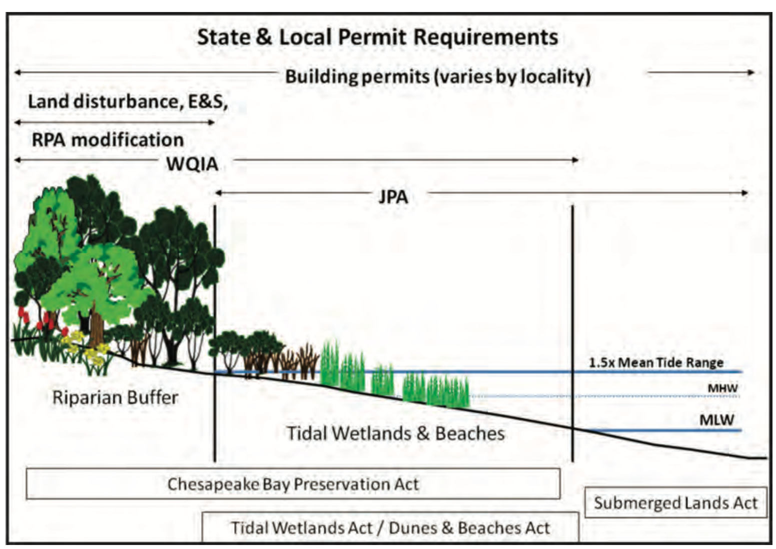
> "Living shoreline" means a shoreline management practice that provides erosion control and water quality benefits; protects, restores or enhances natural shoreline habitat; and maintains coastal processes through the strategic placement of plants, stone, sand fill, and other structural and organic materials.

The enabling legislation, the Virginia Living Shorelines Act (Senate Bill 964), passed initially in 2011 and contained these highlights (Bilkovic et al., 2017, p. 46):

- States that living shoreline methods are the preferred alternative for shore stabilization
- Calls for improved guidance and administrative process
- Authorizes development of a General Permit to expedite permit issuance
- Requires Marine Resources Commission and Dept. of Conservation and Recreation to work with the Virginia Institute of Marine Science (VIMS) to develop the permit and guidelines

In 2015, the Living Shorelines Act was amended to include the new general permit format. Virginia has also made efforts to incentivize the use of living shorelines for homeowners by providing them with cost comparisons between living shorelines and hard structures.

**Figure 5. Virginia Shore Zone Habitats and Related Permitting**




*Hardaway et al., 2017*

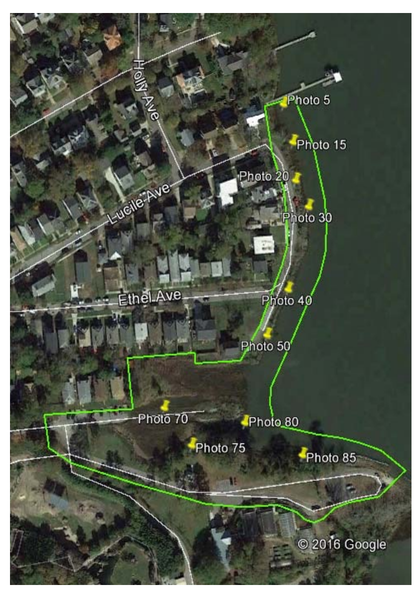
## **Case Studies**

Full case study details are in Appendices A, B, and C. For comparison purposes, the chart below highlights the features of each that illustrate their differences.

| | **Salem, MA** | **Edgartown, MA** | **Norfolk, VA** |
|---|---|---|---|
| Goal | Storm surge mitigation, protect public walking path and homes, marsh enhancement | Erosion control, shoreline stabilization, marsh preservation, research | Shoreline restoration, tidal wetlands restoration and enhancement, coastal resilience |
| Description | Along shore of residential-lined cove, install bioengineered shoreline stabilization and erosion control with fringing salt marsh restoration. | Along eroding edge of coastal pond salt marsh, bioengineered shoreline stabilization and erosion control, experimental model. | Bioengineered shoreline stabilization and erosion control along residential area and public park. Tidal river estuary near southern end Chesapeake Bay. |
| Components | Double row of coir fiber log, in 10 segments; sand fill, marsh grass plantings, high marsh species plantings, rock sill (existing, mid-tide line) | Double 10-foot rows of coir coconut-fiber log, in arcing pattern, marsh grass plantings, biodegradable burlap sacks containing local oyster and quahog shells, wooden stakes | Coir logs, rocky sill, sill fill, oyster bags, oyster shells, tidal marsh plantings |
| Size | 76 feet length, 0.88 acres | 3 site areas, each approx.100 feet long, totaling approx. 300 feet. 3 control sites | 1,202 linear feet of bioengineered structure, 0.81 acres restored wetland, 0.22 acre oyster reef creation |
| Timeline | 2014-2017: Planning, funding, design<br>2017-2018: Permitting<br>2019: Anticipated construction | 2015: Conservation Commission determined only local permitting required.<br>2015-16: project planning, partner engagement, design<br>2016: Construction | 2016, Nov.18: applic. submitted<br>2017, March 10: Permit granted<br>2018, January: Estimated completion |

*Salem Conservation Commission, 2017*

*Massachusetts Audubon, 2018*




*VMRC, 2018b, Application #1860*

# V. Discussion

Discussion of the results of the comparisons between Massachusetts and Virginia, and their implications for living shoreline proponents, focuses on the differences between the two states, and what challenges exist for living shorelines in Massachusetts.

**Comparison of Massachusetts' and Virginia's Living Shoreline Inventories**

The fact that there is no comprehensive or concentrated record of living shoreline projects in the Commonwealth seems to confirm the premise that, despite state government's goals of promoting this type of coastal adaptation, the practice is not supported in action.

Virginia is clearly ahead of Massachusetts in its public acceptance of living shoreline techniques, and in their permitting, regulatory, and support structures. Virginia's streamlined permitting process should not be interpreted as being lenient on regulations and requirements, however. Each permit process outlined in Table 6 (see Results) stipulates rigorous conditions and standards that must be met before a permit is granted. The Joint Permit Application is 19 pages long. The process is not without its challenges and criticisms (Rivers and Coasts, 2014). However, it is still a young program, and the support structures, notably VIMS and the Center for Coastal Resource Management, are in place to implement adaptive changes.

The Virginia system is aimed primarily at property owners and the state of Virginia provides decision-making tools and funding support for homeowners (Rivers and Coasts, 2014). This may explain why records for permitted Virginia Living Shorelines contain a preponderance of private projects and do not yield as many in the public sphere as might be expected. The results indicate a public acceptance of living shoreline techniques, unlike in Massachusetts.

Several things are notable about the Virginia living shorelines inventory. One is the efficiency and transparency of the record-keeping system. Extensive documentation is generally available in the system within two months of application filing. Another is that some of the state's 16 Demonstration Sites, widely promoted by VIMS and NOAA, have been in operation for over a decade, showing their longer history of engagement with living shorelines. One was established in 1999, and many were established between 2006 and 2013 (VIMS, n.d.). And, perusal of project descriptions reveals widespread use of oyster reefs as components in many projects, in stark contrast with Massachusetts where oyster reef construction is rare.

**Examining Massachusetts' Living Shoreline Regulations**

The complexity of the permitting systems in Massachusetts illustrates the state's lack of dedication to soft engineering. Participants in the Woods Hole Group (2017) New England workshop indicated that coastal permitting is time-consuming and regulations are subject to uncertainties. A close examination of the system reveals redundancies and inconsistencies.

As mentioned, the three layers of jurisdiction operate separately, but their processes often overlap. Each municipal Conservation Commission, state agency, and federal agency has its own website with guidance about how to proceed with its own permit applications. However, the multitude of websites can be confusing or even contradictory. It often is unclear as to which actions should be taken in sequence, and which should be undertaken concurrently. For example, federal Wetlands Protection Act guidelines advise one to contact the local Conservation Commission as a first step in starting a project, but Massachusetts Environmental Protection Agency guidelines advise contacting the EPA to begin.

Jurisdictional responsibilities of agencies sometimes overlap as well. For instance, the Public Waterfront Act (Chapter 91) authorizes state oversight of coastal structures, dredging or filling from Mean Low Water (MLW) to the state territorial boundary three miles offshore (Commonwealth of Massachusetts, 2018a). Yet the U.S. Army Corps of Engineers also is responsible for regulating any construction, dredging or filling operations within navigable U.S. waters under the Clean Water Act. Navigable waters in tidal areas extend seaward from the highest tide line (USACE, 2015).

In another hindrance, living shoreline projects are lumped together with dissimilar coastal constructions that have widely differing goals. Chapter 91 requires a specific type of license for "Water Dependent" projects (BRP WW01), but the list of activities covered by that license includes "shore protection structures" along with buildings and hard structures such as docks, piers, marinas, fish processing facilities, aquaculture facilities, bridges, and discharge pipes (Commonwealth of Massachusetts, 2018c). From a regulatory standpoint, green infrastructure and the built environment of hard structures require different considerations in terms of zoning, environmental impact, and human impact. For example, hard structures occur primarily above the high tide line rather than in the intertidal, and thus do not require federal permits (except of course in the case of docks and discharge pipes). Additionally, the build environment may require environmental impact analyses of the effects of such impacts as runoff and discharges, displacement of sediment and substrate, and waste streams. Goals and tradeoffs are aimed more at gaining maximum human convenience while minimizing environmental harm.

Living shoreline goals, on the other hand, are primarily aimed at preserving natural function and maximizing biodiversity, while minimizing interruption of human uses of the shoreline. They require site analyses of parameters such as sediment transport, bathymetry, erosion rates, and slope (Hardaway et al., 2017). They also require different follow-up monitoring and maintenance regimes. A permit application specifically for green, environmentally-engineered structures could bypass much of the supporting documentation required for buildings and docks, and would require regulators to build institutional knowledge that differentiates between the two regulatory needs.

## Examining Reasons for the Differences Between Levels of Participation

Physical. Some of the differences between Massachusetts and Virginia living shoreline statuses are due to the differences in coastal hydrology and climate (Woods Hole Group, 2017). Virginia has a gentler wave energy regime, more temperate climate, and smaller tidal range. New England is subject to more violent storms, temperature extremes, winter ice, and has a larger tidal range, making relatively fewer areas conducive to successful living shoreline projects.

Historical Impacts on Restoration Focus. Massachusetts has been more heavily industrialized than Virginia, and New England salt marshes in particular have been assaulted by ditching, grazing, harvesting of salt marsh hay, draining for mosquito control, extensive filling, and fragmenting by culverts, dams, and roads (Bertness, 2007, p. 370). Current marsh restoration efforts are more focused on culvert and dam removal in order to restore tidal flow, as witnessed by the multitude of such projects on NOAA's Habitat Restoration tracking map (NOAA, 2015b). In contrast, Virginia's coastline is dominated by the Chesapeake Bay and its historic, critical oyster industry (Zu Ermgassen et al., 2012). Restoration is primarily focused on saving the oyster population's decimation from pollution, overharvesting, and excess nitrogen (Jacobsen, 2009). Massachusetts, on the other hand, long ago lost most of its native oyster beds (Kirk, 2015).

Historical Impacts on Regulation. Historical differences shed light on why and how the regulatory regime is so different in the two states. The Massachusetts Public Waterfront Act, Chapter 91 of the Massachusetts General Laws, is the oldest coastal law in the Commonwealth, and has had layers added over time, compounding the bureaucratic burden. One coastal historian

(Pastore, 2014) hypothesizes that attempts to delineate the chaotic coastal zone have resulted in our overlapping regulations.

Chapter 91 is the main tool for protection of Massachusetts waterways and regulates any kind of structure, filling, dredging, change in use, alterations, or removal in the coastal zone (Commonwealth of Massachusetts, 2018a). The law has its roots in the Massachusetts Bay Colony ordinances of the 17th century, which upheld the "public trust doctrine" wherein natural resources belong to the public. Access to the shoreline for "fishing, fowling, and navigation" was formalized in 1866 as part of the Commonwealth's general laws. The MassDEP Waterways Regulation Program now administers Chapter 91, which retains its primary function as a defender of public use of waterways (Commonwealth of Massachusetts, 2018a).

An examination of Virginia's history with the living shoreline concept sheds light on how the state's more supportive attitude developed. By 1990 Virginia was confronting erosion problems and promoting "green" solutions instead of hard structures to homeowners, according to Bilkovic et al. (2017). In the early 2000s, the documented rapid loss of wetlands led the state to conduct an inventory of coastal armoring. That analysis showed that a proliferation of hard structures over time had degraded the shore. A no-net-loss goal was established, with a program to incentivize wetlands protection. With Virginia facing high rates of sea level rise, a long-term strategy of retreating coastal communities from the shoreline (known as "managed retreat"), along with restoring buffer zones, began to be considered (Bilkovic et al., 2017, p. 88).

Virginia's Coastal Zone Management Program, along with other agency and non-profit partners, spearheaded the Living Shorelines Initiative, developing design standards, training workshops, research studies, educational materials and websites (Rivers and Coasts, 2014). Its Living Shorelines Summit in 2006 in Williamsburg, VA spurred activity in other Mid-Atlantic states to consider living shorelines as a viable practice needing government support. Outcomes of the Summit were the enactment of Virginia's Living Shorelines Act (outlined in Results) the involvement of the Virginia Institute of Marine Science (VIMS) as a central player and leader, and the authorization of the expedited General Permit for living shorelines.

## Beyond Permitting: Examining Challenges to Implementing Living Shorelines

The difficulty of obtaining permitting is a major barrier in Massachusetts for implementing living shorelines. But there are other challenges that bear discussion. These include a lack of a consistent terminology, physical challenges posed by New England conditions, and funding access for public projects.

### Terminology

The lack of consensus on definitions and terminology for living shorelines can make it difficult to discuss the practice because there is no one shared language -- both nationally and in Massachusetts (Pilkey et al., 2012). For example, the difficulty of finding living shoreline projects in the state is exacerbated by the use of the term "marsh restoration" to encompass projects that include culvert and dam removal. Close examination of NOAA's Habitat Restoration funded projects on its Restoration Atlas map (2015b) shows that, of the approximately three dozen projects using the words "marsh restoration," none involve living shorelines and most involve culvert removal and other attempts to restore tidal flow.

There are many guidance documents for living shorelines in the U.S. They provide instruction for technology choices, construction design, and site selection, as well as advice on how to proceed through completion. They also illustrate variations in terminology. Table 7 lists several of these documents. (The plenitude of sources demonstrates the advanced state of acceptance of living shoreline strategies nationally, and how active is the state of research.)

**Table 7. Sources for Living Shoreline Technical Guidance**

| Document | Source |
|---|---|
| Practical Guidance for Coastal Climate-Smart Conservation Projects in the Northeast | https://www.nwf.org/~/media/PDFs/Global-Warming/Climate-Smart-Conservation/Final%20coastal%20climate-smart%20guidance%20document.ashx |
| Living Shoreline Design Guidelines for Shore Protection in Virginia's Estuarine Environments, Version 2.0 | https://publish.wm.edu/reports/559/ |
| Stevens Institute Living Shorelines Engineering Guidelines | http://www.nj.gov/dep/cmp/docs/living-shorelines-engineering-guidelines-final.pdf |
| Living Shorelines in New England: State of the Practice, Woods Hole Group, Inc. | https://www.conservationgateway.org/ConservationPractices/Marine/crr/Documents/Final_StateofthePractice_7.2017.pdf |
| Great Marsh Coastal Adaptation Plan | https://www.nwf.org/greatmarshadaptation |
| NOAA Living Shorelines Workgroup, *Guidance for Considering the Use of Living Shorelines* (2012) | http://www.habitat.noaa.gov/pdf/noaa_guidance_for_considering_the_use_of_living_shorelines_2015.pdf |

## Construction and Physical Challenges

Siting. Once an objective in a given location is identified, the design of a living shoreline structure and site selection are complex parts of project initiation. Site analysis is central to successful design and a placement that best fits the site and the goals (Woods Hole Group, 2017; NOAA, 2011). Living shorelines are generally not compatible with high-energy environments. Analyses include potential wave impact, wind exposure, soil and sediment structure and dynamics, tidal range and elevation, and intertidal and nearshore slope. According to some experts, projects that have failed to thrive were not properly sited in the first place (Woods Hole Group, 2017). Compared with Virginia, the harsher Massachusetts climate compounds these issues.

The Felix Neck case study is an example of the tradeoffs that often are made in site selection (Brown et al., 2014). Two of the installation's experimental sites face north/northeast and suffer significant storm damage as a result, whereas the third site faces more southerly and has had the most success. The more protected sites, where green infrastructure have the best chance of plants and shellfish taking hold and surviving, are less at risk from wave energy.

Sediment. According to Suzanne Ayvazian of the EPA's Atlantic Ecology Division (the EPA's scientific research arm), one of the challenges in New England versus the Mid-Atlantic States is the slower rate of sediment accretion on marshes. Sediment accretion is a normal marsh process that allows for marsh buildup, and the ability of the marsh to migrate landward over time. In a place like Delaware Bay, up to a meter of sediment can accrete in a marsh each year; in New England, she says, it can be as little as one centimeter per year because of the higher wave energy and harsh winter storms that drag soil away from low marshes (S. Ayvazian, personal communication, March 29, 2018).

Maintenance. Follow-up and maintenance are essential to the success of a living shoreline construction. Like any living system, it is a work in progress that grows, evolves and interacts with biotic and abiotic influences. Susceptibilities that challenge successful establishment include the destruction of cordgrass plantings by storms; climate change stressors such as increased acidification and temperature variations; grazing of marsh grass plantings by crabs (Bertness et al., 2014), and competition from invasive species (Bertness et al., 2007).

## Funding and Cost Considerations

Funding for public projects often requires multiple grant proposals and solicitations from funding sources such as government agencies, nonprofits, towns, citizen groups, foundations, or private donors (Bilkovic et al, 2017). Combined with a daunting permit process, accessing funding for a project can be a real barrier. Virginia's encouragement of private property owners by reducing fees and proposing loan structures would be a useful subject of future study (Rivers and Coasts, 2014), as would investigations of the funding sources for Virginia's public projects.

Massachusetts faces the same challenges as any state in need of shoreline restoration funding: with limited resources, and with uncertainties around rates of future coastal change, how are decisions to be made about which area should be a focus of preservation? Coastal cities will most likely be a priority, at the expense of areas with less critical infrastructure.

However, this reality can be offset by comparing living shoreline construction costs with the costs of hard structures (see Table 8). For areas where armoring is not a necessity, the cost factor weighs in favor of soft structures, which when fully established require no maintenance.

**Table 8. Cost Estimate Comparisons for Shoreline Management Approaches (avg. cost/linear foot)**

| NON-STRUCTURAL (PLANTING/ GRADING/FILL) | HYBRID (MARSH + SILL) | BREAKWATER (OFF-SHORE) | STRUCTURAL (REVETMENT) | LOCATION | DATE |
|---|---|---|---|---|---|
| $100-200 | $250-$400 | $450-$600 | $500–$1,200 | Maryland | circa 2014 |
| $100-225 | $250-$700 | $450-$1,000 | $500-$1,500 | Delaware Estuary | circa 2012 |
| $45+ | $120-$395 | $125-$200 | $115-$285 (low energy) | Northern Gulf of Mexico | circa 2008 |
| $50 - $100 | $150-$300 | $350-$500 | $500-$1,000 | Maryland | 2007 |
| $45+ | $100+ | $150-$250 | $115-$1,200 | Florida | 2008 |

*Restore America's Estuaries, 2015*

## Discussion of Case Studies

The three case studies reveal much about the permitting landscape. In Massachusetts, the processes for Salem and Edgartown were decidedly different. The Salem project, initiated by the city in 2014 and following the full trajectory of permitting, has been four years in the planning and has not yet been constructed (see Appendix A, page 41). The Edgartown Felix Neck project was initiated by a town employee and, because the local Conservation Commission ruled that the living shoreline did not require wetland permitting and approved its construction, it did not follow the extended permitting path. The timeline for the project, therefore, was unusually speedy, taking approximately one year between initiation and installation. The project also was fortunate to receive funding and technical assistance from a division of the EPA that was eager to develop an experimental site for data collection. As a result, two years of performance data have already been collected by a qualified agency, at minimal cost to the town. The project has the additional benefit of a large public education component (see Appendix B, page 43). The project illustrates how much could be gained by an expedited process for other living shorelines.

Virginia's City of Norfolk project was developed at a relatively speedy rate also, but apparently for different reasons. The expedited permit process, in addition to the existence of many precedent projects in the state, resulted in the 15-month timeline from application submission to the (anticipated) start of construction. Notably, this project is more complex and covers a much larger area than either of the Massachusetts projects. (See Appendix C, page 45.)

Protocol in both states appears to require similar supporting documents for a proposed project, including engineering plans; detailed descriptions of goals and materials; site metrics; evaluation of current conditions; and evaluations of impacts.

## What Does This Mean Going Forward?

On balance, the analysis of the results, case studies, and Massachusetts living shoreline studies demonstrate that challenges are surmountable. Coastal vulnerabilities make it clear that the need for flexibility and sustainable solutions for coastal protection is great. Although the potential viable sites for living shorelines in salt marshes may be limited in Massachusetts compared with Virginia, they can nevertheless be used effectively if placement is carefully considered. The example provided by Virginia points to how changes in regulation can help this happen.

# V. Recommendations

Removing regulatory barriers and reducing the timeline for the installation of living shorelines in Massachusetts is possible. Based on examination of the permitting processes in Massachusetts as compared with Virginia, the maze of regulatory processes can be simplified and policy reframed. Recommendations here focus on streamlining permitting by reducing redundancies and creating a central agency devoted to supporting coastal restoration.

## Recommendation 1: Streamlined Permitting

Permitting simplification and better coordination among agencies is needed in order to move forward, because the relatively new living shoreline methodologies do not fit into most existing coastal zone regulatory frameworks, as many analysts agree (Bierbaum et al., 2013; Bilkovic et al., 2016; O'Donnell, 2016; Portman, 2006; Wigand et al., 2017). Bierbaum et al. (2013) cite "rigid laws and regulations" and "rigid and entrenched political structures" as among the barriers to implementation of climate adaptation strategies in general. This is true for Massachusetts, as the existing framework for regulation of activities in the coastal zone is outdated and makes little distinction between green structures and hard construction.

Simplification can be accomplished without violating the intent of the regulations. The overarching goals implicit in all the governing legislations are to minimize harm to the environment, and weigh tradeoffs for the greater good. Thus, although each agency has its specific and separate mandate, the processes by which they carry out their mandates are similar. In several cases, particularly at the local and state levels, permitting steps occur concurrently and require the same or similar information to be submitted by applicants. By consulting Table 5 and Appendix D (the Permitting Roadmap), redundancies in the process can be identified. These redundancies are presented in Table 9. (Explanations of acronyms can be found in Appendix F.)

**Table 9. Redundancies in the Massachusetts Permitting Process**

| **5 pre-filing meetings** | **6 applications with similar required docs.** | **2 public meetings** | **4 public comment periods** | **2 appeal periods & deed filings** | **3 published notifications** | **3 permits issued** |
|---|---|---|---|---|---|---|
| Conservation Commission | RFD (ConComm)<br>NOI (ConComm & MassDEP) | RFD<br>NOI | | OOC | RFD<br>NOI | Order of Conditions |
| MEPA | ENF | | ENF | | | |
| MassDEP | Ch. 91 Waterways License | | Ch. 91 License | Ch. 91 | Ch. 91 | Ch. 91 License |
| CZM | Fed. Consistency App. | | Consistency Review | | | |
| USACE | Notification Form | | Notification filing | | | General Permit |

The following consolidations can reduce the redundancies at the local and state levels.

1. When the applicant requests a pre-filing consultation with the local Conservation Commission, the Commission requests representatives from MassDEP, MEPA, CZM, and other agencies to also attend. In this way, identification of stakeholders and of potential issues in the applicant's preliminary plan happens early at both the local and state levels.
2. If applicable, the applicant files Request for Determination of wetland status with the Conservation Commission, submitting preliminary plans. As happens now, a public meeting is held for local review and airing of local concerns and questions.
3. Once determination of wetland status is made and public comments have been addressed, a single joint permit application is filed with Conservation Commission, MEPA, MassDEP, and any other agencies identified as stakeholders. This application would combine elements of the Notice of Intent, Environmental Notification Form, and Ch. 91 Waterways applications; all have similar filing requirements, including detailed applicant information and supporting documents such as site analyses, maps, and engineering drawings.
4. One set of published notifications and a single public comment period follow the filing.
5. Reviews by each agency occur in parallel during the same period of time.
6. When all previous steps have taken place, a single joint local/state permit is issued, with one appeal period and one filing at the Registry of Deeds.
7. The federal level as overseen by USACE remains a separate process. But, it would further simplify the process if the New England region approved use of the new Army Corps Nationwide Permit 54 for Living Shorelines (Talton, 2017), which currently Massachusetts foregoes in favor of continuing to utilize regional permits.

Table 10 outlines the potential streamlined permitting process. See Appendix E, page 48, for the Streamlined Roadmap.

**Table 10. Streamlined Massachusetts Permitting Process**

| **2 pre-filing meetings** | **3 applications with supporting documents** | **1 local public meeting** | **2 public comment periods** | **1 appeal period & deed filing** | **2 published notifications** | **2 permits issued** |
|---|---|---|---|---|---|---|
| | RFD to ConComm | RFD | | | RFD | |
| Joint agencies | Joint Permit app. | | Joint Permit | Joint Permit | Joint Permit | Joint Permit |
| USACE | Notification Form | | Notif. Form | | | Gen'l Permit |

**Recommendation 2: Centralized State Agency**

A central agency to provide broad institutional support would be an important driver to facilitating living shoreline use. It would send a strong top-down signal that in many situations living shorelines are a preferred alternative to hard structures.

This "Massachusetts Coastal Adaptation Agency" could oversee implementation of all coastal protection strategies, including armoring as well as soft engineering techniques. It would incorporate the following resources and functions:

- *An advisory board for project design and permitting*. An informed board could advise practitioners about realistic goals, how to engage stakeholders and partners, best practices, funding opportunities, and appropriate monitoring and research models. It would provide guidance on applicable laws and regulations, and help usher applicants through the process.
- *A professional organization.* This would be an information-sharing group composed of scientists, government and nonprofit agency professionals, academics, and engineers who are experienced in coastline protection. Such a group would share ideas and experiences, pose research needs, and share reports with the agency. One model is the Massachusetts Licensed Site Professionals Association, which performs a similar function for hazardous waste cleanups.
- *A state-wide record-keeping mechanism*. A centralized system for tracking coastal projects is critical to authenticating living shoreline and other green projects. Virginia's system, a database under the aegis of its Virginia Marine Resources Commission, is an excellent model (VMRC, 2018b). The database is publicly accessible and transparent, and contains information on permit requests that includes all supporting documents.

- *Framework of definitions and terminology*. To facilitate communication about projects, a common set of definitions and terminology for all stakeholders is needed. The work of the Woods Hole Group (2017) is a practical framework to adopt. In their report "Living Shorelines in New England: State of the Practice," they publish the results of a series of workshops in which teams of practitioners, regulators, and experts from NGOs refined definitions and terminology specifically for New England conditions.
- *Design guideline document*. The Virginia Institute of Marine Science's guideline document for the design of living shorelines in Virginia waters can serve as a model for Massachusetts (Hardaway et al., 2017). It assesses the state shoreline, and explains tradeoffs and parameters for site conditions. It leaves little uncertainty about where to begin, how to proceed with a design, whom to engage, and how to walk through permitting. The Massachusetts office of CZM could engage a university that is committed to coastal research, such as Northeastern University's Marine Science Center, or the University of Massachusetts Dartmouth, to create the document.
- *Demonstration and research sites*. Because one of the hesitations on the part of practitioners and regulators concerns lack of precedents and data, a series of demonstration sites should be built. These would host scientific studies that can provide the knowledge needed to inform future construction. To aid site selection, the estuary delineation work of the MassBays National Estuary Program (MassBays, 2017, August) and the assessments of resilient coastal sites by The Nature Conservancy (2017) can be used to prioritize areas for pilot projects.
- *A central repository of supportive documents and resources*. As noted in the Discussion section, there are many online information resources for practitioners. A central compilation of studies, guides, and consultants would be valuable for project planning.

## Future Needs

Research studies. There are few studies of living shorelines in the New England area (Woods Hole Group, 2017), and there is need for scientific research on living shoreline performance metrics to substantiate and inform future projects (Roman, 2017). Studies conducted in the Chesapeake and Delaware Bays and in the Gulf of Mexico demonstrate the positive effects of living shorelines (Dutta, 2016; Kornis et al., 2017). These studies can be applied generally but not specifically to the Massachusetts/New England shoreline ecology (Woods Hole Group, 2017). Research is necessary to record impacts, successes, and failures in order to evaluate the net benefits and tradeoffs of different living shoreline strategies in the New England environment. For example, under what types of wave energy regimes have living shoreline structures survived best? Which patterns of coir log placement have resulted in the most sediment capture? Do living shorelines have an effect on marsh and offshore biodiversity? Such studies might build on existing studies of marsh dynamics and salt marsh restoration.

Related to the need for research studies is the importance of consistent long-term site monitoring and adaptive management. A central agency could establish monitoring standards. Scientists in the Woods Hole Group (2017) study advise a minimum of five years of monitoring. According to Suzanne Ayvazian, research ecologist at the U.S. EPA's Atlantic Ecology Division, most natural restoration projects such as living shorelines need approximately 10 years to fully develop and become part of the environment, and ideally, monitoring and data should be collected for that long. (S. Ayvazian, personal communication, March 29, 2018).

One idea for handling long-term studies is to engage as a stakeholder a separate, committed research arm for the project, such as the EPA or a university.

In addition, study of the regulatory and permitting systems in other Atlantic states would provide additional useful guidance in shaping New England's future actions. Knowledge of how living shorelines came to be widely utilized in Maryland, Delaware, and North Carolina could help inform regulatory reform in Massachusetts. These states are the most progressive in living shoreline implementation on the Atlantic coast (Bilkovic et al., 2017); however, New York and New Jersey are developing their own approaches to living shoreline principles. These northern states are adapting lessons learned from their southern neighbors, applying them to the

Northeast's climate, geography, and coastal use patterns. Illustrating that there is no one-size-fits-all method for enabling living shoreline use, New York and New Jersey have thus far taken very different approaches to promoting them (Bilkovic et al, 2017). It would be instructive to track their progress as well.

Public education. For living shorelines to become a core part of coastal management, the Massachusetts public needs to be engaged. Coastal homeowners who tend toward armoring to protect their property need to be persuaded that bioengineering techniques are viable alternatives, and this would require committed and consistent action by the state. Public education also can open new opportunities in public/private partnerships.

Communities and individual stakeholders will more willingly endorse green coastal projects if they are convinced of their worth. One challenge may be managing expectations; a public that is accustomed to the solid and visible protection provided by a seawall may be hard to convince of the long-term protective benefits of a marsh system. However, again turning to Virginia's example, demonstration sites can be an effective educational tool.

# VI. Conclusion

Attempting to preserve the shoreline in its present state might seem a Sisyphean task that will merely postpone the inevitable, given the dire predictions of sea level rise and slow inundation. Yet doing so buys time to acquire more accurate climate models and knowledge of what is to come. Coastal communities will be able to adapt and plan for the unavoidable outcome with a margin of protection. Living shorelines fit the goals of state and local regulators, non-profit organizations, and federal agencies to rely more on natural infrastructure and less on solid barriers. Maintaining barriers to living shoreline projects defeats these long-term goals.

It is possible that the Commonwealth's early focus on public rights to shoreline ownership and access – the function of Chapter 91 law, as summarized in the Discussion section -- led to overzealous protection of those rights. The once-useful "public access doctrine" may need reexamination, as it overshadows current needs that differ from those of the past. It began as a protection of everyone's rights to earn a living from coastal bounty, then evolved to encompass a more general right to recreational as well as economic access. Certainly the long history of coastal regulation and the development of bureaucratic layers over time (Portman, 2006) have come up hard against today's need to be nimble and flexible with rapid responses to sea level rise. The tradeoffs need to be reevaluated. The greater good now is preservation of the estuarine system for its long-term protective services, which have an economic value as well.

Without protection or assistance in the face of accelerating climate change impacts, erosion will continue to incrementally tear away the margins of land, until no marshes remain and the communities behind them are forced to beat their own retreat. Also lost at that point would be the other values that a marsh provides – habitat for a rich diversity of biota, nursery for fisheries, flood absorption, sediment capture, pollution filtering, and sequestration of nitrogen and carbon.

The consideration of living shorelines as a coastal protection strategy in Massachusetts is still evolving, as nonprofit organizations and citizen groups actively explore how and where they can best be put to use. But, as evidenced by examination of how this strategy is being used elsewhere, it is clear that the path could be made more efficient and productive. Doing so would be a boost for resiliency strategies against sea level rise in the coming decades.

The damage inflicted by Hurricane Sandy on the shores of Rhode Island, Connecticut, New Jersey, and New York resulted in a flood of disaster relief funding for restoration. The U.S. Fish and Wildlife Service, for example, spent $167 million on over 70 restoration projects as part of the Department of the Interior's Disaster Relief Appropriations Act of 2013 (The Nature Conservancy, 2018). Must Massachusetts wait for a disaster of that scale for increased restoration funding and a welcoming regulatory environment to be made available? Already, a series of 100-year storms in the late winter of 2018 has quickened the pace of discussion about adaptive measures in Boston and the state. But, action is sluggish (Fears, 2018).

If the Massachusetts state government is proactive, solutions might be initiated in response to the slow and steady pace of destruction rather than wait for an acute attack. As Bierbaum et al. (2017) point out, "The climate of the past will not be the climate of the future." Action now, rather than continued planning for action, is essential.

# Appendix A

## Case Study 1: Salem, MA

**Collins Cove Living Shoreline Project**

Narrative

The City of Salem began with a Climate Change Vulnerability Assessment & Adaptation Plan in 2014, working with a consulting engineering firm. Analysis of climate models yielded the prediction that Salem would experience a "30% increase in the likelihood of a 100-year storm in a given year," and an additional four feet of both sea level rise and storm surge by 2100 (Salem Conservation Commission, 2017).

A $75,000 grant from the Massachusetts Office of Coastal Zone Management (CZM) for "Green Infrastructure for Coastal Resilience" provided Salem with technical resources to explore living shoreline approaches for at-risk areas for 18 months. After performing a full shoreline assessment with CZM's guidance, they chose three priority sites. A final site was selected using a Priority Matrix.

Two public presentations informed citizens about the project, provided historical conditions and trends, educated citizens about the risks the city faces, and secured their approval.

The project is in final planning and permitting stages and Salem plans to construct in 2019.

Project Goals: Storm surge mitigation, protect public walking path and homes, marsh enhancement.

Proponent: City of Salem Dept. of Planning and Community Development

Proposal Description: Bioengineered shoreline stabilization and erosion control with fringing salt marsh restoration.

Techniques and Materials: Double row of coir fiber log, in 10 segments; sand fill, marsh grass plantings, high marsh species plantings, rock sill (existing, mid-tide line).

Project size: 76 feet length, 0.88 acres

Project partners: Mass. Office of CZM (funding and project guidance), Epsilon Associates Engineering and Environmental Consultants, Salem Sound Coastwatch (nonprofit), MassBays

Status: In permitting process. Seeking further funding.

Monitoring and maintenance plans: Current plans limited to 2 years maintenance, with replacement of marsh grass plugs removed by storms, until marsh is well established.

Conditions: Low-moderate energy site. Walking/biking path lines cove shore. Vegetation: *Spartina alterniflora*, *S. patens*, cattails, sea lavender, spike grass, seaside goldenrod.

Estimated cost: Unknown

Timeline:

1. Dec. 2014 - City of Salem Climate Change Vulnerability Assessment & Adaptation Plan
2. CZM grant 1 awarded – Green Infrastructure for Coastal Resilience, "financial and technical resources to advance... natural approaches to mitigate coastal erosion..."

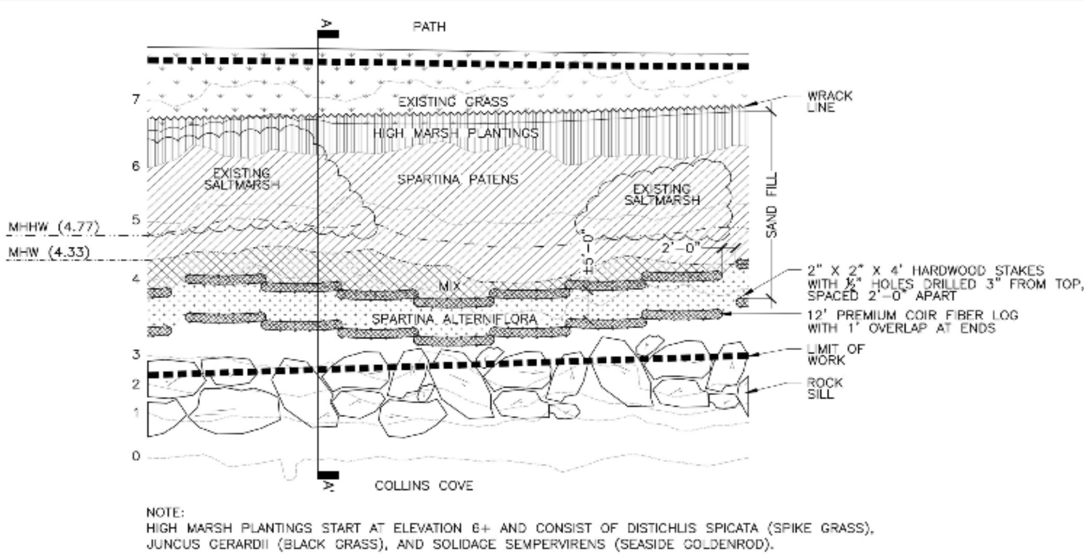
3. Dec. 2014-June 2017 - Planning stages: Municipal Shoreline Survey, project design and initial permitting
4. 2017 - CZM grant 2 awarded - Coastal Resilience Grant under the StormSmart Program for design and permitting of Collins Cove living shoreline project
5. February 16, 2017 and June 8, 2017- Public meetings to present plan
6. Projected June 30, 2018 - Submit final documents with construction-ready design to MassDEP for construction permit
7. Projected March/April 2019 – Construction

**Proposed site**

*Salem Conservation Commission, 2017.*

*Collins Cove after March 2018 Nor'easter. (Leanne Cowley)*

Collins Cove Design Plan (Salem Conservation Commission, 2017)



# Appendix B

## Case Study 2: Edgartown, MA

### Felix Neck Sanctuary Living Shoreline Project

Narrative

During the harsh winter of 2014-15, the director of the Felix Neck Sanctuary observed a high rate of erosion at edge of the coastal pond and mentioned it to the local shellfish constable, who conceived of a living shoreline experiment and began conversations with the EPA Atlantic Ecology Division. The EPA devised the project design and monitoring studies, which include nitrogen attenuation studies. (Previously, unrelated studies had been made of the excess nitrogen pollution in the salt pond and established a suggested Total Maximum Daily Load (TMDL) goal [Friends of Sengekontacket, n.d.].) The two adjacent towns provided initial funding for the living shoreline, and the EPA provided further funding (Flynn, 2016).

The hope was that the arc-shaped placement of the coir logs, creating crescent-shaped pools between the logs and marsh edge, would trap sediment and help build the marsh edge by creating baseline material for marsh elevation. Results thus far are that not as much sediment was trapped as expected (D. Grunden, personal communication, March 12, 2018).

Three control sites alongside the experimental sites provide perspective. An adaptive management process was adopted, and some sites were redesigned the second summer after installation, following lessons learned about which materials survived best during storms. For example, it was found that smaller mesh openings in the fiber bags and coir logs were more damage resistant. Sites facing primarily east fared better than northeast-facing, and 3.5 foot stakes held the coir logs in place better than shorter ones (Grunden et al., 2018).

There is a significant education and outreach component to the project. The Sanctuary public education framework has incorporated the experiment and information on living shorelines into school vacation and summer camp programs, adult education, and kayak tours.

Project Goals: Erosion control, shoreline stabilization, marsh preservation, research.

Proponent: Town of Edgartown and Town of Oak Bluffs Shellfish Departments

Proposal description: Along eroding edge of coastal pond salt marsh in Mass Audubon sanctuary, bioengineered shoreline stabilization and erosion control, experimental model.

Techniques and materials: Double 10-foot rows of coir coconut-fiber log, in arcing pattern, marsh grass plantings, biodegradable burlap sacks containing local oyster and quahog shells, wooden stakes

Project size: 3 site areas, each approx.100 feet long, totaling approx. 80 meters. 3 control sites.

Project partners: MA Audubon Felix Neck Wildlife Sanctuary; U.S. Environmental Protection Agency Atlantic Ecology Division (funding and research agency); University of Rhode Island; Delaware Bay Living Shoreline Initiative

Status: Constructed, in research and monitoring phase.

Monitoring: Accretion measurements 2x/year, erosion rates, Nitrogen tracking, nekton studies, water quality and soil metrics, habitat and biodiversity effects

Conditions: Moderate-high energy site on shore of coastal salt water pond with opening to ocean. Site faces east/northeast and receives storm surge. Vegetation: *Spartina alterniflora*, *S. patens.* Sandy sediment.

Estimated cost: Unknown

Timeline:

1. 2014-2015 – erosion observation
2. 2015 - Request for Determination of Applicability filed, permission to begin construction granted.
3. 2015-16 – project planning, partner engagement, design
4. June 1, 2016 – installation 1st site
5. Summer 2016 – installation 2 additional sites
6. 2016-17 – monitoring and data collection
7. Summer 2017 – *Spartina* planted inside edges coir logs, ribbed mussel seed scattered
8. Ongoing - monitoring studies.

**Felix Neck initial construction, 2016**

*https://www.massaudubon.org/get-outdoors/wildlife-sanctuaries/felix-neck/about/our-conservation-work/shoreline-restoration*

**After winter nor'easter, March 2018**

*Photos: Leanne Cowley*

# Appendix C

## Case Study 3: City of Norfolk, VA

### Beach Avenue Living Shoreline Restoration Project

Narrative

The City of Norfolk has initiated several living shoreline projects. Beach Avenue is one of the largest.

In addition to the local/state/federal Living Shoreline Group 2 General Permit, this project required the USACE Nationwide General Permit and a Regional Permit 19 for the Norfolk District from the USACE for its use of a rocky sill and fill material. This was to "authorize impacts to jurisdictional resources associated with the City of Norfolk" (VMRC, 2018b, Supplemental Documentation for Application #1860). The Norfolk Local Wetlands Board (Virginia's equivalent to the Massachusetts Conservation Commission) gave the project a "government activity exemption," determining that no wetlands permit was required (VMRC, 2018b, Application #1860).

Project Goals: Shoreline restoration, tidal wetlands restoration and enhancement, coastal resilience.

Proponent: City of Norfolk

Proposal Description: Bioengineered shoreline stabilization and erosion control

Techniques and materials: Coir logs, rocky sill, sill fill, oyster bags, oyster shells, tidal marsh plantings

Project size: 1,202 linear feet of bioengineered structure, 0.81 acres restored wetland, 0.22 acres oyster reef creation

Project partners: Grant funding from National Fish and Wildlife Foundation-Hurricane Sandy Coastal Resiliency Competitive Grants Program.

Status: Unknown

Monitoring: Unknown

Conditions: Tidal river estuary of Lafayette River near southern end Chesapeake Bay, highly developed area. Project is along edge of a city park and residential neighborhood

Estimated cost: $400-700,000 (Source: https://www.norfolk.gov/DocumentCenter/View/31618 )

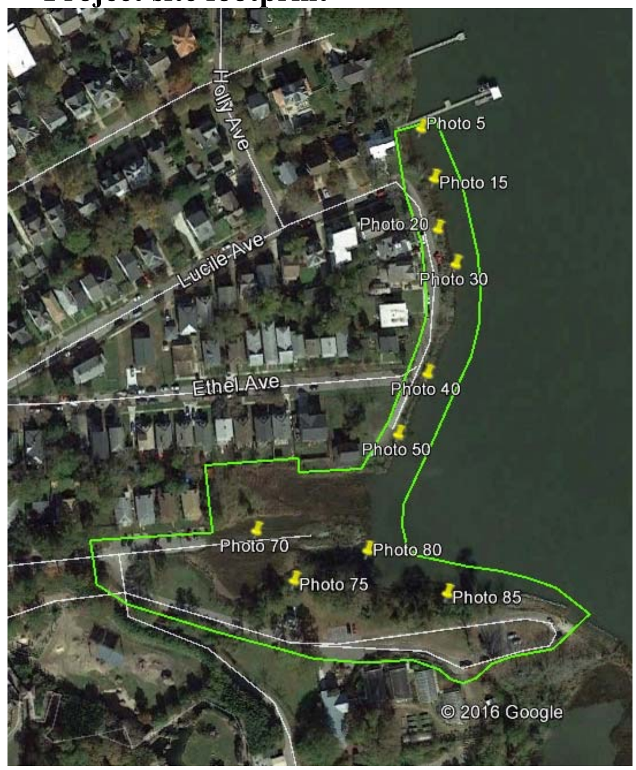
Timeline:

1. 2016, November 18 – application submitted
2. 2017, January 3 - Public notice
3. 2017, January-February – design revisions submitted
4. 2017, February – Norfolk Wetlands Board decision: no wetlands permit required (government activity exemption)
5. 2017, February-March – comments received

6. March 10, 2017 - Permit granted
7. July 2017 – engineering bid awarded
8. Estimated construction January- February 2018

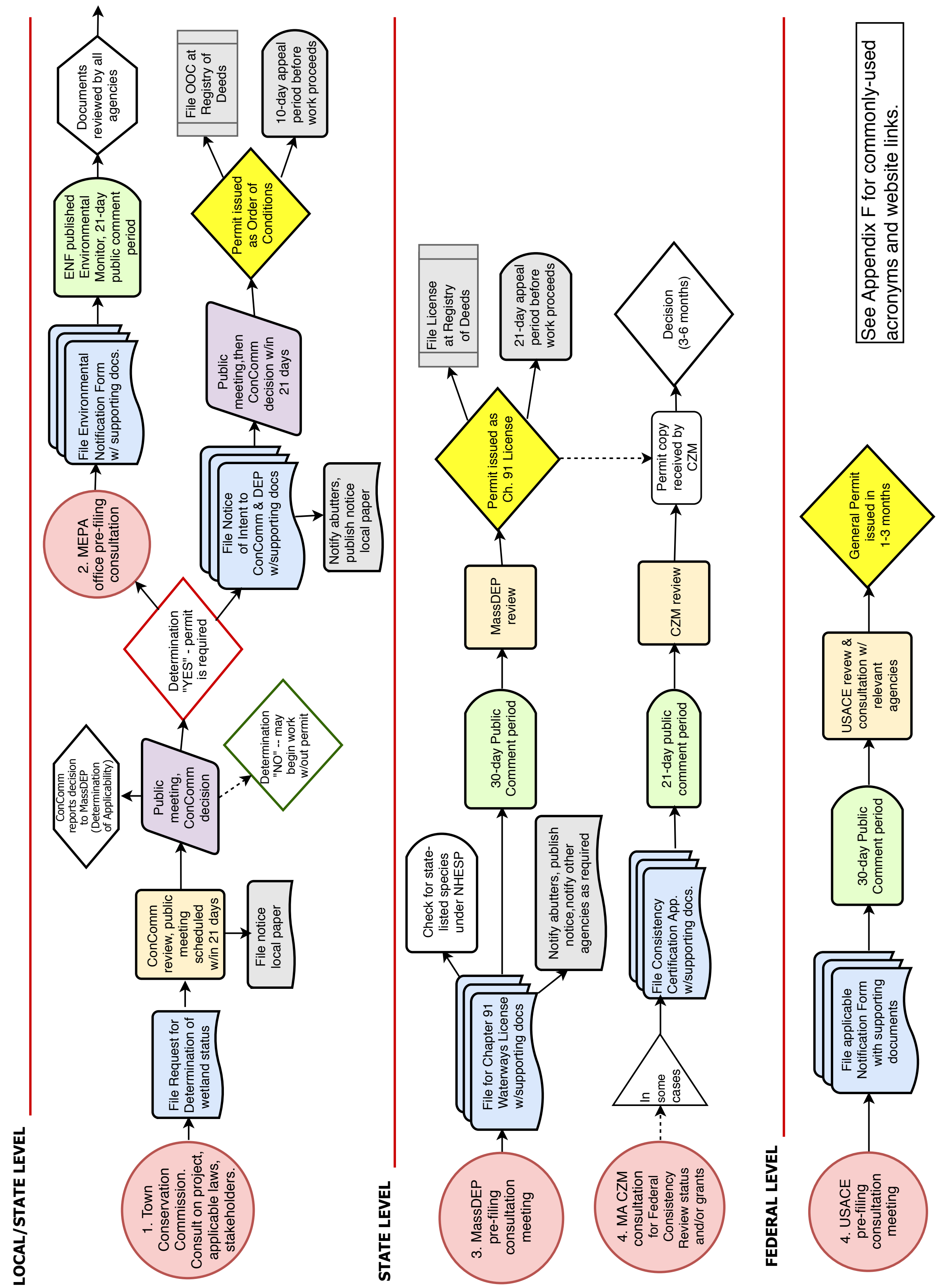
**January 2017 site photo**

**Project site footprint**

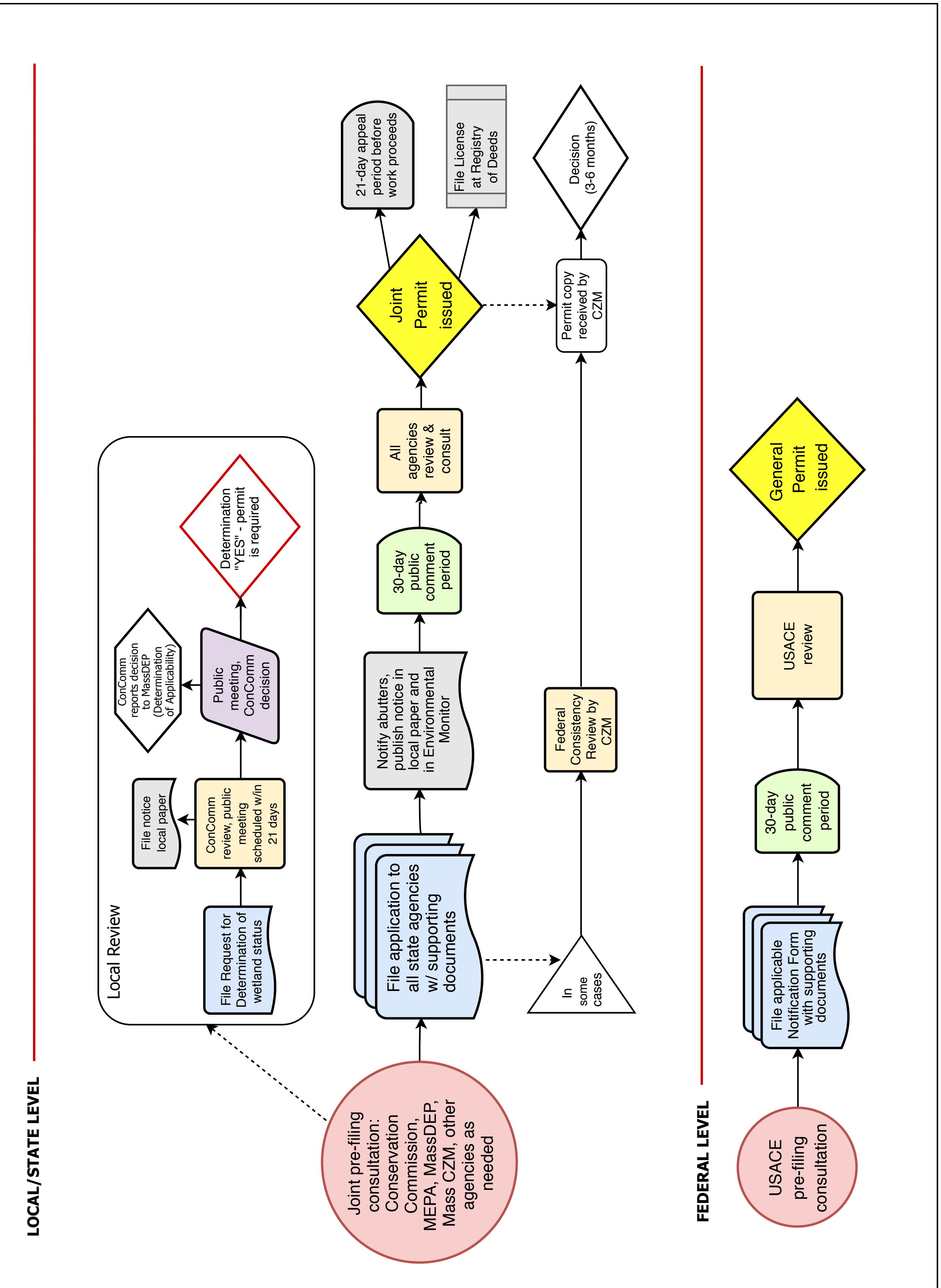



*Report documents Application #1860, VMRC, 2018b*

## Appendix D. Living Shoreline Massachusetts Permitting Roadmap: *Current*



## Appendix E. Living Shoreline Massachusetts Permitting Roadmap: *Streamlined*



## Appendix F

## Commonly Used Acronyms and Links

RFD – Request for Determination of Applicability
https://www.mass.gov/lists/wetlands-permitting-forms

ENF – Environmental Notification Form
https://www.mass.gov/guides/environmental-notification-form-enf-preparation-and-filing

MEPA - Massachusetts Environmental Protection Act
https://www.mass.gov/service-details/purpose-and-intent-of-mepa

NOI – Notice of Intent (WPA Form 3)
https://www.mass.gov/how-to/wpa-form-3-wetlands-notice-of-intent

OOC – Order of Conditions (WPA Form 5)
https://www.mass.gov/how-to/wpa-form-5-order-of-conditions

MassDEP – Massachusetts Dept. of Environmental Protection
https://www.mass.gov/massdep-permitting-reporting

NHESP – Natural Heritage & Endangered Species Program
https://www.mass.gov/orgs/masswildlifes-natural-heritage-endangered-species-program

CZM – MA Office of Coastal Zone Management
https://www.mass.gov/orgs/massachusetts-office-of-coastal-zone-management

FCR -- Federal Consistency Review
https://www.mass.gov/federal-consistency-review-program

NOAA – National Oceanic and Atmospheric Administration
http://www.noaa.gov

USACE – U.S. Army Corps of Engineers
http://www.nae.usace.army.mil/Portals/74/docs/regulatory/StateGeneralPermits/MAGPs9March2015.pdf

References

Anderson, M.G. & Barnett, A. (2017). Resilient Coastal Sites for Conservation in the Northeast and Mid-Atlantic US. *The Nature Conservancy, Eastern Conservation Science.* Retrieved March 4, 2018 from http://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/reportsdata/climate/CoastalResilience/Pages/default.aspx

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. *Ecological Monographs 81*(2), 169-193. **DOI**: 10.1890/10-1510.1. Retrieved April 2, 2018 from https://esajournals.onlinelibrary.wiley.com/doi/full/10.1890/10-1510.1

BEAT: Berkshire Environmental Action Team. (n.d.). *Massachusetts Wetlands Protection Act: Understanding the regulatory process.* Retrieved March 20, 2018 from http://www.thebeatnews.org/BeatTeam/agencies-regs/laws-and-regs/wetlands-protection-act-1/

Bertness, M. D. (2007). *Atlantic Shorelines: Natural History and Ecology*. Princeton NJ: Princeton University Press.

Bertness. M. D., Brisson, C. P., Coverdale, T. C., Bevil, M. C., Crotty, S. M., & Suglia, E. R. (2014). Experimental predator removal causes rapid salt marsh die-off. *Ecology Letters 17*(7), 830-835. **DOI:** 10.1111/ele.12287. Retrieved March 11, 2018 from http://onlinelibrary.wiley.com.ezp-prod1.hul.harvard.edu/doi/10.1111/ele.12287/full

Bierbaum, R., Smith, J. B., Lee, A., Blair, M., Carter, L., Chapin, F.S. III, Fleming, P., Ruffo, S., Stults, M., McNeeley, S., Wasley, E., & Verduzco, L. (2013). A comprehensive review of climate adaptation in the United States: more than before, but less than needed. *Mitigation and Adaptation Strategies for Global Change 18*(3), 361-406. DOI 10.1007/s11027-012-9423-1 . Retrieved March 17, 2018 from https://link-springer-com.ezp-prod1.hul.harvard.edu/article/10.1007%2Fs11027-012-9423-1#aboutcontent

Bilkovic, D. M., Mitchell, M., Mason, P., Duhring, K. (2016). The role of living shorelines as estuarine habitat conservation strategies. *Coastal Management 44*(3), 161–174. http://dx.doi.org/10.1080/08920753.2016.1160201. Retrieved February 12, 2018 from http://web.a.ebscohost.com.ezpprod1.hul.harvard.edu/ehost/pdfviewer/pdfviewer?vid=1&sid=f537b00b-0e01-44e3-a427-573cf8b9c59b%40sessionmgr4010

Bilkovic, D.M., Mitchell, M. M., La Peyre, M. K., Toft, J. D. (Eds.) (2017). *Living Shorelines: The Science and Management of Nature-Based Coastal Protection*. Boca Raton: CRC Press, Taylor & Francis Group.

Bromberg, K. D. & Bertness, M. D. (2005). Reconstructing New England salt marsh losses using historical maps. *Estuaries, 28*(6), 823-832. Retrieved February 28, 2018 from http://www.jstor.org.ezp-prod1.hul.harvard.edu/stable/pdf/3526949.pdf?refreqid=excelsior%3Ae081fdc12b9f8d6fb1b373dc4a206c06

Brown, D. S., Ruddock, K., & Smith, R. (2014). Living Shorelines: Non-structural Erosion Control Practices. [Presentation]. *Presented at Rhode Island Land & Water Summit, 2014, The Nature Conservancy and U.S. Fish and Wildlife Service.* Retrieved March 1, 2018 from https://www.landandwaterpartnership.org/documents/Summit2014/2G_Erosion_Control.pdf

Commonwealth of Massachusetts. (2011). *Massachusetts Climate Change Adaptation Report.* Executive Office of Energy and Environmental Affairs. Retrieved Feb. 27, 2018 from https://www.mass.gov/files/documents/2017/11/29/Full%20report.pdf

Commonwealth of Massachusetts. (2017). Environmental Look-ups and Online Services: Search for Wetlands NOI Projects. Retrieved March 22, 2018 from https://eeaonline.eea.state.ma.us/portal#!/search/wire

Commonwealth of Massachusetts. (2018a). *Chapter 91, The Massachusetts Public Waterfront Act*. Retrieved March 5, 2018 from https://www.mass.gov/guides/chapter-91-the-massachusetts-public-waterfront-act

Commonwealth of Massachusetts (2018b). Coastal Resilience Grant Program. Retrieved March 20, 2018 from https://www.mass.gov/service-details/coastal-resilience-grant-program

Commonwealth of Massachusetts (2018c). Chapter 91 Permitting Guide. Retrieved February 14, 2018 from https://www.mass.gov/lists/chapter-91-forms-massdep

Commonwealth of Massachusetts (2018d). Division of Marine Fisheries, Marine Fisheries Management. Retrieved March 20, 2018 from https://www.mass.gov/marine-fisheries-management

Commonwealth of Massachusetts (2018e). Massachusetts Sea Level Rise and Coastal Flooding Viewer. Retrieved March 20, 2018 from http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/flooding-impacts-viewer/

Costanza, R., Farber, S. C., & Maxwell, J. (1989). Valuation and management of wetland ecosystems. *Ecological Economics 1*(4), 335-361. DOI: 10.1016/0921-8009(89)90014-1. Retrieved April 1, 2018 from https://www.sciencedirect.com/science/article/pii/0921800989900141

Daniel, S. (2017, July 14). Wynn Begins Work on Living Shoreline, but What is a Living Shoreline? *Everett Independent – Everett Massachusetts Newspaper*. Retrieved March 18, 2018 from http://www.everettindependent.com/2017/07/14/wynn-begins-work-on-living-shoreline-but-what-is-a-living-shoreline/

Duhring, K. (2014, May 22). Living Shorelines in Virginia: What's Happened Since the 2006 Living Shorelines Summit? [Presentation]. Retrieved from Center for Coastal Resources Management, Virginia Institute of Marine Science, College of William & Mary website. Retrieved March 23, 2018 from http://ccrm.vims.edu/education/workshops_events/spring2014/1_Duhring_May22_PDF.pdf

Dutta, S. (2016). Do living shorelines contribute to the accumulation of nutrients, sediment, and organic matter needed for the maintenance of coastal wetlands? (Doctoral dissertation). ProQuest Dissertations Publishing, 2016. 10141571. Retrieved March 7, 2018 from https://search-proquest-com.ezp-prod1.hul.harvard.edu/docview/1822211245?pq-origsite=primo

Elvin, A. (2016, June 20). Coconut Fiber to the Rescue: Island's First Living Shoreline Installed at Felix Neck. *The Vineyard Gazette*. Retrieved March 9, 2018 from https://vineyardgazette.com/news/2016/06/20/coconut-fiber-rescue-islands-first-living-shoreline-installed-felix-neck

Fears, D. (2018, March 3). As giant storms hammer Boston, officials are doing little to prepare for them. *The Washington Post*. Retrieved March 24, 2018 from https://www.washingtonpost.com/national/health-science/as-giant-storms-hammer-boston-officials-are-doing-little-to-prepare-for-them/2018/03/02/30e559e2-1e5f-11e8-ae5a-16e60e4605f3_story.html?mc_cid=759ef1b7da&mc_eid=855fff9cb7&utm_campaign=BHEN%20March%202018&utm_medium=email&utm_source=BHEN%20March%202018&utm_term=.c4e4f6744aaa

Flaherty, M. (2011). Oyster Reef Restoration and Monitoring, Wellfleet, MA. Draft Final Report. Retrieved March 28, 2018 from https://www.mass.gov/files/documents/2016/08/ny/oyster-reef-mass-audubon-r-and-p-2011.pdf

Friends of Sengekontacket website. (n.d.) FOS MEP presentation to Selectmen, 2013. Retrieved March 9, 2018 from http://www.sengekontacket.org/blog/

Gittman, R., Peterson, C., Currin, C., Joel Fodrie, F., Piehler, M., & Bruno, J. (2016). Living shorelines can enhance the nursery role of threatened estuarine habitats. *Ecological Applications, 26*(1), 249-263. Retrieved April 1, 2018 from https://esajournals-onlinelibrary-wiley-com.ezp-prod1.hul.harvard.edu/doi/abs/10.1890/14-0716

Grabowski, J. H., Brumbaugh, R. D., Conrad, R. F., Keeler, A. G., Opaluch, J. J., Peterson, C. H., Piehler, M. F., Powers, S. P., and Smyth, A. R. (2012). Economic valuation of ecosystem services provided by oyster reefs. *BioScience 62* (10), 900-909. Retrieved 2/12/2018 from http://www.bioone.org.ezp-prod1.hul.harvard.edu/doi/abs/10.1525/bio.2012.62.10.10

Grunden, D. W., Bagnal, P., Schoell, M., Gerber-Williams, A., Ayvasian, S., Chintala, M., Strobel, C., Rocha, K., Bellencampi, S., & Josephs, L. (2018). [Presentation]. Salt Marsh Restoration Through Living Shoreline. *PowerPoint presented at January 11, 2018 meeting of the Martha's Vineyard Water Alliance*. Provided by personal communication from D. Grunden, February 14, 2018.

Hardaway, Jr., C.S., Milligan, D.A., Duhring, K., & Wilcox, C.A. (2017). Living shoreline design guidelines for shore protection in Virginia's estuarine environment (SRAMSOE #463). *Virginia Institute of Marine Science.* https://doi.org/ 10.21220/V5CF1N . Retrieved March 8, 2018 from http://www.vims.edu/research/departments/physical/programs/ssp/shoreline_management/living_shorelines/class_info/index.php

International Panel on Climate Change (IPCC). (2007). IPCC Fourth Assessment Report (AR4). Climate Change 2007: Synthesis Report. Retrieved February 27, 2018 from http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

Jacobsen, R. (2009). *The Living Shore: Rediscovering a Lost World*. New York: Bloomsbury USA. ISBN-13: 978-1-59691-684-5.

Kirk, S. (2015, June 8). Shellfish Restoration in Massachusetts. The Nature Conservancy, Conservation Gateway website. Retrieved March 1, 2018 from https://www.conservationgateway.org/ConservationPractices/Marine/HabitatProtectionandRestoration/Pages/MA-shellfish-restoration.aspx

Kornis, M.S., Breitburg, D., Balouskus, R., Bilkovic, D. M., Davias, L. A., Giordano, S., Heggie, K., Hines, A. H., Jacobs, J. M., Jordan, T. E., King, R. S., Patrick, C. J., Seitz, R. D., Soulen, H., Targett, T. E., Weller, D. E., Whigham, D. F., & Uphoff Jr., J. (2017). Linking the abundance of estuarine fish and crustaceans in nearshore waters to shoreline hardening and land cover. *Estuaries and Coasts 40*(5), 1464-1486. Retrieved March 7, 2018 from https://link-springer-com.ezp-prod1.hul.harvard.edu/article/10.1007/s12237-017-0213-6#citeas

Maryland Department of the Environment. (2018). New Tidal Wetlands Regulations for Living Shorelines Effective February 4, 2013. Retrieved May 18, 2018 from http://www.mde.state.md.us/programs/Water/WetlandsandWaterways/Pages/LivingShorelines.aspx

Massachusetts Audubon Society. (2018). Felix Neck Wildlife Sanctuary: Living Shoreline Restoration Project. Retrieved March 9, 2018 from https://www.massaudubon.org/get-outdoors/wildlife-sanctuaries/felix-neck/about/our-conservation-work/shoreline-restoration

Massachusetts Bays National Estuary Program (MassBays). (2017, August). Massachusetts Bays National Estuary Program, Estuary Delineation and Assessment 2.0. Retrieved April 1, 2018 from https://www.mass.gov/files/documents/2017/11/27/EDA2.0_revised_august2017_no%20maps.pdf

Massachusetts Office of Coastal Zone Management (CZM). (2011, October). *Policy Guide.* Retrieved Feb. 9, 2018 from https://www.mass.gov/service-details/massachusetts-office-of-coastal-zone-management-czm-policy-guide

National Oceanic and Atmospheric Administration (NOAA). (n.d.a). NOAA's Restoration Center Funded Living Shorelines Projects. Retrieved 2/21/18 from https://www.habitatblueprint.noaa.gov/storymap/ls/index.html#

National Oceanic and Atmospheric Administration (NOAA). (n.d.b). NOAA Habitat Blueprint: Living Shorelines. Retrieved February 15, 2018 from https://www.habitatblueprint.noaa.gov/living-shorelines/

National Oceanic and Atmospheric Administration (NOAA). (2011). *Planning for Sea Level Rise in the Northeast: Considerations for the Implementation of Tidal Wetland Habitat Restoration Projects.* Workshop Report, NOAA Restoration Center, Northeast Region. Retrieved March 8, 2018 from http://web.archive.org/web/20170206214954/http://www.habitat.noaa.gov/pdf/slr_workshop_report_november_2011.pdf

National Oceanic and Atmospheric Administration (NOAA). (2015). *Guidance for Considering the Use of Living Shorelines.* Retrieved February 23, 2018 from https://www.habitatblueprint.noaa.gov/wp-content/uploads/2018/01/NOAA-Guidance-for-Considering-the-Use-of-Living-Shorelines_2015.pdf

National Oceanic and Atmospheric Administration (NOAA). (2015a). *Natural and Structural Measures for Shoreline Stabilization.* Retrieved March 10, 2018 from https://coast.noaa.gov/data/digitalcoast/pdf/living-shoreline.pdf

National Oceanic and Atmospheric Administration (NOAA). (2015b). Restoration Atlas. Retrieved March 23 from https://restoration.atlas.noaa.gov/src/html/index.html

National Oceanic and Atmospheric Administration (NOAA). (2017a). Estuarine Habitats: Salt Marshes. National Ocean Service website. Retrieved January 27, 2018 from https://oceanservice.noaa.gov/education/kits/estuaries/media/supp_estuar06a_saltmarsh.html

National Oceanic and Atmospheric Administration (NOAA). (2017b). What is a salt marsh? National Ocean Service website. Retrieved January 27, 2018 from https://oceanservice.noaa.gov/facts/saltmarsh.html

National Research Council. (2006). Mitigating Shore Erosion on Sheltered Coasts: Report in Brief. Retrieved April 7, 2018 from http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/shore_erosion_final.pdf

The Nature Conservancy. (2017). Resilient Coastal Sites for Conservation in the Northeast and Mid-Atlantic. Retrieved March 15, 2018 from https://conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/reportsdata/climate/CoastalResilience/Pages/default.aspx

The Nature Conservancy. (2018). Sachuest Point Marsh Restoration. [Video]. Retrieved March 10, 2018 from https://www.nature.org/photos-and-video/video/sachuest-point-marsh-restoration

O'Donnell, J. E. D. (2016). Regulatory Issues for Implementing Living Shorelines. *National Wetlands Newsletter, 38*(2). Environmental Law Institute, Washington, D.C., USA. Retrieved April 7, 2018 from https://www.eli.org/sites/default/files/nwn/issue/38.2_Odonnell.pdf

Pastore, C. J. (2014). *Between Land and Sea. The Atlantic Coast and the Transformation of New England*. Cambridge MA: Harvard University Press.

Pilkey, O. H., Young, R., Longo, N., & Coburn, A. (2012). Rethinking Living Shorelines. *Program for the Study of Developed Shorelines, Western Carolina University*. Retrieved March 26, 2018 from https://www.wcu.edu/WebFiles/PDFs/PSDS_Living_Shorelines_White_Paper.pdf

Portman, M. (2006). Tidelands Management: Implementation of the Massachusetts Public Waterfront Act. *Journal of Environmental Policy & Planning 8*(4), 293-308. Retrieved March 8, 2018 from http://portman.net.technion.ac.il/files/2012/07/WRP-PPR_PUBLISHED1.pdf

Restore America's Estuaries. (2015). *Living Shorelines: From Barriers to Opportunities.* Arlington, VA. Retrieved 2/21/18 from https://www.estuaries.org/images/stories/RAEReports/RAE_LS_Barriers_report_final.pdf

Rivers and Coasts. (2014, Summer). *Newsletter of the Center for Coastal Resources Management 9*(2). Retrieved March 12, 2018 from http://ccrm.vims.edu/publications/pubs/rivers&coast/RC914.pdf

Roman, C.T. (2017). Salt marsh sustainability: Challenges during an uncertain future. *Estuaries and Coasts 40*, 711. Retrieved February 2, 2018 from https://link-springer-com.ezp-prod1.hul.harvard.edu/article/10.1007/s12237-016-0149-2

Salem Conservation Commission. (2017, June 8). Salem Living Shoreline Project. [Presentation]. Provided by Ashley Green, Salem Conservation Agent, March 6, 2018.

Sallenger, A. H. Jr., Doran, K. S., & Howd, P. A. (2012). Hotspot of accelerated sea-level rise on the Atlantic coast of North America. *Nature Climate Change 2*, 884-888. Retrieved February 27, 2018 from http://www.nature.com.ezp-prod1.hul.harvard.edu/articles/nclimate1597

Save the Bay. (2013, May). Coastal Erosion and Adaptation on the Rhode Island Coastline. Summary Report. Retrieved February 21, 2018 from http://northeastoceancouncil.org/wp-content/uploads/2015/06/RIWhitePaper_Coastal-Erosion-and-Adaptation-on-the-RI-Coastline.pdf

Schoell, M., Gerber, A., Ayvazian, S., Chintala, M., Grunden, D., Cobb, D., Strobel, C., & Rocha, K. (2016). Living Shorelines in New England: monitoring marsh stabilization, restoration benefits, and nitrogen removal. New England Estuarine Research Society (NEERS) Fall Meeting, Block Island, Rhode Island, October 20 - 22, 2016. Retrieved March 24, 2018 from https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=330530

Schottland, T., Merriam, M.G., Hilke, C., Grubbs, K. & Castonguay, W. (2017). *Great Marsh Coastal Adaptation Plan*. National Wildlife Federation Northeast Regional Office, Montpelier, VT. Retrieved February 9, 2018 from https://www.nwf.org/greatmarshadaptation

Talton, T. (2017, January 12). Corps Eases Living Shoreline Permit Process. *Coastal Review Online*. Retrieved March 12, 2018 from https://www.coastalreview.org/2017/01/corps-eases-living-shoreline-permit-process/

US Army Corps of Engineers (USACE). (n.d.). New England District, State General Permits. Retrieved March 24, 2018 from http://www.nae.usace.army.mil/Missions/Regulatory/State-General-Permits/

US Army Corps of Engineers (USACE). (2015). Department of the Army General Permits for Massachusetts. Retrieved March 25, 2018 from http://www.nae.usace.army.mil/Portals/74/docs/regulatory/StateGeneralPermits/MAGPs9March2015.pdf

US Army Corps of Engineers (USACE). (2016). Nationwide Permit 54: Decision Document, Nationwide Permit 54. Retrieved March 26, 2018 from http://www.usace.army.mil/Portals/2/docs/civilworks/nwp/2017/NWP_54_2017_final_Dec2016.pdf?ver=2017-01-06-125514-560

US Army Corps of Engineers (USACE). (2017). Nationwide Permit 13: Bank Stabilization. Retrieved March 26, 2018 from http://www.nao.usace.army.mil/Portals/31/docs/regulatory/nationwidepermits/Nationwide_Permit_13.pdf

Virginia Institute of Marine Science (VIMS). (n.d.) Living Shorelines Story Map. Retrieved March 15, 2018 from http://vimswm.maps.arcgis.com/apps/MapJournal/index.html?appid=95bfc110379844d5809bce8d09487538# .

Virginia Institute of Marine Science (VIMS). (2018). Laws, Policies, and Permits. Retrieved March 22, 2018 from http://www.vims.edu/ccrm/outreach/living_shorelines/laws/index.php

Virginia Marine Resources Commission (VMRC). (2015). Living Shoreline Group 1 General Permit for Certain Living Shoreline Treatments Involving Tidal Wetlands. Retrieved March 25, 2018 from http://mrc.virginia.gov/regulations/MRC_Scanned_Regs/Habitat/FR1300_09-01-15.pdf

Virginia Marine Resources Commission (VMRC). (2018a). Habitat Management Division Permitting. Retrieved March 22, 2018 from http://www.mrc.virginia.gov/regulations/hm-permits.shtm

Virginia Marine Resources Commission (VMRC). (2018b). Habitat Management Permits and Applications. Retrieved March 22, 2018 from https://webapps.mrc.virginia.gov/public/habitat/

Wigand, C., Ardito, T., Chaffee, C., Ferguson, W., Paton, S., Raposa, K., Vandemoer, C., & Watson, E. (2017). A climate change adaptation strategy for management of coastal marsh systems. *Estuaries and Coasts 40*, 682-693. Retrieved 2/2/18 from https://link-springer-com.ezp-prod1.hul.harvard.edu/article/10.1007/s12237-015-0003-y

Woods Hole Group. (2017). Living Shorelines in New England: State of the Practice. Retrieved 2/21/18 from https://www.conservationgateway.org/ConservationPractices/Marine/crr/Documents/Final_StateofthePractice_7.2017.pdf

Zu Ermgassen, P. S. E., Spalding, M. D., Blake, B., Coen, L. D., Dumbauld, B., Geiger, S., Grabowski, J.H., Grizzle, R. Luckenbach, M., McGraw, K., Rodney, W., Ruesink, J.L., Powers, S. P., & Brumbaugh, R. (2012). Historical ecology with real numbers: past and present extent and biomass of an imperiled estuarine habitat. *Proceedings of the Royal Society B: Biological Sciences*, *279*(1742), 3393–3400. Retrieved February 12, 2018 from https://www-ncbi-nlm-nih-gov.ezp-prod1.hul.harvard.edu/pmc/articles/PMC3396889/