CHARACTERISTICS AND CONFLICTS OF MUNICIPAL COASTAL RESILIENCE IN MASSACHUSETTS

A dissertation presented

by

Lisa A. Granquist

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In partial fulfillment of the requirements for the degree of

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In the field of

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ABSTRACT OF DISSERTATION

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ABSTRACT

Building coastal resilience is the process of building adaptive capacity into social, built, and ecological systems. Resilience goes beyond disaster mitigation and loss prevention. It suggests that a system can be strengthened by the forces that pressure it. For communities to become resilient, coastal protection must do more than mitigate single-event disaster losses. To build resilience, or engage in any climate adaptation activities, there must be a foundation of laws and policies and instruments of governance that specifically support adoption and implementation of best practices.

The goal of this study was to produce an integrated analysis to examine the capacity and potential of Massachusetts coastal communities to implement coastal resilience practices given their existing regulatory, policy, and governance environments. A document review of municipal regulations of three towns and a content analysis of interviews comprised the case study, and a localized spatial and econometric study examined the effects of accelerated erosion.

Coastal resilience best practices from the field and the literature were used as benchmarks to evaluate the resilience-readiness of hundreds of pages of municipal regulations and policies in three Massachusetts towns that are experiencing frequent and particularly challenging coastal inundation and shoreline erosion: Chatham, Newbury, and Scituate. The analysis showed that the majority (64%) of reasons stated as the regulatory purpose was economic in nature (loss reduction or property protection). Public benefit plus ecosystem protection motivated the rest. Land use practices (77%) and building and infrastructure modifications (18%) references together dominated the almost 400 mentions of resilience practices. Less than 2% referenced green

infrastructure practices like marsh restoration, beach renourishment or dewatering, dune stabilization, and using vegetation to prevent erosion.

The content analysis of the interviews with municipal and federal coastal resource managers ascertained their views about the challenges and barriers they face in implementing coastal resilience practices and under what circumstances they would or would not want to implement particular practices. All of the participants expressed exasperation about funding, communication, and public awareness. There was consensus that coordinated long-term cross-jurisdictional comprehensive planning and implementation were critical to successful coastal resilience efforts.

The spatial and econometric analyses showed the ecological and economic effects of accelerated shoreline erosion rates before and after the installation of hard-engineered coastal protection structures in two communities (Plymouth and Scituate), and then calculated coastal erosion's effect on waterfront property values over time. The findings provided data that engaged the thorny issues raised by the Public Trust Doctrine theoretical framework of this dissertation. Namely, it is clear that there are unintended consequences to public lands and private property from employing individual and community traditional hard-engineered protection solutions like seawalls and that there is a negative net economic public benefit. Using recent case law, it is argued that the erosion effects can be considered a polluting public nuisance. Interview participants agreed that these business-as-usual practices inhibit building effective coastal resilience.

Based on these findings, I make recommendations for municipalities to increase the inclusion of resilience best practices in regulations, to engage in interjurisdictional adaptive governance activities, and to shift coastal protection strategies to proven financially and ecologically sustainable methods that build resilience.

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Chapters

Chapter 1, Introduction

What is coastal resilience?

Climate change and sea level rise challenge coastal communities with shoreline erosion and more frequent and severe flooding. Infrastructure, homes, and businesses are damaged and destroyed. Lives are threatened. There is public outcry for government at all levels to *do something about it.* What should be done when and by whom? And the eternal policy question, who will pay? These are the central practice and policy questions of the emerging field of climate change adaptation, recently expanded and rebranded as "resilience."

Resilience is the preferred outcome when human and natural systems clash and compete for resources. Building resilience is the process of building adaptive capacity into social, built, and ecological systems. There is not a fixed comprehensive definition of resilience[1], but one that is used often and has garnered consensus is from the team at the *Stockholm Resilience Centre (SRC)* at Stockholm University:

> The capacity of a system - be it a forest, city or economy - to deal with change and continue to develop; withstanding shocks and disturbances (such as climate change or financial crises) and using such events to catalyse renewal and innovation. (Moberg & Simonsen 2014)

---

[1] Here is another example of a widely-accepted definition of resilience: The New York City Panel on Climate Change uses the definition of the term resilience presented by the Intergovernmental Panel on Climate Change (IPCC) in Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (Lavell et al., 2012), but with emphasis on improvement of city systems in contrast to their simple restoration. "Resilience is the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a potentially hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures" Rosenzweig & Solecki (2015).

This definition moves resilience objectives beyond those of existing adaptation models that encompass only "withstanding shocks and disturbances" (Moberg & Simonsen 2014) or bouncing back after a hazardous event (NOAA Ocean 2015). Systems that are resilient would have the adaptive capacities to use disastrous events to become stronger. They would be "antifragile, gaining from disorder" (Taleb 2012). What would this look like? How could a coastal environment and community gain from flooding and inundation? Could eroding shorelines catalyze some kinds of environmental or economic renewal? Across the globe, coastal resource managers, engineers, urban planners, ecologists, sociologists, economists, architects, attorneys, policymakers, community leaders and others are working together to explore what resilience means and how to achieve it. To plan and achieve resilient systems, we first need to identify and describe what resilience is for any given set of systems, and then quantify, qualify, and measure it. Indeed, according to Gibbs, "…there is a lack of consensus-based definitions and performance measures for assessing resilience. These factors, along with other barriers, will need to be overcome before effective resilience-based management can be implemented" (Gibbs 2009, p. 322).

This lack of precise definitions and measures (Ford et al. 2013) of coastal resilience are problematic to the adaptation field and present analytical challenges to this study. In lieu of a set of specific coastal resilience definitions, the adaptation practices found in the municipal regulations in Chapter 3 and the expert opinions from the interviews presented in Chapter 4 are used as definitions and practice benchmarks. The descriptive statistics and qualitative characteristics of the municipal regulations and interviews are used to measure prominence and relationships, but do not measure resilience on the ground. The presence of coastal adaptation practices in a town's regulations does not indicate that the town is resilient or whether or to what extent it has implemented any of these practices. Therefore, this study does not attempt to discover

whether a particular town's systems are, in fact, resilient. It does seek to answer a foundational question of whether a town has municipal regulations that can support or facilitate coastal resilience practices. One of this study's conclusions is that in the process of quantifying and qualifying resilience and adaptation practices, aspects emerge to define resilience and create the frameworks for measuring coastal resilience.

Used broadly, if the term "resilience" is going to be more than a rebranding of adaptation, it needs to be defined and measured (i.e. characterized) in terms of both human and natural systems and the relationships between those systems. It would be ideal to have between-systems coastal resilience measurement definitions and tools. Most existing tools measure either economic (human) or ecological (natural) system impacts, but not both together, though new between-systems resilience measurement tools are being developed.[2,3] Chapter 5 of this study presents an integrated spatial-econometric method to measure localized economic and ecologic impacts of accelerated erosion caused by coastal protection structures like seawalls. The results demonstrate the effects of a feedback loop between human systems (seawalls, property values) and a natural system (shoreline).

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[2] An important example of new between-systems measurement for coastal systems resilience is presented in "Assessing Measures of Resilience in Coastal Communities, an analysis and evaluation of existing resilience indicators and indices (measurement tools) by Porter Hoagland of the Marine Policy Center at Woods Hole Oceanographic Institution. He has concluded that eight commonly used major indicators and indices have significant limitations and constraints and so are inadequate or unwieldy to use as a standard metric for measuring coastal resilience Hoagland (2016). His critique includes tool limitations of being too-slow-to-change, too subjective, having spatial and temporal constraints, or too many components. He and his team have developed and presented a metric that addresses these limitations using a time series econometric formula that includes per capita income and chained GDP to estimate the effects of a coastal hazard events like hurricanes and storm-surge. The metric returns an event analysis that "reveal[s] a range of vulnerability-resilience combinations" on an easy-to-interpret curve and cross-tabulation Hoagland (2016, pp. 14–19).

[3] Note that Porter Hoagland, PhD, Senior Research Specialist, Marine Policy Center, Woods Hole Oceanographic Institution, is a member of this dissertation's committee. He is the main advisor for Chapter 5.

Facilitating coastal resilience

This study identifies coastal resilience practices from the field and the literature and uses them to evaluate the resilience-readiness of municipal regulations in three Massachusetts towns that are experiencing frequent and challenging coastal shocks and disturbances. To build resilience, or engage in any other activities, there must be a foundation of laws and policies that facilitate, or at least do not prohibit, changes in how things are done. Business-as-usual has brought us to a place where we see annual personal and property loss, crumbling seawalls, inundated infrastructures, and strained municipal budgets. Society is well-versed in traditional coastal adaptation practices. We know how to build seawalls and floodgates. To fulfill the public's demand that governments "do something about it" there needs to be a departure from business-as-usual. What are the practices that will leap coastal systems forward into resilience? What are the policies and regulations needed to support those practices? How will governance need to adapt to facilitate building resilience?

During the interviews for this study, Massachusetts municipal officials in charge of coastal management expressed frustration that there is not comprehensive coordinated project planning and implementation to achieve long-term resilience on the Massachusetts and Atlantic coasts. Their assessment is that although current state and municipal regulations and policies do prohibit many egregious activities, they do little to advance meaningful comprehensive planning and action. This is most concerning given that sea level rise and erosion are and will continue to press the physical boundaries and use of our shorelines (*Sea Level Rise Study: Marshfield, Duxbury, Scituate, Massachusetts*, 2013, Union of Concerned Scientists 2014). Regulations and policies must address environmental practices, coastal stabilization, land use, building practices, and

property rights. In her 2013 article in the *Boston College Environmental Affairs Law Review*, Lara Guercio concludes:

> Most of the state's [Massachusetts'] existing coastal property law and legal doctrines likely will prove inadequate over the course of the current century for resolving public versus private property ownership and use disputes. As unprecedented changes and shifts in local coastlines associated with and primarily caused by climate change occur, the current jurisprudence will prove ineffective. (Guercio 2013, p. 401)

Officials expressed concern about the trend of using property rights to tie up coastal protection and resilience projects in the courts. So, in addition to the need for adaptive governance, meaningful regulations and best practice tools, there is a need to resolve the conflicts of the Public Trust and private property rights in terms of the public benefits of resilience objectives. These conflicts appeared in every stage of this study. Interview participants discussed some actions to mitigate these conflicts, there are solutions presented from the literature, and proposed actions and recommendations are discussed.

Central purpose of this study

The central purpose of this dissertation is to contribute to the understanding of municipal coastal resilience policy and practice in the emerging multidisciplinary field of resilience studies. I address foundational policy questions with the express intent of contributing to the development of the discipline. This project identifies municipal coastal resilience characteristics, how resilience (and adaptation) is expressed legally through regulations, governance, and property rights, whether those expressions facilitate resilience practice at the municipal level, and what some of the

economic and ecological effects are of the existing dominant default coastal stabilization practice (building hard structures like seawalls).

Characteristics of coastal resilience are explored by identifying the presence of resilience practices in municipal regulations in Chapter 3. The regulations of three Massachusetts coastal towns are examined to evaluate how they compare to the coastal resilience practices found in the literature and in practice. Recommended municipal actions that should facilitate their implementation are discussed. The results of the evaluations of regulations and policies in this study should help to inform municipal governments to build adaptive capacity[4] and resilience into community systems.

Practitioners' experiences with coastal planning, implementation, and their views on governance are collected through the content analysis of interviews presented in Chapter 4. These contribute to identifying characteristics of coastal resilience. Coastal governance characteristics are examined from these officials' viewpoints at the municipal, regional, and federal levels. Real-life conflicts are revealed by the interview participants. Many of these conflicts constitute barriers to resilience project implementation are around issues found in the literature and case law. There are battles between private property rights and actions proposed to protect and enhance the public benefits that coastal ecosystems provide to the community-at-large. The analysis of these conversations with officials and practitioners will contribute to understanding the complexities and conflicts in decision-making and implementation of coastal projects.

---

[4] "adaptive capacity - the idea that it is not simply possible or even desirable to return to a former conditions; that entities (people, organizations, communities) should strive to learn from and creatively respond to disasters and disruptive events and trends; and that they should evolve and move from a crisis or disaster to a new and perhaps improved (but undoubtedly different) set of circumstances" Beatley (2009, p. 5).

Results of the spatial and hedonic price analysis model presented in Chapter 5 can help inform municipal decisions about coastal stabilization projects. The model exposes the unintended consequences of accelerated erosion from coastal armoring. It demonstrates the friction of public versus private benefit and quantifies the economic inequities driven by the feedback loop of human and natural coastal systems. It shows, among other things, that the prevalent "armoring as first defense" response may not be resilient, and can, in fact, inflict economic and ecological damage. It supports the case for municipalities to check their automatic response to property owners' pressures to "build a wall," and to consider the net benefit and employ more resilient options. This study demonstrates the relationship between coastal protection structures, accelerated erosion, and waterfront property values in Massachusetts using before and after seawall simulations and a framework for net benefit analysis.

Resilience practices

It is common for coastal communities to protect developed shorelines from coastal erosion and storm-related flooding with costly publicly funded engineered hard structures like seawalls, bulkheads, jetties, and groynes. These forms of coastal protection can degrade coastal ecosystems and disrupt geological processes, resulting in unintended erosion and its consequent effects on property and infrastructure (Beatley 2009, Mague 1999a, 1999b). Coastal resilience practices offer communities more economically and environmentally sustainable ways of adapting to the impacts of shoreline change and the negative effects of climate change like sea level rise and increased coastal storm activity that bring more frequent and severe inundation.[5]

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[5] In Chapter 3, all categories of coastal resilience practices and governance actions are compiled as the coding structure in the NVivo *NVivo 11 Pro for Windows* analyses.

The concept of coastal resilience combines the principles of sustainability, hazard mitigation, and a community's ability to adapt and respond to abrupt or gradual environmental changes (Beatley 2009). Coastal resilience practices that this study addresses encompass three broad categories of actions: coastal resource management, building codes, and land use regulations. Governance that adapts to society's and the environment's changing needs is a key feature of successful resilience (Bosselmann et al. 2008).

Examples of resilient coastal resource management practices are beach renourishment, dune stabilization, movable marshes, and living shorelines (Swann 2008). These strategies are informed and supported by the coastal sciences that predict that allowing unobstructed tidal action in the littoral zone, that area that extends from the high water (tide) mark on a beach seaward to include the intertidal zone (Davis & FitzGerald 2004), of beaches and the shore can improve the health of coastal ecosystems (Sloss et al. 2012). In turn, healthy ecosystems provide valuable services, including resilience to coastal hazards (Cunniff & Schwartz 2015). Barrier beaches and dunes provide buffers during storm events (Taylor et al. 2015). Estuaries and coastal wetlands act as natural flood and inundation control systems and carbon exchanges (Davis and FitzGerald 2004).

Examples of resilient building codes are requirements for elevated and anchored buildings, elevated utilities, use of breakaway walls, and permeable ground floors (Aerts, Jeroen C. J. H. & Wouter Botzen 2011, Grannis 2011).

Examples of resilient land use practices are rolling easements (Titus 2011), special zoning overlays, restricted building zones, elevation of structures and utilities (FEMA 2016a), property buybacks (Grannis 2011), and managed retreat (Siders 2013) and relocation (Grannis 2011, Kim & Karp 2012).

In this study, these resilience practices are quantified in the municipal regulations and their implementation is discussed by practitioners.

Why our coasts need to be resilient

Resilience is a system's (or a network of systems') capacity to withstand severe shock and then become stronger by learning from and adapting to the disaster (Beatley 2009, pp. 3–4).

As extreme weather events and sea level rise intensify, the risks and hazards to people and property on the coast multiply. The costs of emergency response, disaster management, rebuilding, insurance subsidies, compromised utility and transportation systems, and lost revenue can overwhelm municipal, state, and federal budgets (H. John Heinz III Center for Science, Economics, and the Environment 2000). Climate change and rising seas magnify extreme weather events and their costs. *Superstorm Sandy* was estimated at $65 billion (Executive Office of the President 2013).

Analysis of existing development suggests that 25% of homes within 500ft of the U.S. coast could be lost to erosion in the next 60 years, at a potential cost of $530 million dollars each year (Heinz Center 2000, Landry & Hindsley 2011, pp. 92–93).

- Approximately 60% (3.6 billion) of the world's population lives within 60km (37 miles) of the coast.
- Coastal counties constitute only 10% of the land in the lower 48 states, but have nearly five times the population density of the rest of the country.
- By 2025, 75% of the U.S. population will live within 50 miles of a coast.
- 14 of the 20 largest U.S. cities are located in coastal zones.
- Over the past 30 years coastal population growth has quadrupled; more than 69 million people now reside along hurricane prone coastlines in the United States.

Figure 1-1. NOAA facts (Coastal Storms Program 2011)

- More than 155 million people (**53% of the population**) reside in U.S. coastal counties comprising less than 11 percent of the land area of the lower 48 states.
- Roughly **1,500 homes are lost** to erosion each year.
- Nearly 180 million people visit the U.S. coast every year, and coastal states account for **85% of US tourism revenues**. The tourism industry is the nation's largest employer and second largest contributor to gross domestic product.
- **71% of annual U.S. disaster losses** are the result of coastal storms.
- Close to 350,000 homes and buildings are located within 150 meters of the ocean. Within 60 years, **1 out of every 4** of those structures will be destroyed.

Figure 1-2 WHOI Oceanus Magazine, Coastal hazard facts (Evans 2004)

As U.S. and global coastal populations increase and damages from coastal hazards escalate (Coastal Storms Program 2011, Evans 2004), the practice of using public funds to protect coastal private property, especially with expensive engineered hard structures like seawalls, is quickly becoming financially unsustainable for many communities. It is imperative that policymakers are aware of how their local bylaws and regulations will or will not support the implementation of the more sustainable methods of adaptation and protection that comprise coastal resilience practices.

Policymakers must also have access to credible arguments that will allow them to adopt coastal management policies that do more than just limit or do not permit business-as-usual engineered hard shoreline protection, but that facilitate policy changes that uphold government's obligation to preserve coastal lands in the public trust and ensure net benefits for their communities. In this study, the regulations, land use ordinances, and policies affecting coastal adaptation and protection of three Massachusetts coastal towns are examined through the lenses of The Public Trust Doctrine, private property rights, land use law, and the evolving resilience principles of climate adaptation.

The coastal sciences have provided solutions in the form of coastal resilience practices for the problems of coastal flooding, inundation, erosion, property loss, and methods to restore our coastal ecosystems so that they help mitigate the effects of climate change and coastal hazards. There remains only the political will to adopt the policies that will benefit non-human habitats, human populations, and our great coastal socioeconomic engines.

Chapter 2, Research Design and Resilience Practices

Overview of the research design

The goal of the research design is to use quantitative and qualitative methods to produce an integrated analysis (Teddlie & Tashakkori 2009) that examines the capacity and potential for Massachusetts coastal communities to implement coastal resilience practices given existing regulatory, policy, and governance environments. The case study is used as the platform to produce a "research synthesis…of the drawing together [of] the evidence" of the mixed methods analyses from the regulations review, interview content analysis and the spatial-hedonic price analysis sections (Pawson 2008, p. 130).

Each method and combination of methods address a part of the multi-faceted question this dissertation asks, "What is the capacity of local regulations and governance to facilitate coastal resilience in Massachusetts?" It is evident from the analysis in this study that new paradigms in regulatory frameworks and governance are needed to address and cope with impacts of climate change, including sea level rise and inundation. Quantitative information alone is not sufficient to understand the dynamics at work in the feedback loops of the human and natural systems on the coast. The challenges faced by those responsible for local coastal governance are more complex than quantitative analysis of a survey instrument could capture, so qualitative content analysis of interviews was used to achieve a deeper understanding.

There are three sections to this study, each with its own research design. An overview of each is presented here with more detailed descriptions in the corresponding chapters. The results of each inform the conclusions discussed in Chapter 6. First, in Chapter 3, is an integrated content and quantitative analysis with descriptive statistics using *Nvivo (NVivo 11 Pro for Windows)* of

municipal coastal regulations and policies of three Massachusetts towns, Chatham, Newbury, and Scituate.[6]

Second, in Chapter 4, is a qualitative content analysis of in-person semi-structured interviews with coastal resource professionals. The six interview participants include municipal coastal resource managers and conservation commissioners, and a federal-level coastal expert that works with Massachusetts state and municipal officials and on Atlantic regional coastal planning and projects. The relationships of these interviews with the findings of the regulations analysis in Chapter 3 are discussed in the context of the local governance issues raised by the interview participants.

Third, in Chapter 5, is a spatial-temporal simulation using geographic information system (GIS) software (*ArcGIS for Desktop 10.2*) to calculate erosion rates that are used in a hedonic price model (HPM) in *MS Excel* (*Microsoft Excel*) to estimate the cost effects on property values of accelerated erosion related to the installation of seawalls. The findings of this section provide data that engages the difficult issues raised by the theoretical framework of this dissertation. Namely, there are unintended consequences to public lands and private property from the use of traditional hard-engineered coastal protection practices like seawalls. How can our regulatory and governance environments evolve to honor the covenant of the Public Trust (and possibly to use that covenant to advance more resilient and sustainable solutions) and at the same time address the demands and avoid the legal ire of private property owners? Some conclusions and recommendations are offered that include characteristics about the scope and limitations of municipal regulations and coastal resilience practices. Conclusions from the interviews reveal the struggles and constraints faced by

[6] See the "Table of Regulations Analyzed" in Chapter 3.

coastal resource managers in trying to piece together and pay for solutions that work in the best long-term interests of our coastal shorelines and of those that live, work, and play there.

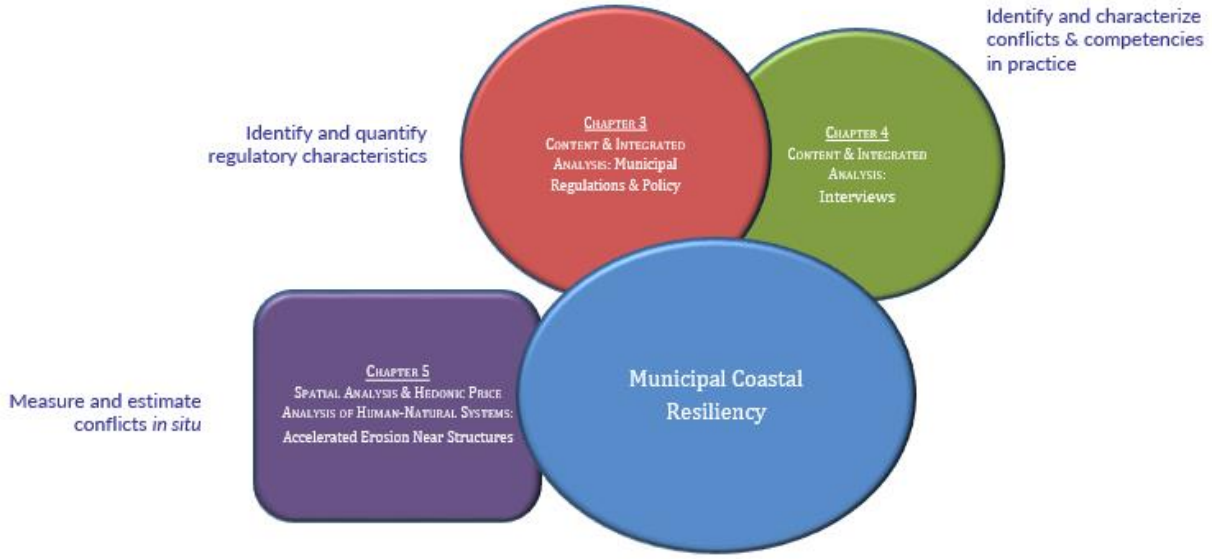

Figure 2-1 Research design

Frameworks

Theoretical framework: A discussion of The Public Trust Doctrine and Coastal Resilience

Coastal resilience and climate adaptation in general, are about, or should be about, the greater good. Humans adapt. Our species survived because it adapted to climate change (Smithsonian National Museum of Natural History 2016). Now, we are faced with the tasks of adapting our built environments, preserving and harnessing natural systems, and modifying individual and group behaviors to cope with the impacts of climate change. On the coast, adaptation efforts often benefit small groups or private interests, as in the case of the two coastal structures examined in Chapter 5. To progress from simpler traditional coastal adaptations like building seawalls to more comprehensive resilience programs that engage human and natural systems for the greater good, it is necessary to tackle the opposing concepts of the Commons (Bollier 2015) and private property rights (Mague 1999a). The Commons is

preserved in the Public Trust Doctrine (Slade et al. 1997).[7] In Massachusetts, because of the way rights in tidelands is demarcated as explained below, the coastal commons is not as wide-ranging as it is in most other coastal states. However, the public does have rights in trust to the shore and also a responsibility to preserve our coastal environments (MCZM 2005). There is one theory that has the potential to carry the legal and public policy burdens needed to support the difficult governance decisions in favor of the public benefit of our coasts, the Public Trust Doctrine (Hansen 2015, Sax 2010).

Justification for asking the questions in this study is provided in part by the principles found in The Public Trust Doctrine (PTD). Case law involving PTD issues has supported the rationale of governments' positions that coastal private property lines are not static, particularly in questions of public benefit (Guercio 2013, Mague 1999b). As explained below, this confirmation by the courts will be vital to a local jurisdiction's ability to implement certain coastal resilience practices that may involve infringement on private property for the public good that would otherwise result in a taking (Titus 2009). Without a legal basis for implementing these resilience practices, some of this study's research questions would be moot. The following discussion is an overview of the relationship of the PTD and the research questions.

As coastal hazards increase,[8] and as more coastal properties experience erosion and flooding, the inclination of property owners is to appeal to local and state governments for help to protect their properties. Using tools like armoring the coast with seawalls and other built structures, and replenishing sand on beaches with beach renourishment projects have been

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[7] "The Public Trust Doctrine is a common-law doctrine of property law, customized by each state, which establishes public rights in navigable waters and on the shore." https://shoreline.noaa.gov/policy/

[8] See the NOAA and WHOI facts in the section titled "Why our coasts need to be resilient" in Chapter 1.

common practice for centuries. Coastal communities have typically chosen to protect developed shorelines from coastal erosion and storm-related flooding with engineered "hard" structures like seawalls, bulkheads, jetties, and groynes. These structures are expensive to construct and maintain. Their protection benefits may accrue only to a small percentage of the population that financed them, and the damage they cause to the natural environment and even nearby properties is coming under increased scrutiny (Foster 2010). The figure below shows some negative effects from seawalls to Massachusetts' public trust interests (Mague 1999b, p. 105).

Table 2-1. Effects of coastal structures on Mass. Public Trust interests, From Mague 1999b

Summary of effects associated with seawall construction and impacts to Massachusetts' public trust interests.		
Effects Associated with Seawall Construction	**Direct or Indirect Impacts on MA Public Trust Interests**	**Public Rights Impacted**
Reduction of sand available to shoreline reach	• loss of downdrift coastal resources • loss of finfish and shellfish habitat, nursery, and spawning areas • loss of shorebird & migratory waterfowl habitat • degradation & destructions of highly productive marsh-estuarine ecosystem	FISHING and FOWLING
Alteration of tideland seaward of shoreline protection structure	alteration and degradation of shellfish habitat	FISHING
Loss of beach & projection of seawall into surf zone, at most stages of the tide	obstruction of access between high water and low water marks	FISHING, FOWLING, and NAVIGATION
(Note: The Negative Impacts to Coastal Resources, Associated with Shoreline Protection Structures, are Cumulative and Magnify with Time)		
Figure 5 from Mague, S.T., 1999. Private Property, Public Rights, and Shifting Sands: The Public Trust doctrine as a Source of Authority for Coastal Management Decisions, Part 2 of 2, p. 105		

In Massachusetts, the public has the right to access and use the private tidelands[9] for three types of activities: fishing, fowling, and navigation. General recreation activities that are not related to fishing, fowling and navigation, like strolling or sunbathing, are not permitted on private tidelands (i.e. the beach and other areas between the low tide line and the private waterfront property) (MCZM 2005).[10] Fishing, fowling, and navigation are the traditional public rights in the tidelands, but in other coastal states that apply the PTD more broadly than Massachusetts, the public's rights held in the PTD are expanding to other uses. For example, recreational activities and environmental preservation projects have been adjudicated using the Public Trust Doctrine (Sagarin & Turnispeed 2012). Massachusetts' legal and legislative agility to adapt the common law principles of the PTD to the rapid changes on the shore may lag behind the coastal states that use the mean high tide line as the limit of private property, but public pressure on policymakers to respond to the damages from more intense storms and inundation will spur Mass. officials to act.

Practitioners, advocacy organizations, and the public want proven coastal resilience practices to be adopted and implemented. However, some of these practices, like rolling easements and movable marshes, can require private property owners to relinquish portions of their property for the public benefit. How can cities and towns implement such resilience practices? On what grounds can a municipality enact land use policies, zoning ordinances, or other regulations that would facilitate the implementation of these coastal resilience practices

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[9] Private tidelands are the area from a waterfront property extending to the low water line (i.e. the lowest point at low tide). So, private waterfront property includes the beach (and other area like dunes) all the way to the low tide line. In most other coastal states, private property extends only to the high water line (i.e. the highest point at high tide often indicated by the line of vegetation that gets washed up onto the beach at high tide) Fischman (2012).

[10] If a person is walking along the beach that is adjacent to private property, that beach belongs to the private property owner, so the casual beachgoer is unwittingly trespassing MCZM (2005). In other states where lands held by the state in the public trust extend from the private property line all the way to the low tide line, the public has rights of access and use to use the beach for recreation; walking along the beach between the high tide line and the water is permissible.

that are designed to preserve and protect human and natural resources that vibrant coastal economies rely on? Local jurisdictions should be able to use the principles established by legal precedence using the Public Trust Doctrine to defend regulations and policies that enable the implementation of coastal resilience practices (Sax 2010). In fact, since the 1960s, the PTD has been used as the basis of statutes to protect non-navigable public lands and "has been applied to protect a wide range of natural resources for nonconsumptive uses" (Sagarin & Turnispeed 2012). Another factor that will spur "inventive legislation" that supports resilience practices (like rolling public easements over private land) is the landward migration of the shoreline (and thus property lines) as rapid and dramatic coastal ecosystem changes occur because of more severe storm activity and sea level rise (Byrne 2010).

The Massachusetts Public Trust Doctrine protects the interests of the public in public lands and private property rights do not subordinate these public interests (Mague 1999a).[11] Even though the Massachusetts Doctrine narrowly interprets the public rights to the traditional purposes of fishing, fowling, and navigation and their natural derivatives (Public Rights), Massachusetts courts have strictly protected these rights (Mague 1999a). Both the protection of private property by armoring coastal areas with seawalls and other structures, and economic development projects are subject to the rights of the public in tidelands under the Public Trust Doctrine.[12] This means that as shorelines erode and coastal conditions become more threatening to the public's rights in the tidelands, there is potential that in Massachusetts as in other states, the PTD could also support public benefit claims (Sax 2010).

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[11] The Mague reference includes these cases: *Pazolt v. Director of the Division of Marine Fisheries*, 417 Mass. 565, 571 (1994), citing *Crocker v. Champlin*, 202 Mass. 437 (1909). Also, *Opinion of the Justices*, 365 Mass. 681, 685 (1974).

[12] The permitting and building of coastal protection structures are also subjected and regulated by the Mass. Wetlands Protection Act, 310 Code Mass. Regs. Section 10.

In *Boston Waterfront Development Corp v. Commonwealth*, 378 Mass. 649 (1979) *(Boston Waterfront, 1979)*, the Massachusetts Supreme Judicial Court held that "the [tide] land in question is not, like ordinary private land held in fee simple absolute, subject to development at the sole whim of the owner, but it is impressed with a public trust, which gives the public's representatives an interest and responsibility in its development." This is an important concept, especially considering that about 70% of the total population of Massachusetts resides in coastal areas and that more than half of the state's development activities take place in only 25% of its area, namely, in the coastal zones.[13] In addition, coastal property lines shift with the changing shoreline, adding a layer of complexity and frustration not usually found in inland property disputes. The Massachusetts Office of Coastal Zone Management calls for "mutual respect" between the public and private coastal landowners.[14] This mutual respect is virtually nonexistent when it comes to disputes about private property lines, the public's right to access and use of the shore, and the deleterious effects to public lands caused by the effects on the shoreline of coastal structures to armor the shore installed by private parties and governments. Coastal communities interested in adopting coastal resilience practices must attempt to manage these competing interests when they develop the regulations policies that support resilience practices. In order to assess their legal position when they implement resilience practices, they must also be aware of how their existing regulations may or may not support the interests of the public benefit over private property rights (Byrne 2010).

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[13] NOAA, Mass. coastal facts, 7.8 mil people in coastal areas, 1519 miles, http://coastalmanagement.noaa.gov/mystate/ma.html and Mass. Coastal Zone Management Program, Shoreline facts on population and development, Chapter 2. http://www.mass.gov/czm/plan/docs/czm_plan_ch2.pdf and U.S. Census 2010, Mass. population facts at http://quickfacts.census.gov/qfd/states/25000.html

[14] Mass. Office of Coastal Zone Management, *Public Rights Along the Shoreline – Fact Sheet,* http://www.mass.gov/czm/shorelinepublicaccess.htm and *Shoreline Public Access,* http://www.mass.gov/czm/spa2.htm

The enactment in Massachusetts of the Colonial Ordinances of 1641 – 1647 which is considered to have established the geographic scope of the Massachusetts Public Trust Doctrine (Mague 1999a) recognizes that the coast is not static, but changing, and that the boundaries of public lands change when the natural processes of shoreline change create more new public trust lands landward of existing boundaries (Mague 1999b). This presents one of the most contentious features in the battles between private property boundaries and the public rights in tidelands. The changing shoreline is a condition that can prompt a community to consider coastal resilience practices like rolling easements.

The unanimously decided (J. Stevens recused) U.S. Supreme Court case, *Stop the Beach Renourishment, Inc. v. Florida Dept. of Environmental Protection,* 560 US 702 (2010), (*Stop the Beach v. Florida EPA, 560 US 702 (2010)*), reaffirmed the principle of the Public Trust Doctrine that private property rights are subject to the Public Trust and the state's obligation to preserve those rights. The decision also reminded private coastal property owners that they do not automatically gain title to land area added to beaches by manmade or natural processes and that their coastal property lines are subject to change. This decision, though not directly related to coastal armoring with hard structures like seawalls and revetments, is expected to affect decisions by private coastal landowners and municipalities when they are considering installing new or replacing aging structures. It is reasonable to expect that the decision will also offer support for states and municipalities when they implement coastal resilience practices that may require infringement of private property for the public benefit.

The boundary lines that demarcate public and private rights in tidelands vary from state to state depending on a state's current and historical applications of the Public Trust Doctrine. In Massachusetts, the public trust boundary is marked by the mean low water line (MLW),

sometimes referred to as the low water vegetation line (Higgins 2008). Massachusetts and six other coastal states use the Mean Low Water line (MLW) method, see the tidelands jurisdictional boundaries figure below (Hicks 2006, p. 56). Consequently, the Massachusetts method gives deference to private landowners (Mague 1999a), and some issues of public access to the shore may be moot because the line of demarcation automatically excludes public access. This may seem to work against the idea that resilience practices that infringe on private property rights would be legally accepted. But, despite the Massachusetts line of demarcation, the principles in the Public Trust Doctrine that apply to changes in private property lines and any deleterious effects to public lands caused by unintended erosion from coastal structures should still support the implementation of coastal resilience practices in Massachusetts. Alternatively, Joseph Sax argues for a change from common law rules dominating these types of property disputes to a balanced approach that accounts for the legal complexities and is also sensitive to the government's interest in the public's greater good:

> "The traditional common law rules do not fit contemporary circumstances. The rate and magnitude of the rising sea levels are physically quite different from the historical experience out of which the common law rules [i.e. applications of the PTD] grew. We are facing a historically distinct situation that is not a good factual fit with the "background" rules." (Sax 2010, p. 645)

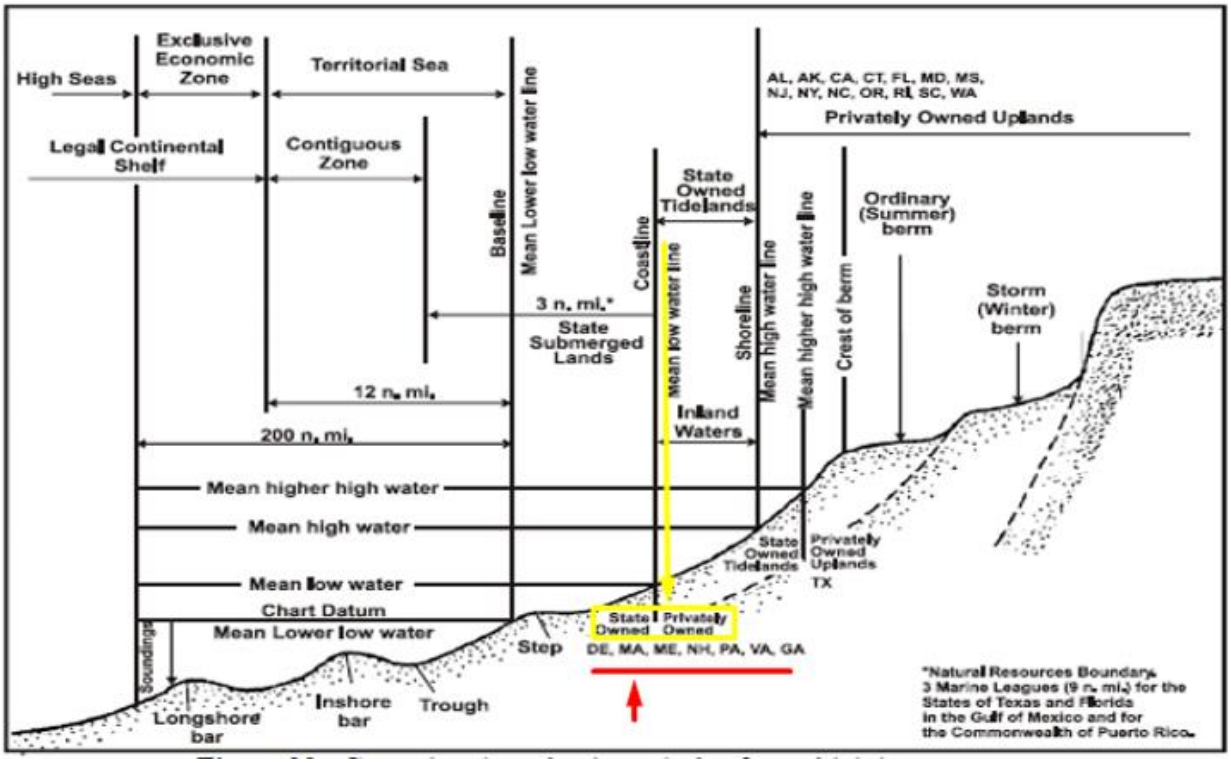

Figure 2-2 "Diagram of coastal and marine jurisdictional boundaries in tidelands" shows the different tidal zones and various state boundaries in tidelands (Hicks 2006, p. 56)

The discussion about how to adapt and preserve our coastal areas in their capacities as economic centers, recreational and scenic enjoyment areas, habitats, and will continue to be held, at least in part, in the courts, as the perceptions of private rights and public benefits collide with the adoption and implementation of coastal resilience practices in coastal communities.

A theoretical framework in the making: Advocacy Coalition Framework

Rapid and continuous policy learning and development are taking place in the emerging field of resilience studies and practices. This paper does not attempt to identify all the policy analysis theories that could apply, but some are prominent and worth mentioning here. I expect that there will be many dissertations and journal articles in the next decade that will examine the policy theories in play today. In terms of governance, policy actors and stakeholders are trying to

figure out how and with whom to work and ally themselves with. These are advocacy coalitions in the vein of Sabatier's and Jenkins-Smith's Advocacy Coalition Framework (Weible et al. 2011). The process of forming advocacy coalitions is fluid and dynamic. Through this study, I have observed coalitions shape-shift to fit the targeted governmental level of action. Interview participants expressed the need to form alliances with different groups of stakeholders depending on the level of governance from which action was expected: local, state, regional, national, trans-national.

Conceptual and analytical frameworks

Climate change adaptation and resilience studies is an emerging academic discipline, as previously discussed, that draws on concepts from other disciplines like environmental science, sociology, engineering, law, economics, and political science. The disciplines that provided the main concepts in this study follow.

Legal concepts from land use and environmental law (Callies 2004, Percival et al. 2009, Titus & Craghan 2009), and coastal law (Baur et al. 2008, Christie & Hildreth 2007), informed each section of this study. Land use law is a major driver of coastal adaptation and resilience practices since many of the issues revolve around zoning. In fact, of the 389 mentions of *Resilience* practices in the analysis of municipal regulations in Chapter 3, 299 (77%) of them were in the Land Use category.

Coastal processes science was necessary to understand erosion and how shorelines change, the manmade methods used to combat erosion and the natural coastal features that provide ecosystem services (Borrelli 2009, Davis & FitzGerald 2004).

Coastal zone management and policy provided the basis to understand the interplay of natural resource management, land use law and regulation, and public policy that is in constant flux in coastal communities (Beatley et al. 2002, Brzeski et al. 2013, Heinz Center 2000).

Economics in the coastal zone, especially the economic effects of coastal structures, proved to be a key conceptual framework in each section of this study (Eberbach & Hoagland 2011, Fankhauser 2010, Kraus & Pilkey 1988, Yohe 1991). Ecological and public sector economics, and particularly the economics of the commons, contributed concepts that deepened the discussion about the parameters of governance (Fankhauser 2010, Hinkel et al. 2014, Krause 2012, Ostrom 2007, 2008). Policy decisions are often made, or at least highly influenced by using greatest net benefit or cost-benefit analysis. In the Chapter 3 analysis of municipal coastal regulations, the majority (64%) of reasons stated as the purpose of a regulation was economic in nature (loss reduction or protection). In the Chapter 4 analysis of the interviews, all the participants expressed exasperation about funding issues. Their complaints were not always about lack of funding, although there was consensus that there is never enough funding for long-term coordinated cross-jurisdictional comprehensive coastal adaptation. Every participant mentioned that the piecemeal way funds were allocated resulted in either wasted money on short-term ineffectual projects or took away funding from more substantial projects.

Analytical protocols

Analysis involved identifying those types of and specific regulations that would facilitate or hinder coastal resilience practices in communities. Interviews with coastal resource managers and others that have extensive experience in the field yielded significant guidance to the analysis. The following principles of land use law, private property rights; coastal governance, law and

policy; and public sector and ecological economics informed the analysis of the qualitative results regulations and interviews and the discussions in the conclusions in Chapter 6.

Land use law and private property rights

The Coastal Zone Management Act of 1972 (CZMA) (*Coastal Zone Management Act of 1972, 16 U.S. Code Chapter 33, Sections 1451 - 1466*, 2006) drives most of the land use and shoreline protection responses to coastal hazards. CZMA articulates the requirement to protect natural coastal systems, but recognizes that the governmental "arrangements for planning and regulating land and water uses" are "inadequate" to address these competing demands (Callies 2004).

Private property rights fall under the purview of land use law. Regulatory takings lawsuits are a constant concern to coastal resource managers. Some of the coastal resilience practices that result in the best outcomes are fraught with property rights issues (Titus 2009). Experts in the coastal zone management field have argued that the Public Trust Doctrine does indeed encompass many of these property rights issues and provides the necessary "legal cover" in the form of public benefit to the implementation of some of the more contentious coastal resilience practices like rolling easements and no-build zones (Mague 1999b). In fact, some traditionally allowable practices that are codified in local land use ordinances like the construction of privately owned seawalls or revetments encourage responses to coastal hazards and shoreline change that can be shown to be contrary to the public benefit (Coburn 2011). These traditional responses may also delay the adoption of more beneficial coastal resilience practices.

Public benefit

Public benefit is determined many times by employing economic measures. Indeed, in the U.S., economic considerations often trump environmental in debates on how to proceed with coastal resilience projects. Part of this impulse to rely on economic measures is because, until relatively recently, the economic benefits of ecosystem services had not been quantified. The vague (to policy makers) notion of the value of beaches and marshes as shoreline protection features, for example, had not been part of budget conversations. As the field of ecological (sometimes also called "environmental") economics develops and its proponents' studies filter into the public debate, policymakers are more comfortable including these topics in their deliberations.

Implementing coastal resilience practices requires a sea change in thinking about coastal property and resources. In other words, common pool resources like these afford benefits to users that do not have the motivation to "cooperate to overcome the commons dilemmas they face" (Ostrom 2007), but state and local governments can and should have "the motivation to design efficient and effective rules to sustain" the use of these resources "over the long run" (Ostrom 2007). This updated theory of application to the Tragedy of The Commons (Feeny et al. 1990, Hardin 1968) operates in the background, driving public opinion and perception about protecting the shared economic and ecologic benefits of coastal resources.

Another facet of the economic analysis comes from the established and relatively straightforward concept of cost benefit analysis in public sector economics. It is easy to grasp that building a $5 million seawall to protect a group of homes that cumulatively returns $200,000 per year in property taxes is not a project that is designed for the greater public benefit of all taxpayers in a town (Coburn 2011).

An extension of this simplified cost benefit scenario in ecological economics involves applying and modifying tenets of the Coase Theorem (Tresch 2008) of shared and negotiated solutions to cases where not all consumers of a public good (the coastal shoreline) are equally affected by the risks and costs of coastal hazards or the negative externalities caused by the presence of publicly or privately owned coastal protection structures like seawalls (Eberbach & Hoagland 2011, Eberbach 2007, Jin et al. 2015, Kolstad 2000, Kriesel et al. 2000).

This is the motivating idea behind Chapter 5 of this study that contributes data that shows a relationship between the presence of coastal engineered protection structures like seawalls and revetments to accelerated erosion rates (a negative externality) that affect properties that do not benefit from the structures.

Introduction to Coastal Resilience Practices

Coastal resilience is a relatively new policy area. Data about what practices and combination of practices work in what conditions is being gathered to help inform policy decisions, but not enough data exists to make many determinations. There is data about traditional standalone practices like seawalls, but most of the data was analyzed with only the simplest cost-benefit methods that ignored lost opportunity costs of strengthening existing ecosystem services, failed to account for degrading ecosystems, and failed to consider proven unintended consequences, despite the calls to do so in early works of researchers (Fankhauser et al. 1999, Yohe et al. 1995) among others. More recent analyses using do incorporate these (Landry & Hindsley 2011). Studies of combinations of practices that quantify the costs and benefits of strengthening ecosystem services (e.g. biobag-reinforced dune revegetation, beach dewatering) including socio-economic analyses are emerging that consider the recreational, aesthetic, and commercial values of ecosystems

(Häyhä & Franzese 2014, Scheufele & Bennett 2012). But, coastal resilience is as of now, basically a repackaging and reframing of the most effective new and existing hazard mitigation and adaptation practices, flood avoidance and response strategies, ecosystem restoration practices, negotiated solutions between at-risk property owners, and innovations in land use planning (like managed retreat). Researchers and practitioners are building and sharing knowledge bases to identify the practices and governance instruments and the legal agility that work together to build systems resilience. Methods of analysis are developing along with the definitions and measurements of resilience that are providing data for the next level of evaluations of coastal resilience (Ford et al. 2013, Hoagland 2016).

Which, if any, of the practices discovered in the analyses in this study would help make Massachusetts coastal communities resilient? The practices named and recommended in the literature (that apply to the types of shorelines in this study), town regulations, and interviews are assumed to be best-suited to the coastal conditions of the Massachusetts case towns. It is also assumed, based on the literature, that these practices are foundational to building coastal resilience.

Though the term "resilience" is conceptually well-defined, the practical mechanics of how to approach it are works in progress. This study identified methods and regulations used "on-the-ground" and suggested by practitioners that contribute to building resilience. The content analysis of the regulations chapter provides specific information about the types and frequency of mentions of resilience practices. The analysis of the semi-structured interviews creates a picture of the relationships of the regulatory and practice environments. Specificity is a goal of the research design to tackle issues in an emerging field with early-stage concepts (Booth et al. 2008). Choosing a research design with methods and analytic protocols to discover specific patterns and information was important to contribute to the policy discussions about coastal resilience. These discussions

are fraught with politics and uninformed opinions on the one hand, and dry siloed scientific facts on the other. The findings of this study can be of assistance to policymakers in understanding what coastal resilience means to the communities they represent.

In addition to the concepts from the disciplines described above, there was an element of "reverse engineering" from practice to identify concepts in adaptation and resilience for this study. Practices discovered during the analyses of the regulations and practitioner interviews (i.e. *in vivo*) were added to the *a priori* list of resilience practices gleaned from the literature. As public policy professor James Connolly explains, practitioners, often unconsciously, are always operationalizing theory:

> Every practitioner approaches problems with a particular view and asks a particular set of questions based in the literature of their field (whether or not they actually realize that this is where the questions come from). They operationalize a theory. For example, urban planners ask questions from political and environmental sciences theory like, "What causes inequality, and what drives sustainability?" They the proceed to find practical solutions to those questions. (Connolly 2014)

Coastal adaptation and resilience cases from the field (often found in professional practice journals) from the US, Canada, and the EU were examined for evidence of operationalized theories, and then included in the practices list taken from the literature.

As a relatively new scholarly discipline, coastal adaptation and resilience literature is being added every month from all over the world. This poses some challenges and opportunities. A challenge is that definitions and practices of resilience in various settings and applications are being discussed and revised in the community of scholars. No particular set of definitions is standard, and "best" practices depend on the location and application; "do no harm" and "leave no trace" being objectives. The literature is sufficiently developed, though, to present consensus on many of the factors that should be included in the development of definitions and practices. The

stage of development of this field presents an opportunity for this study to contribute to the discussions.

The modern ideas of coastal resilience in the U.S. find their conceptual home in the discipline of coastal zone management (Beatley et al. 2002). Coastal zone management is built on principles from ocean and coastal law and policy (Baur et al. 2008), land use law and policy (Callies 2004, Nolon & Salkin 2006), natural resource management, sustainable development and sustainability, and increasingly from the tenets of European Integrated Coastal Zone Management (ICZM) (EC 2013). It is worth including text from the EC's description of ICZM. It is one of the best working definitions of coastal climate adaptation governance that U.S. states, municipalities, and the federal government can emulate.[15]

> ICZM aims for the coordinated application of the different policies affecting the coastal zone and related to activities such as nature protection, aquaculture, fisheries, agriculture, industry, off shore wind energy, shipping, tourism, development of infrastructure and mitigation and adaptation to climate change. It will contribute to sustainable development of coastal zones by the application of an approach that respects the limits of natural resources and ecosystems, the so-called 'ecosystem based approach'. Integrated coastal management covers the full cycle of information collection, planning, decision-making, management and monitoring of implementation. It is important to involve all stakeholders across the different sectors to ensure broad support for the implementation of management strategies. (European Commission 2013)

The next section describes the coastal resilience (and adaptation) practices collected from the literature, the regulations, and interviews.

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[15] One of the striking differences between the ability of European and U.S. jurisdictions to implement coastal resilience practices is characterized in the adage that in the U.S. all land use is local. In the EU, land use in most nation states is determined by the national government and is implemented with little or no modification by local jurisdictions. ICZM policies are constructed at the European Commission level and implemented at the national level with modifications to accommodate local conditions. This scenario somewhat mirrors U.S. federalism, so may be a valuable model when U.S. state and local jurisdictions contemplate ways to adopt and implement coastal resilience practices.

The majority of the mentions in the literature and content analyses of "physical" resilience practices fell into three categories: Building and Infrastructure Modifications, Land Use, and Green Infrastructure. The number of mentions of "non-physical" practices, also in three categories (Funding, Outreach, and Partnerships) together comprised less than 2% of the total mentions in the regulations. This section will focus on the three physical practices categories. The Funding, Outreach, and Partnerships categories were mentioned with much more frequency in the interviews, and will be discussed in Chapters 3 and 4.

Building and Infrastructure Modifications

Building and infrastructure modifications are practices that help make the built environment less vulnerable to damage from flooding, wave action and storm surge, high winds, and erosion. Many of these practices have been required for a long time, like frontage and drainage areas around buildings. Some that are relatively new to Massachusetts municipal building codes, like "freeboard" - elevating buildings sometimes on stilt-like structures - are borrowed from areas and cultures that adapted to living with coastal hazards generations ago (FEMA 2016a). Recent coastal disasters like *Superstorm Sandy* have prompted cities to promote and implement coastal resilience plans. New York City incorporated building and infrastructure practices into the city's vision and development plan, #OneNYC[16] that encompasses planning for "growth, sustainability, resiliency, and equity" (City of New York 2016a). The resiliency program budget alone is over $20 billion (City of New York 2016b).

[16] http://www1.nyc.gov/html/onenyc/index.html (Previously named PlaNYC, New York City's climate adaptation plan.)

Building resilience practices being implemented in New York are becoming common in other states and municipalities, including in Massachusetts coastal communities. When these practices are translated into building codes, they are codified as specific requirements for structure size and use, building materials, design elements, and mechanical systems and utilities placement, among others. For example, codes for: Minimum building elevation above base flood levels; structural designs that allow flood waters to pass through lower levels of the buildings ("permeability") and for "breakaway" sections that will collapse under severe conditions, but will reduce damage to the building; height, story, and use restrictions designed to mitigate damage; restrictions and requirements for storm-damaged buildings that will be rebuilt in flood or coastal hazard zones, like building floor area ratio and building lot coverage, septic bans; elevation of a building's walkways and utilities; and codes that specify the use of permeable materials like paving stones instead of concrete that mitigate the effects of stormwater runoff and floodwaters (Aerts, Jeroen C. J. H. & Wouter Botzen 2011).

Massachusetts state building codes could preempt a town's "imposition of resilient building design standards" through its own building codes (Rinke & Fort 2012, p. 93). No analysis of whether a town's building codes were consistent with Massachusetts state building codes was done in this study. It was assumed that all types of municipal regulations (building and otherwise) were compliant at the time of analysis. Building and infrastructure coastal resilience practices accounted for almost 20% of the mentions in the regulations analyzed in the three case study towns.

Land Use

Land Use coastal resilience practices, in contrast, accounted for about 80% of the mentions in the case study towns' regulations. Land use practices found in the regulations that support or

foster coastal resilience range from permitting and enforcement rules, pollution limits, conservation inducements, deed restrictions and development limitations. They address the built and natural environments. The function of land use regulations is two-fold; (1) to encourage practices that build adaptive capacity and resilience between the built environment and human activities and coastal ecological systems, and (2) to prohibit or restrict practices that increase risk or damage to coastal human and natural systems. Many municipal land use bylaws and regulations promulgate the requirements of the Massachusetts Wetlands Protection Act (WPA) that govern the "removal, fill, dredging or altering of land bordering waters" (WPA 1978, updated 2012). The WPA is expansive in jurisdiction and scope. Every conceivable activity is addressed that could impact inland and coastal wetland ecosystems. The activities include ordinary municipal actions like dredging waterways, filling land, and installation of utility poles and sewage systems. While these activities could affect resilience, this study focuses on the land use practices that the literature and practitioners identify as basic to coastal resilience.

Almost 90% of the mentions in the hundreds of pages of town regulations analyzed came from eight types of land use practices: Permitting (23%), enforcement (19%), prohibited alterations of natural features (15%), restricted and prohibited uses (16% together), setbacks and buffer zones (6%), no build zones (5%), and zoning overlays (5%). These are common land use and zoning instruments, but the literature calls out ways these can be used specifically to build resilience.

Zoning is the primary tool that municipalities use to control development and protect critical natural resources. Local governments can create special zones (overlay districts) that "impose special regulations" to existing zones that advance local adaptation and resilience goals (Grannis 2011, p. 19). For example, a special overlay zone in coastal high hazard zone could

require elevation of new and rebuilt houses, greater setback footage from dunes and salt marshes, or prohibitions on building and coastal armoring and restrictions on building usage (Grannis 2011). These land use strategies build resilience by preventing degradation of the natural coastal features like dunes and salt marshes that act as buffers of inundation from storm surge and wave action (Davis & FitzGerald 2004, Shepard et al. 2011). These special zones like increased setbacks and buffers can keep buildings, roads, and utilities farther away from shorelines that are at risk of erosion than is required by the regular zone for that area. This protects property and reduces storm damage to buildings and the shore.

Preventing degradation of naturally protective coastal features is just one side of the coin. The other side, that the shoreline is not static and needs to move, challenges human development that assumes the shoreline will remain where is it forever. The nature of sandy beaches, dunes, and salt marshes is to move and reform according to wave energy, tides, and winds (Davis & FitzGerald 2004). Their protective properties are determined by the natural forces that form them (except when humans engage in projects like beach and marsh restoration). A salt marsh lies between an ocean coast and land and acts like a sponge, absorbing wave energy and seawater that would otherwise inundate the land and properties. Salt marshes naturally "migrate" - they move, form and reform in response to the actions of the tides and beaches (sand movement). When these coastal processes cause the salt marsh to move landward, but the development on the marsh shoreline prevents its landward migration, the marsh is in danger of "drowning." This means that the marsh will be permanently under water and the ecosystem services of the marsh will be lost; there will be no buffer between the ocean and the land (Davis & FitzGerald 2004). The new shoreline will be someone's lawn or a road. How can zoning help natural features move?

Rolling easements are a land use "tool, derived from law (statutory or common) or regulatory authority [i.e. zoning], that allows publicly owned tidelands to migrate inland as the sea rises, thereby preserving ecosystem structure and function" (Higgins 2008). However, the idea of a movable property line that is at the whim of nature might elicit a vigorous "not in my backyard" response from property owners (Byrne 2010). There are ways to implement rolling easements that minimize this response and limit or prevent economic harm to property owners (Titus 2009). Rolling easements and other zoning tools like managed coastal retreat, the systematic moving of buildings and infrastructure away from sensitive or unstable shorelines, that involve more complex socioeconomic and legal issues are included in the regulations analysis in Chapter 3 (Siders 2013).

Green Infrastructure

Green infrastructure solutions are natural or nature-based features used alone or with structural methods to mitigate risk and prevent damage to the built or natural environments. The more well-known green infrastructure methods like green roofs (to reduce heat island effect) and vegetated swales (to control storm runoff) are in urban settings where they are visible to passersby (Sailor 2006). Coastal green infrastructure methods include vegetated dunes, marsh and barrier island restoration, and living shorelines. Cunniff and Schwartz of the Environmental Defense Fund produced an excellent review of the effectiveness of natural infrastructure methods in coastal settings (Cunniff & Schwartz 2015).

Living shorelines "use a variety of stabilization and habitat restoration techniques that span several habitat zones and use a variety of materials" (NOAA Habitat 2016). These can be single method strategies like planting marsh grasses in the intertidal zone to create a more robust marsh area that dissipates wave energy, filters upland runoff, and improves habitats (NOAA Habitat

2016). Living shorelines can be combinations of methods that have outperformed armored shorelines during storm events, like a marsh restoration with a stone sill or geotubes (also called biologs: large biodegradable bags filled with sand that are placed just seaward of or at the low water line parallel to the shore) (NOAA LS 2015, p. 11). Living shorelines are effective at reducing shoreline erosion, mitigating the effects of storms, strengthening habitats, and creating economically valuable coastal venues by enhancing the natural beauty of the shore (ch2m & The Nature Conservancy 2015, Lamont, G., Readshaw, J., Robinson, C., St-Germain, P. 2014, Swann 2008). The key to successful living shoreline projects is tailored selection of shoreline stabilization techniques for each project setting (Schneider 2013). Municipal regulations must be updated to support this customization and town governance should include practices like adaptive co-management and the flexibility to plan, fund, and implement projects with other jurisdictions and levels of government (Plummer 2013).

Adaptive Governance

Interview participants in this study all expressed the need for inter-jurisdictional resilience planning so that shoreline stabilization and habitat restoration projects would be designed for whole coastal ecosystems regardless of the political boundaries they cross. They said this was essential to achieve coastal resilience along all 1519 miles of the Massachusetts coast. Projects, they said, were typically focused and funded (typically by the state or federal government) to solve immediate problems for small sections of shoreline resulting in conflicts, instead of coordinated projects designed to work together to build resilience over time. For example, a sandy beach might stretch across three town lines and abut a state conservation area or federal wildlife refuge. One town might get funding for marsh restoration (with the goal of expanding the buffer feature of the

marsh) and the adjacent town might be seeking permitting for a series of stone revetments (with the goal of protecting waterfront houses). These two shoreline stabilization methods might not be compatible in that beach ecosystem. The shift in wave energy and sand movement created by nearby stone revetments might wash away newly planted marsh grasses or bury more mature plants.

Town resource managers in this study's case towns tended to communicate with their colleagues in other towns, with local and regional conservation commissions, and with the Mass. Office of Coastal Zone Management (MCZM) to avoid these kinds of conflicts, but they emphasized that the institutional (governance) structures were not generally conducive to collaborative interjurisdictional shoreline planning. Towns often procured funding for individual "one-off" projects that automatically siloed their planning efforts. The 2011 publication of MCZM's Policy Guide created policy guidance and state agency technical assistance for town projects to ensure consistency with state and federal requirements, that the MCZM called a "networked approach" (MCZM 2011a). Interview participants found this vital to ensure rules compliance, but recommended updated policies geared toward flexible (adaptive) coordinated interjurisdictional planning, funding, and project implementation. This issue is explored in Chapter 4.

Interview participants also described the increased professional and public awareness that coastal adaptation projects impacted other systems and scales than just physical coastal processes. This awareness ushers in the era of adaptive governance that facilitates participation of all types of stakeholders and data in decision-making (Neil Adger et al. 2005). Discussions and recommendations for adaptive governance for the coast include lessons learned from US, Canadian, and European case studies (Valman et al. 2015), and consider governance frameworks

to address complexity and uncertainty in dynamic coupled human and natural systems (Armitage 2008, Moser & Boykoff 2013).

Chapter 3, Characteristics of Resilience in Municipal Coastal Regulations

Introduction

Using the integrated method of content analysis and the resulting descriptive statistics, this chapter compares bylaws, ordinances, and regulations (hereinafter all referred to as "regulations") enacted by three Massachusetts coastal towns: Chatham, Newbury, and Scituate. This comparison is carried out by characterizing the frequencies with which coastal resilience practices are mentioned in the regulations. The coding architecture is derived from practices found in (i) the literature (Chapter 2) (*a priori)*; (ii) the respondent interviews (Chapter 4); and the regulations themselves (*in vivo*).

Public policies that mandate or encourage coastal resilience are implemented in regulatory environments that can either facilitate or hinder such resilience. In this chapter, I argue that characterizing the meaning of regulations can reveal the ways in which local municipalities contend with coastal climate adaptation. The identification and description of practices embodied in regulations, in conjunction with the content analysis of interviews in Chapter 4, increases awareness and understanding of how the regulatory environment can facilitate implementation of resilience practices. It also reveals areas of opportunity for towns to modify or expand public policies that could enhance resilience.[17]

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[17] This study does not evaluate municipal resilience which itself requires definitions and measurement schema. Evaluation metrics are being developed and tested in the field, Milliken (2017).

Summary of findings

Coastal resilience practices were found to have been expressed in the regulations of all three towns.

Chatham, Newbury, and Scituate all experience frequent and challenging coastal inundation and shoreline change events. A content analysis of hundreds of pages of their municipal regulations revealed that the majority (65%) of reasons why regulations had been enacted was because of economic loss reduction or property protection. Public benefits and ecosystem protection were motivating factors for the remaining (35%) reasons. Land use practices (78%) and building and infrastructure (18%) references together dominated the almost 400 "mentions" of resilience practices. Less than 2% referenced green infrastructure practices like marsh restoration, beach renourishment or dewatering, dune stabilization, or using vegetation to prevent erosion.

Some regulations were specifically identified as being stricter than the state requirements for natural environment preservation and habitat protection.

Town Selection

Purposive sampling was used to select the case study towns.

The three case towns are examples of coastal towns that vary by physical setting, beach type, shoreline characteristics, and coastal uses like recreation, tourism, and working (commercial) harbors. Table 3-14 has some town information including the number of linear feet of coastal structures.

Towns were selected that have been and were expected to be vulnerable to sea level rise and increased storm activity and flooding events; they must be in areas rated Moderate, High, or Very

High in NOAA's Coastal Vulnerability to Sea Level Rise index.[18] Such towns may have already implemented coastal resilience practices in response to these threats and may be motivated to build resilience.

The three towns must be in different Massachusetts Coastal Zone Regions (MCZM). This criterion helped select for different physical settings.

Chatham

Chatham is located on the "elbow" of Cape Cod, in the Cape Cod and Island MCZM Region. It has open ocean and bay coastline and mixed land use, including the main commercial fish pier for Cape Cod. Chatham's popular shopping and recreational amenities attract summer visitors in July and August numbering three to four times the town's year-round resident population (Chatham 2016).

Barrier islands off the coast of Chatham were breached by storms in 1987, 1990, 2007, 2010, and 2013. Impacts to Chatham's mainland will require the implementation of adaptive solutions to increase the resilience of Chatham's coast. Chatham has just over 5600 linear feet of town-owned coastal structures that carry an estimated $4.2 million in repair costs (2009 figures).

Chatham's shoreline is largely a natural high-energy barrier beach with a large low energy lagoon (Pleasant Bay) developed shoreline.

Scituate

Like Chatham, Scituate has been battered by storms in recent years that have resulted in increased damage to already strained protective coastal structures like seawalls. Scituate has over

[18] http://stateofthecoast.noaa.gov/vulnerability/welcome.html (This website was retired and not replaced in 2017.)

47,000 linear feet of hard coastal protection structures. Twenty-one miles of road come within 500 feet of those structures, and over 2,000 people live within a half mile of a coastal structure.[19] Estimates by the state in 2009 report approximately $33 million needed to repair coastal structures in the town.[20] Scituate is in the South Coastal MCZM Region.

Scituate will need to make decisions that prioritize available funds to repair existing structures, and should adopt effective resilience practices that could minimize future damage and increase resilience and ecosystem services. The town has one of the largest number of repetitive loss properties in the state, reflecting the continuing impact of storms and flooding on the Town (Scituate 2011).

Located on Boston's South Shore, Scituate has 15 to 20 miles of eroding glacial and barrier beaches. The coast of Scituate is zoned Residential, Residential 3, D (Saltmarsh and Tidelands Conservation District), and a small area of Business Zoning in Scituate Harbor (Scituate 2014). Scituate's town pier has a working fishing fleet. Recreational activities and other amenities make it a desirable South Shore community.

Scituate's shoreline has extensive public seawalls and revetments in developed areas, and low energy barrier beaches that are generally sand-starved.

Newbury

The Town of Newbury on the Massachusetts North Shore holds title to 2/5 of Plum Island, an inhabited barrier island that has been the center of much controversy in recent years as homes have been lost to storm erosion. Newbury has 2640 linear feet of town-owned coastal structures,

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[19] Author's gis analysis using datalayers MCZM (2011 - 2015).
[20] All data for Scituate were derived or calculated from unpublished datasets from the Mass Office of Coastal Zone Management, MCZM (2011b). Used with permission.

with a repair price tag of about $1 million (2009 state estimate). Newbury is especially interesting from a policy perspective because it is in the midst of struggling with property damage, accelerated beach erosion from *Superstorm Sandy* in late 2012 and winter storm *Nemo* in February 2013 (Baker 2013) with all the attending environmental, social, and economic issues. Newbury is in the North Shore MCZM Region.

Newbury is a high-energy sandy barrier that is a fully-developed shoreline.

Municipal regulatory authority and assumptions

Municipalities craft regulations to comply with state (and sometimes federal) requirements as baselines.[21] In many cases, local rules are driven or prescribed by state laws and policies, but as the adage goes, "all land use is local" so towns adopt regulations that meet their land use and development needs. Situations in a town may be subject to state, county, or federal hazard mitigation plans, development plans, or other legislation. It was assumed that all the regulations examined in this study were consistent with all applicable federal and state laws, and with other town bylaws. No attempt was made to determine whether a regulation, policy, or recommendation was stricter than governing state regulations or would be considered a "stretch code."[22] There were two municipal source documents that did identify regulations as "stricter than state" requirements, so a separate *NVivo* code was created to capture this interesting but infrequent call-out. Also, no attempt was made to determine whether any particular practice, like rolling easements, would face legal challenges in Massachusetts. It was assumed that if a practice was mentioned in a bylaw or

[21] Examples of federal law: *Coastal Zone Management Act of 1972, 16 U.S. Code Chapter 33, Sections 1451 - 1466* (2006); *The Clean Water Act, 33 U.S.C. §1251 et seq. (1972)* ;
Massachusetts *301 CMR 20.00: Massachusetts Coastal Zone Management Program* (2013)
[22] A voluntary standard that exceeds legal requirements in attempts to meet ambitious planning goals.

regulation that it could withstand a legal challenge. Towns employ counsel to scrutinize bylaws and regulations for compliance and risk. If a practice was not mentioned, no assumption was made about why it was not, including whether it would be consistent with governing law.

The Massachusetts Wetlands Protection Regulations[23] promulgated by the Commissioner of the Massachusetts Department of Environmental Protection (DEP) under the authority of the Massachusetts Wetlands Protection Act (WPA)[24] are the dominant regulatory basis upon which local coastal regulations build. Some local regulations reiterate much of the state regulations, some towns may rely solely on the state regulations, and some may go beyond.

For the purposes of this content analysis, it is assumed that there are no differences between towns' regulations attributable to compliance with the WPA. As stated previously, this study does not include research on why there may differences in regulatory environments in the towns. However, municipalities adopt regulations to address local issues, so differences could be attributed to policy priorities, zoning and development matters, levels of coastal hazard risk, and site-specific environmental concerns.

Method and Source Documents

Documents analyzed

The documents reviewed in the content analysis include the wetlands protection and zoning bylaws and regulations of each town (Table 3-13).

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[23] *Massachusetts Wetlands Protection Regulations, 310 CMR 10.00* (2014)
[24] *Massachusetts Wetlands Protection Act. M.G.L. c.131 § 40* (2014)

A total of eleven source documents were analyzed. Nine are either bylaws or regulations. In Massachusetts towns, municipal bylaws are enacted by town meeting. The municipal regulations analyzed were promulgated by each town's conservation commission. Scituate's "Elevation Grant Fact Sheet" was included because it provided additional detail to references in the regulations.

Scituate's adopted 2016 "Natural Hazard Mitigation Plan Update" was included in the analysis because it provides a preview of resilience actions being considered by the town, after evaluation of existing projects and policies, including regulatory initiatives such as revised zoning ordinances and land use regulations (Scituate 2016, p. 1). Municipal plans adopted by town meeting or select boards usually carry the same legal force as a bylaw.[25]

Content analysis and coding architecture

Three main themes (coding categories) were used to develop the hierarchical categorical architecture that formed the content analysis coding framework in *Nvivo*.[26] The first two were applied to analyze the municipal regulations and policies in Chapter 3 and all three were applied to the interviews in Chapter 4: (1) The "Purpose" of the regulation, policy, or practice; (2) "Resilience Practices" category includes the *a priori* coastal resilience practices (CRP) identified in the literature and those discovered and *in vivo* in the coding of the regulations and practitioner interviews; and (3) "Governance" that included recommended municipal actions from the

[25] Scituate's 2016 plan update of the 2011 plan went through the required town committee and public presentations and comment periods and was adopted by the Town Board of Selectmen in July 2016. It was also evaluated for compliance with applicable federal regulations by FEMA and DHS, Scituate (2016, pp. 136–137).

[26] The full codebook is in the Appendix.

literature and the *in vivo* during coding of the interviews. These actions may facilitate the adoption or implementation of resilience practices.

Sub-categories (codes) were developed in vivo for all three main themes. Those derived from The Public Trust literature were primarily used under the "Purpose" main theme. Sub-category codes significantly expanded the coding architecture, and so provided an important level of detail for the analyses.

All source documents were manually coded line by line by one user (the author) to ensure all references were coded in context.[27] It is possible that some references were missed, but text queries were used to double-check manual coding. In content analysis, the number of references is the number of discrete mentions of the code for a subcategory. Only explicit mentions were coded as references; intent or purpose was not inferred from the language in a regulation. For example, phrases that were coded to the "Public Trust" category included "public benefit", "public good", and "public welfare." Also, if a purpose was explicitly stated as "hazard mitigation" the reference was coded as such and not under another subcategory like "Property protection," even though protection of property would be a result of the regulation's implementation. This strict coding practice was adhered to throughout the project.

The number of references does not equal the number of individual regulations that contain those mentions. For example, there are twenty-one references for the Land Use subcategory code "Prohibited use." This indicates that there are twenty-one instances of the phrase found across all the source documents (i.e. there may be more than one reference found in a single regulation). References were coded (assigned) only to one subcategory code.

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[27] *NVivo's* auto-coding feature was not used.

Subcategory code lists that started out with a handful of codes grew as practices were encountered in the regulations. For example, coding began with eight *a priori* "Land Use" subcategory codes taken from the literature and the pilot study and ended with twenty-three. Two of those subcategories, "Permitting process" and "Enforcement" each had their own groups of subcategories numbering eight and sixteen respectively. To manage the analysis so the results would be understandable, but maintain the level of detail, a "Top 5" ranking method was used for the two most expansive categories in the "Resilience" main theme: "Buildings & Infrastructure" and "Land Use."

Inference quality of the qualitative content analysis

The strength of this content analysis is directly related to the study's qualitative inference quality. Integrated analysis also depends on the qualitative inference quality. According to Teddlie and Tashakkori, the four aspects of inference quality are: Confirmability, Credibility, Dependability, Transferability (Teddlie & Tashakkori 2009). Definitions of each aspect in the footnotes are from the Web Center for Social Research Methods (Trochim 2015).

Confirmability[28] is high for the document review content analysis of the municipal regulations and policies. These are easily accessible public documents, and the coded sections are accessible and retrievable in *NVivo*, so there is transparency. Another researcher would be likely to code the documents in the same way since the types of regulations and practices mentioned correspond directly to most of the codes.

[28] "Confirmability refers to the degree to which the results could be confirmed or corroborated by others." http://www.socialresearchmethods.net/kb/qualval.php

The content analysis of the interviews in Chapter 4 also has high confirmability. The digitally recorded interviews were transcribed word-for-word, although it has been argued that verbatim transcription is not always necessary (Halcomb & Davidson 2006). Five of the six participants agreed in writing to disclose their names, so their statements could be independently verified if it were necessary.

Credibility[29] is high for the coding architecture for both content analyses (regulations and interviews). The codes for the main themes and subcategories were developed from the literature, enacted legislation, and from information from highly regarded professionals. This means that the perception of those that are responsible for the concepts and recommendations for practice (that group includes the interview participants) would be highly likely to find the study results believable.

Dependability[30] is related to the quantitative criterion for reliability, the assumption of replicability or repeatability. Since the confirmability of both analyses is high, it should follow that other researchers would find the qualitative coding schemes dependable in different contexts (e.g. another U.S. state).

Transferability[31] of findings is moderate to moderately high. The results of the interviews content analysis are specific to Massachusetts jurisdictions, so is probably moderate. The author's

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[29] "The credibility criteria involve establishing that the results of qualitative research are credible or believable from the perspective of the participant in the research. Since from this perspective, the purpose of qualitative research is to describe or understand the phenomena of interest from the participant's eyes, the participants are the only ones who can legitimately judge the credibility of the results" Trochim (2015).

[30] "The idea of dependability…emphasizes the need for the researcher to account for the ever-changing context within which research occurs. The research is responsible for describing the changes that occur in the setting and how these changes affected the way the research approached the study" Trochim (2015).

[31] "Transferability refers to the degree to which the results of qualitative research can be generalized or transferred to other contexts or settings. From a qualitative perspective transferability is primarily the responsibility of the one doing the generalizing. The qualitative researcher can enhance transferability by doing a thorough job of describing the research context and the assumptions that were central to the research. The person who wishes to "transfer" the results to a different context is then responsible for making the judgment of how sensible the transfer is" Trochim (2015).

interactions with adaptation professionals[32] at federal, state and municipal levels (in other states) relay similar policy, implementation, evaluation, communication, and funding practices and issues.

Transferability is probably moderately high between Massachusetts towns because state and municipal coastal regulations comply with or are consistent with federal legislation.[33] This means that since the coding schemes are highly credible and national standards drive state and local consistency, the findings of this section should be transferable, or at the least, they will be very relatable. Since the legislative process is typically slow-moving, the findings should be transferable and relatable for several years.

Findings of the documents review content analysis

Regulatory Purpose

Distribution of "Purpose" main themes in the regulations

Regulations, bylaws, and ordinances codify the intent of the enacting legislative body. In the case of Massachusetts municipal bylaws and ordinances that intent is expressed by residents when they vote for articles proposed at town meetings. This is direct democracy in action. Town conservation commissions are often the bodies that create and enforce the regulations.

The reason or purpose is often written directly into bylaws. There are four "Purpose" categories (or themes): Two *a priori* themes, Protection and Public Trust & Benefit, and two

[32] Most interactions were with members of the policy committee of the American Society of Adaptation Professionals. https://adaptationprofessionals.org/

[33] The Coastal Zone Management Act of 1972, The Clean Water Act, The Coastal Nonpoint Pollution Control Program, and the Water Resources Development Act, see CSO (2016).

themes that emerged from the document analysis (*in vivo*), Loss Reduction and Management (Table 3-1) (Figures 3-3,3-4). Each of these has subcategories that are discussed in this section.

A total 149 of "Purpose" references were distributed across the three towns with Newbury being the most vocal in expressing regulatory intent (37%), then Chatham (33%), and Scituate (30%) (Table 3-1).

The majority (65%) of reasons stated as regulatory purpose were economic in nature (Loss Reduction and Property Protection combined). Almost one-fifth (19%) of the references stated public benefit (Public Trust & Benefit) as intent.

Management objectives (16%) were almost as numerous as public benefit mentions. Scituate has a few more "Management" references than Chatham and Newbury combined. This is because most of those references were found in Scituate's not yet ratified 2016 "Hazard Mitigation Plan."[34] When those are not counted, Scituate has about the same number as the other two towns.

Protection Purpose

As shown in Table 3-2, subcategory "Ecosystem, habitat, and (eco)services protection" comprised 76% of the "Protection" purposes and were found in all the regulations and bylaws source documents.

There were only 10% (6) references for "Property protection," but property protection is achieved through other references in the "Loss Reduction" Purpose subcategory. "Recreation activity protection" is related to Public Trust & Benefits uses and access. Newbury and Scituate each had one instance that was "Stricter than State" requirements. This indicates that a regulation

[34] Municipal plans that are adopted at town meetings have the force of law.

goes above and beyond (e.g. “stretch code”) what is required by the state. Not all regulations that are stricter than state requirements are identified as such when they are written. Knowledge of this condition could inform future regulation evaluations.

Economic and activity protection subcategories together were 10% of the references. Ensuring these activities contributes to socioeconomic resilience.

Loss Reduction Purpose

Loss Reduction categories were 23% of the total references in the “Purpose” main theme (Table 3-1). Flooding and hazard mitigation references together make up almost three-quarters of the Loss Reduction category (Table 3-3). Minimizing inundation damage is a major concern. Sea level rise and coastal hazards like storm surge exacerbate flooding events and cause building and infrastructure damage.

The lone sea level rise loss reduction reference is in Chatham’s regulations. Loss reduction from sea level rise may be the outcome of regulations that are coded to other categories. For example, elevating buildings and utilities, coded in Buildings and Infrastructure, would reduce losses from sea level rise.

Public Trust & Benefit Purpose

Most (82%) of Public Trust references did not specify a Public Trust purpose (Table 3-4) (Figure 3-5). Public Trust uses in Massachusetts are fishing, fowling, and navigation (Ducsik 2008). Public access (2%) refers to access to the shore which is a right reserved in Trust (Ducsik 2008). The “Protect Public benefit, health” references (6%) are not strictly reserved as rights in the Public Trust Doctrine, but these references were coded under “Public Trust” when towns explicitly called out their rationale as “for the public benefit (or health)” in the document texts. There were two mentions (6%) of specific Public Trust use. These were related to fishing and navigation.

Management Purpose

Table 3-5 contains the subcategories of the Management theme. Development management, those constraints on coastal development in sensitive environmental areas, dominated Management references in all three towns, totaling 67%.

Scituate had 54% of all the references. The inclusion of Scituate's 2016 Proposed Hazard Mitigation Plan in the documents reviewed accounts for almost half of the town's references in this category. Featured in Scituate's new plan are public education, disaster management, adaptation, and regional cooperation. Public awareness and education were mentioned as critical to move toward resilience by all the interview participants. Adaptation was included in Scituate's hazard mitigation planning processes – a practice that has been recommended by the Council on Environmental Quality (CEQ 2015) and the European Commission's Integrated Coastal Zone Management Programme (EC 2013). Lack of regional cooperation was major barrier to resilience that was reported by interview participants, and Scituate has included it in their proposed plan.

Chatham had two references (8%) for shoreline management. These did not specify practices, but discussed management process and decision-making.

Resilience Practices

Three of the eight main "Resilience" categories, including their subcategories, account for 92% of the 382 references coded (Table 3-6): "Land Use" (78%), "Building and Infrastructure" (18%), and "Green Infrastructure" (2%). These and the other five "Resilience" main categories are discussed here.

Distribution and frequency of Resilience Practices categories in the regulations

The majority (96%) of resilience practices mentioned fell into two categories, Land Use (78%), and Building and Infrastructure (18%) (Table 3-6) (Figures 3-1, 3-2).

Land use practices were 299 of the 382 total Resilience references (Table 3-6). Over 40% of the land use practices referenced permitting or enforcement (Table 3-7). Strong preservation practices for coastal ecosystems comprise about one in five land use references. These are prohibitions on causing adverse effect, encroachment or alteration of natural features and no-build zones (Table 3-7) (Figures 3-6, 3-7).

Effective building resilience practices from the literature like elevated buildings, walkways and systems, and permeable buildings and pavements, made up 27% of the "Building and Infrastructure" references (Table 3-10). This indicates that towns are aware of and are adopting or facilitating built environment resilience efforts. While it is true that compliance with general wetlands protection rules does result in preservation of natural systems, according to the expert coastal manager interview participants in this study, building resilience must be deliberately and specifically called out in municipal policy documents like bylaws, regulations, and plans.

Green Infrastructure references accounted for 2% (Table 3-6). Some practices that are employed in green infrastructure solutions which are often combinations of resilience practices are included in other categories.

Funding, Outreach, and Partnerships mentions together comprised less than 2% of the total mentions in the regulations. It is more typical for physical practices to be defined through regulations than activities like these. The discussion in this section will focus on the three physical practices. Funding, Outreach, and Partnerships categories were mentioned with much more frequency in the interviews, and will be discussed in Chapter 4.

Land Use

Land use practices accounted for 78% of the total Resilience practices from all categories (Table 3-6). Coverage of total references over the range of practices is evenly distributed in the three towns. The notable exceptions for individual practices are Newbury's dominance of 53% of the "Enforcement" references, and Chatham's 93% share of "No alteration of natural features" references. Scituate has no references to that practice or one of the other prohibitions "No adverse effects." Scituate does however, reference other important resilience prohibitions: "No encroachment [of natural features]" and "No build zones."

Top 5 in Land Use

The "Top 5" practices, ranked by number of references per coding subcategory, account for almost 89% of all Land Use references (Table 3-7).

Permitting and Enforcement subcategories together comprised about 42% of Land Use practices references (Tables 3-8 and 3-9).

Rank 1, tied: Permitting process

Requirements for special permits, variances, public hearings, and notices comprised 77% of the Permitting process references (Table 3-8).

The "Precautionary Principle, burden of proof" practice references appeared in all three towns' wetlands regulations. This practice requires that the permit applicant supply independently verified proof that the proposed action would not significantly (or in some cases, not in any way) alter existing natural features, specific ecosystem services, or cause or increase any adverse effects like stormwater runoff.

Scituate and Chatham have “Emergency permit restrictions” in their Wetlands regulations. Emergency permits typically require the emergency work to be ordered, certified and/or performed by a state agency. In Scituate, under some conditions, an emergency can be certified by the town Conservation Commission. In all cases, approval or certification is required prior to work.

In Scituate’s Wetlands Protection Regulations effective July 2012, there are provisions to waive the prior permission and filing requirements and to have emergency work certified, inspected and ordered revised after work is done (Scituate ConCom 2012, Sec.SWR 10.05, p.26). There were no Emergency permit restrictions references found in Newbury’s regulations. There are anecdotes about a standoff between private property owners and regulators in the aftermath of devastating storm damage in 2013 on Plum Island in Newbury’s jurisdiction when more severe storms were on their way. In essence, the property owners are reported to have sent the message to state and town regulators that they did not care that permits were required or would be denied them to install shoreline stabilization solutions of their choice, and that they were unconcerned about legal consequences. They would protect their properties and felt their right to do so superseded any regulatory requirements, especially under these emergency circumstances when their properties were under threat of complete destruction.

Any unofficial suspension of emergency or ordinary permitting rules would presumably have come from state actors. If the suspension anecdotes are true, and there is every reason to believe they are given the expertise and credibility of the sources and the number of reports, it is evidence that the implementation of even the most carefully and well-developed policies can break down when systems, resources, and people are under duress, leading to “street-level bureaucracy” (Lipsky 2010, Pressman & Wildavsky 1984).

Rank 1, tied: Enforcement

Land use regulations in all three towns carry enforcement provisions. Enforcement is widely discussed in coastal resilience and climate adaptation circles. Policies are great in concept, but unless they can be enforced, widespread adoption and implementation are not likely. The seventeen enforcement practices referenced are in Table 3-9.

The general progression of enforcement actions starts with monetary security deposits on projects, inspections, hearings, and monitoring; proceeds to suspensions of certifications, work orders, and issuance of fines; then on to orders for civil or criminal penalties, and orders to restore a site to its original condition.

Civil and criminal penalties in the town regulations are mostly reserved for violations of federal statutes under the Clean Water Act (*The Clean Water Act, 33 U.S.C. §1251 et seq. (1972)*).

Rank 2: No alteration of natural features

Most of these references (41 of 44) were found in Chatham's regulations, three were in Newbury's, but none in Scituate's (Table 3-7). "Natural features" refers to landforms like dunes, coastal2banks and vegetation, and habitats like fisheries and nesting areas.

The "No encroachment" practice almost always referred to regulatory floodways and waterways, not natural features that provide coastal ecosystem services.

Rank 3, tied: Restricted use

These references were found in all three towns (Table 3-7). Practices in conservancy and overlay districts, and in environmentally sensitive areas ran the gamut from prohibition of building oil and natural gas pipelines, defining permissible agricultural uses and sewage discharge, to acceptable use of signs and fences.

Rank 3, tied: Prohibited use

Prohibited uses were mostly concerned with polluting activities included burning, bringing in and removing fill, and storing of chemicals and waste. Newbury had as many Prohibited use references as Chatham and Scituate combined (Table 3-7).

Rank 4: Setback, buffer increase

Chatham's increases were usually 100 or 200 feet from a natural feature like a dune or coastal bank and 50 feet from dwelling property lines. Chatham had as many references as Newbury and Scituate combined (Table 3-7).

Newbury had special setbacks and buffers for Plum Island: 200 feet from coastal banks and dunes, and a setback requirement of at least 30 times the average yearly historical erosion rate for all new buildings (Newbury 2015a, Sec. 95-4, E and F).

Rank 5, tied: No build zone

Chatham prohibits building in specific FEMA hazard zones and all activities except narrowly defined maintenance to existing structures in conservation districts and close to natural features like dunes (Table 3-7).

Newbury also prohibits building specific FEMA hazard zones.

Scituate prohibits building in floodplain and watershed protection districts.

Rank 5, tied: Zoning overlay

Zoning overlays are special zoning districts made for specific purposes that are created "on top" of an existing zone. The existing zone's requirements remain in effect. If the overlay district's regulations supersede those of the existing zone, they are almost always stricter.

The three towns each had 5 Zoning overly references (Table 3-7). The special overlay zones were for conservancy including saltmarsh and tidelands, water supply protection, floodplains and watershed, and planned development.

Building and Infrastructure

Table10 shows ranked Building and Infrastructure (referred to as "Buildings") practices subcategories with the number of references by town.

It is possible that there may be other building and infrastructure requirements codified in municipal regulations not included in this study. For the most part, municipal building requirements are usually included in zoning bylaws. Towns usually have separate building codes, but the general requirements that are relevant to this study were found in bylaws and regulations. Several of the interview participants confirmed this for each of the study towns and recommended that examining the construction building codes would not yield information pertinent to this study that would not be found in the bylaws.

"Buildings" subcategories

The predominant subcategory is "Building elevated" with 15% of the total references in the Buildings category (Table 3-10). It is noteworthy that this practice is one of the two Buildings practices mentioned in all three towns' regulations; the other is "Utilities elevated" ranked third. It is not in the scope of this study to describe every resilience practice in detail, but elevating buildings, also known as "freeboard" (ranked first) is the practice of raising buildings a number of feet above a certain watermark (FEMA 2016a). For example, Chatham's Protective Zoning bylaws require that "residential structures shall have the lowest floor (including basement) elevated to not less than one (1) foot above the base flood elevation."

The 2015 Scituate Zoning Bylaws contained the only reference for "No municipal services provided" (Table 3-10). The reference was found in the lot frontage requirements for residential compound developments, §610.2(D)4c, "That the town will not be requested or required to accept

or maintain any municipal services whatsoever including but not limited to the private access, drainage, open space or any other improvement within said tract." Frontage requirements can act to limit waterfront development. Even if a frontage waiver is granted, a bylaw like this one is not necessarily automatically waived, so could be enforced.

Codifying municipal warnings that a town will not provide services under certain conditions is being discussed in adaptation and disaster management policy circles.[35] If towns refuse to provide "any municipal services whatsoever" including road maintenance and emergency services, for example, the prospects of making money on new or rebuilt waterfront developments can plummet, and property owners could baulk at bearing the burdens of transferred risks.

There were no references in any of the towns' regulations for "Repetitive loss rules" (Table 3-10). This may be because the new FEMA rules cover repetitive loss properties (FEMA 2015), so towns are depending on federal restrictions and insurance underwriters to address these properties. Scituate has the most repetitive loss properties in Massachusetts (as of 2010).[36]

Newbury's regulations accounted for just over half (53%) of the total number of "Buildings" references with the subcategories "Building elevated" and "Rebuilding restrictions" comprising almost 30% of the town's "Buildings" references (Table 3-10). Scituate's regulations accounted for 26% and Chatham's for 21%.

Chatham's zoning bylaws have a separate section for regulations applied to overlay districts (Chatham 2015, Sec. IV, Overlay Regulations). This made it possible to focus coding effort in the sections most likely to address coastal areas in the initial passes of coding done using

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[35] From discussions (2013-2016) with municipal officials in the context of professional association roundtables.
[36] Town of Scituate Hazard Mitigation Plan, 2010, p. 9,10
http://www.town.scituate.ma.us/flood/Scituate_Hazard_Mitigation_Plan.pdf

Dedoose (Lieber & Weisner 2013) and *QDA Miner* (*QDA Miner 4*, 2014) in a coding trial. Coding was redone from scratch in *NVivo* for the main study and included all pages of every source document.

Top 5 in Buildings and Infrastructure

Eleven practices comprise the "Top 5" rankings and account for 73% of all Buildings references (Table 3-10).

Rank 1: "Building elevated" is the practice of freeboard. It is often one of the first building resilience practices implemented, so it has been widely adopted. Freeboard's close, but more advanced relative, subcategory "Building permeability" has been adopted by only one town, Chatham. (Table 3-10)

Rank 2, tied: Building Lot Coverage refers to the area a building takes on a lot. Newbury Wetlands Protection Bylaw defines this as "…the sum of the footprint of all structures or buildings would not exceed 20% of the area of the lot" (Newbury 2015a). (Table 3-10)

Rank 2, tied: Rebuilding restrictions include prohibitions of rebuilding per wetlands provisions and in FEMA velocity (flood) hazard zones, restrictions on building lot coverage and building footprint, and time restrictions on rebuilds. (Table 3-10)

Rank 3, tied: Frontage required. Newbury's frontage requirement in the Plum Island Overlay Zoning District that no building permit will be issued unless the lot has frontage on a street (Newbury 2015b, Art.IV, Sec.97-7, D(5)g), ties in with the regulation coded under subcategory item number 14 "No municipal services provided." Scituate's Zoning Bylaws frontage requirements are applicable to lots in all zoning districts (Scituate 2015, Sec. 610.2)

Rank 3, tied: Utilities modified. Chatham's Zoning Bylaws for the Flood Plain District require flood-proofed/resistant HVAC and plumbing equipment, and that all public utilities and facilities "be located and constructed to minimize or eliminate flood damage" (Chatham 2015, Sec. B). (Table 3-10)

Rank 4: Building height. Thirty-five feet was often used as maximum height for a new or rebuilt structure, or height could not exceed height of a demolished building. (Table 3-10)

Rank 5, tied: Together account for 22% of the total mentions in Buildings (Table 3-10)

Rank 5, tied: Lot size restriction(s) were zoning district specific.

Rank 5, tied: No fill material allowed (in special or overlay districts like flood plains)

Rank 5, tied: No reconstruction or alteration of building or footprint

Rank 5, tied: Restricted use areas in buildings. Chatham restricts use to vehicle parking and storage for buildings in the Flood Plain District that do not meet minimum wind and water loading values (Chatham 2015, Sec. B.4.g.2).

Rank 5, tied: Septic ban or restriction

Chatham's regulations reference only nine of the twenty-four practices (about 1/3) of "Buildings" practices, and eight of those are resilience practices found in the literature. For example, Chatham references permeable buildings and pavements, two of the "Advanced Practices" discussed later in this chapter. Scituate references ten of the twenty-four practices, but none of the "Advanced Practices." Newbury referencing sixteen, has the greatest coverage over the range of the twenty-four practices.

Green Infrastructure

There are seven Green Infrastructure practices (Table 3-11), and only nine references found in the regulations. Newbury had only one reference (for Vegetation) and Scituate had only one reference (for Dune stabilization). Three of the seven practices were not referenced at all (Dewatering, Living Shorelines, Sediment recycling). Living shorelines projects can use combinations of methods like marsh restoration and dune or low-impact ("soft") shoreline stabilization, so regulations may address the individual methods. As living shorelines

Chatham had seven of the nine refences in four of the practices: Beach renourishment, Dune stabilization or development, Marsh restoration, and Vegetation (using vegetation in ways other than in marsh restoration).

Regulations often follow practices in the field. As lessons are learned, practices are refined, then regulations are created and amended to reflect the improvements in practice. Policy learning takes place between localities and municipal officials visit international sites using green infrastructure practices their towns are interested in.

Advanced Resilience Practices

Newer-to-the-field and difficult-to-implement-but-effective resilience practices were identified as advanced practices from the Buildings & Infrastructure and Land Use resilience categories and presented together in Table 3-12, Figure 3-10. Only Chatham and Newbury had references in their regulations. Permeable pavements had two mentions, one each in Chatham and Newbury. Building permeability had two mentions, both in Chatham.

There are four advanced practices with no references.

Retreat or move building back: Away or landward from a hazard like erosion, but the building usually stays on the same property.

Property buy-back: Funding program to purchase properties that cannot or should not be rebuilt after damage, repetitive loss properties. Funding can be from a mix of federal, state, and local sources. The City of New York offered a program of buy-backs with relocation services to affected property owners using federal funds from *Superstorm Sandy*. The program was not fully implemented.

Relocation: Similar to Retreat, but damaged building on existing lot is typically razed, rebuilding is not allowed. Sometimes relocation assistance services are offered (e.g. NYC).

Rolling or moveable easements: Special easements that allow a saltwater marsh (usually) to migrate onto private property, even permanently, with or without compensation from the town.

These practices would most probably invoke takings actions against a town if they were adopted as compulsory. If they are found in regulations, municipal plans, or policy guidelines, the language can address process and offer guidance about agreements and execution for voluntary cooperative transactions.

Outreach, Partnerships, Planning, and Funding

Only Scituate had references in these categories and all were found in the town's 2016 Proposed Hazard Mitigation Plan (Table 3-6). Examples of Outreach and Partnerships subcategories are public education and public-private partnerships. Since these are collaboration and fiscal practices, their presence would not be expected in bylaws and regulations.

The single Funding reference was in Scituate's Elevation Grant Fact Sheet and referred to FEMA funding.

Discussion and Conclusions

I found that coastal resilience practices are expressed ("mentioned") in the municipal regulations of all three case study towns. This expression indicates that municipal regulations facilitate at least a minimal threshold of resilience practice implementation. This finding further reveals that there may be additional innovative strategies that towns could use to contend with climate adaptation.

Most of the resilience practices in the three towns are land use methods. Historically, zoning has been used by localities "to maintain public welfare and a sense of order" (Talen 2012, p. 202).[37] All three towns employ land use permitting and enforcement actions: these actions comprise 60% of actions in Newbury compared with 50% in Scituate and 23% in Chatham (Table 3-7).

Almost 40% (49 of 126) of Chatham's land use references were for "No alteration of natural features," minimizing adverse effects and limiting encroachment on natural features (Table 3-7). This finding indicates an emphasis on environmental protection as a resilience strategy rather than reliance on administrative actions. Scituate and Newbury do not exhibit the same emphasis, but they too value, understand, or have strategies to protect natural features and ecosystem services. Scituate regulations do not mention "No alteration of natural features," but they do incorporate two references for "No encroachment," which arguably is a synonymous practice. Both Scituate and Newbury regulations incorporate references for "Minimize adverse effects on natural resources."

Use prohibitions and restrictions and no-build zones are among the most commonly referenced practices in all three towns. Combining references for "Setback, buffer increase" and "Zoning

[37] Also refer to the discussion in Chapter 2 about the history of The Public Trust Doctrine and land use in Massachusetts.

overlay" accounts for 10-12% of each town's total land use references (Table 3-7). These land use tools help to achieve the environmental objectives expressed in "No alteration, encroachment, or adverse effects."

Building and Infrastructure[38] resilience practices were referenced in the regulations of all three towns. The most frequent reference was to "Building elevated," and Newbury was observed to have as many of these references as Chatham and Scituate combined. This finding may represent an effect of the physical setting on policy and regulations. Newbury's shoreline is a densely developed, high-energy, sandy barrier. Elevating buildings may be more relevant there than in Chatham (less densely developed) or in Scituate (more heavily armored).

Some innovative resilience building and infrastructure practices, including permeable pavements and buildings, were mentioned in the regulations. All but one of the Green Infrastructure practices references belonged to Chatham, but the most recently heralded of these practices, beach dewatering, was unmentioned.

The Land Use resilience practices that have been moving to the forefront of the adaptation literature also were unmentioned, including retreat, relocation, rolling easements, and property buy-backs. These practices are now at the frontier of land use policy, and they could be interpreted by property owners as interfering with their perceptions of private rights. As sea levels rise and coastal damages intensify, and as the effectiveness of strategies of adaptation begins to plateau, these frontier strategies may yet find a place in the resilience policy toolbox, even in US municipalities where property right concerns still predominate.

Building resilience into coupled human and natural systems can be a complex undertaking. Comprehensive planning across systems is necessary, but implementation solutions often require

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[38] Also referred to as "grey infrastructure" in contrast to "green infrastructure" practices.

site- and situation-specific customization (Schneider 2013, RAE 2015). No one solution or project type can best address the challenges for every conceivable situation. Policy and practice learning among municipalities and other political jurisdictions can help to support local project success. Municipalities can now begin to take advantage of online resources for identifying and potentially implementing many types of resilience projects (Adaptation Clearinghouse 2016, EPA 2015).

Regulations can be interpreted as signals of policy priorities. The content analysis undertaken in this chapter revealed the presence of resilience practices encouraged by public policy in the regulations. The absence of references to some of the more innovative practices implies some clear opportunities through which towns can continue to expand upon and improve coastal resilience in the future.

Tables and figures

Table 3-2. Regulation Purposes main categories by town

Purpose main categories	Chatham	Newbury	Scituate	Total references	Percent Total
Protection	24	23	16	**63**	**42%**
Loss Reduction	11	15	8	**34**	**23%**
Public Trust & Benefit	9	11	8	**28**	**19%**
Management	5	6	13	**24**	**16%**
Totals	**49**	**55**	**45**	**149**	
Percent totals by Town	**33%**	**37%**	**30%**		**100%**

Table 3-3. Protection Purpose subcategories by town

Protection Purpose	Chatham	Newbury	Scituate	Total	Percent Total
Ecosystem, habitat, services protection	18	18	12	**48**	**76%**
Property protection	3	2	1	**6**	**10%**
Economic activity protection	1	2	0	**3**	**5%**
Recreation activity protection	2	0	1	**3**	**5%**
Stricter protection than State regs	0	1	1	**2**	**3%**
Pollution prevention	0	0	1	**1**	**2%**
Totals	**24**	**23**	**16**	**63**	
Percent totals by Town	**38%**	**37%**	**25%**		**100%**

Table 3-4. Loss Reduction Purpose subcategories by town

Loss Reduction Purpose	Chatham	Newbury	Scituate	Total	Percent Total
Flooding, stormwater loss reduction	4	7	2	**13**	**38%**
Hazard mitigation	4	5	3	**12**	**35%**
Building loss reduction	1	1	2	**4**	**12%**
Infrastructure loss reduction	1	2	1	**4**	**12%**
Sea level rise loss reduction	1	0	0	**1**	**3%**
Totals	**11**	**15**	**8**	**34**	
Percent totals by Town	**32%**	**44%**	**24%**		**100%**

Table 3-5. Public Trust & Benefit subcategories by town

Public Trust & Benefit Purpose	Chatham	Newbury	Scituate	Total	Percent Total
Protect public benefit, health	8	9	6	**23**	**82%**
Protec Public Truse use	0	2	1	**3**	**11%**
Protect public access	1	0	1	**2**	**7%**
Totals	**9**	**11**	**8**	**28**	
Percent totals by Town	**32%**	**39%**	**29%**		**100%**

Table 3-6. Management Purpose subcategories by town

Management Purpose	Chatham	Newbury	Scituate	Total	Percent Total
Development management	3	6	7	16	67%
Educate the public	0	0	2	2	8%
Emergency, disaster management	0	0	2	2	8%
Shoreline management	2	0	0	2	8%
Adaptation	0	0	1	1	4%
Regional cooperation	0	0	1	1	4%
Totals	**5**	**6**	**13**	**24**	
Percent totals by Town	**21%**	**25%**	**54%**		**100%**

Table 3-7. Resilience Practices Main Categories by town

Resilience Practices Main Categories by Town	Chatham	Newbury	Scituate	Total References	Percent Total
Land Use	126	99	74	**299**	**78%**
Building and Infrastructure	14	36	18	**68**	**18%**
Green Infrastructure	7	1	1	**9**	**2%**
Partnerships*	0	0	3	**3**	**1%**
Outreach*	0	0	2	**2**	**1%**
Funding*	0	0	1	**1**	**0%**
Totals	**147**	**136**	**99**	**382**	**100%**

*In Scituate 2016 Proposed Hazard Mitigation Plan

Table 3-8. Land Use Practices ranked references by town

Land Use Practices	Total References	Chatham	Newbury	Scituate	Percent Totals	Rank
Permitting process	**68**	18	29	21	23%	**1**
Enforcement	**57**	11	30	16	19%	
No alteration of natural features	**44**	41	3	0	15%	**2**
Restricted use	**26**	11	4	11	9%	**3**
Prohibited use	**21**	8	11	2	7%	
Setback, buffer increase	**19**	10	5	4	6%	**4**
No build zone	**15**	10	2	3	5%	**5**
Zoning overlay	**15**	5	5	5	5%	
Minimize adverse effects on natural resources	**10**	8	1	1	3%	**6**
More restrictive than state regs	**6**	0	1	5	2%	**7**
No adverse effects	**4**	0	4	0	1%	**8**
No encroachment	**4**	1	1	2	1%	
Pollution prevention, reduction	**3**	1	2	0	1%	
Restricted number of structures	**2**	1	1	0	1%	
Conservation general	**1**	0	0	1	0.3%	**9**
Deed restrictions	**1**	0	0	1	0.3%	
Limitation on further development	**1**	0	0	1	0.3%	
No coastal structures	**1**	1	0	0	0.3%	
Open space requirement	**1**	0	0	1	0.3%	
Property buy-back	**0**	0	0	0	0%	**10**
Relocation	**0**	0	0	0	0%	
Restricted access	**0**	0	0	0	0%	
Rolling or moveable easement	**0**	0	0	0	0%	
Totals	**299**	**126**	**99**	**74**		
Percent Totals		**42%**	**33%**	**25%**	**100%**	

Table 3-9. Permitting process references

Permitting process	References
Special permits required	**25**
Variances, waivers special process, restrictions	**12**
Public hearings, notice to abutters	**12**
Precautionary Principle, burden of proof	**10**
Deny, delay permit	**4**
Emergency permit restrictions	**2**
Consultants fees, restrictions	**2**
Investigations	**1**
Total	**68**

Table 3-10. Enforcement references by town

Enforcement	Chatham	Newbury	Scituate	Total References
Inspect, Assess deviation, violation. compliance	4	2	3	**9**
Fines	1	5	2	**8**
Civil	1	4	1	**6**
Monitoring after, during project completion	1	3	1	**5**
Issue enforcement order	1	3	1	**5**
Criminal	1	2	2	**5**
Stop work order	1	1	1	**3**
Security money, performance guarantee	1	1	1	**3**
Revoke, modify cert of compliance	0	1	2	**3**
Deny cert of compliance	0	2	1	**3**
Time limits	0	1	1	**2**
Town directly remedies violation	0	1	0	**1**
Security for land restriction	0	1	0	**1**
Restore to original condition	0	1	0	**1**
Public hearing additional	0	1	0	**1**
Increased flood insurance rates	0	1	0	**1**
Project instead of fine	0	0	0	**0**
Totals	**11**	**30**	**16**	**57**

Table 3-11. Building and Infrastructure ranked references by town

Building & Infrastructure References	Totals	Chatham	Newbury	Scituate	Percent	Rank
*Building elevated	10	2	5	3	15%	**1**
Building Lot Coverage	6	0	4	2	9%	**2**
*Rebuilding restrictions	6	0	5	1	9%	
Frontage required	5	0	2	3	7%	**3**
*Utilities modified	5	3	1	1	7%	
Building height	4	0	4	0	6%	**4**
Lot size restriction	3	0	1	2	4%	**5**
No fill material allowed	3	0	2	1	4%	
*No reconstruction, alteration of bldg c	3	0	3	0	4%	
*Restricted use areas in buildings	3	1	2	0	4%	
Septic ban or restriction	3	0	0	3	4%	
*Building permeability	2	2	0	0	3%	6
*Building systems elevated	2	1	0	1	3%	
Manufactured home, RV limitations	2	0	2	0	3%	
*Pavement permeable or no hardened	2	1	1	0	3%	
*Walkways elevated	2	2	0	0	3%	
*Water and sewer modifications	2	1	1	0	3%	
Building Floor Area Ratio	1	0	1	0	1%	7
*Building fortification	1	1	0	0	1%	
Building stories	1	0	1	0	1%	
Drainage around structures	1	0	1	0	1%	
No municipal services provided	1	0	0	1	1%	
*Repetitive loss rules	0	0	0	0	0%	8
*Retreat or Move building back	0	0	0	0	0%	
Totals	**68**	**14**	**36**	**18**		
Percent Totals		**21%**	**53%**	**26%**	**100%**	

* Resilience practices also found in the literature

Table 3-12. Green Infrastructure references by town

Green Infrastructure	Chatham	Newbury	Scituate	Total References
Beach renourishment	1	0	0	**1**
Dewatering	0	0	0	**0**
Dune stabilization or development	2	0	1	**3**
Living Shorelines	0	0	0	**0**
Marsh restoration	1	0	0	**1**
Sediment recycling	0	0	0	**0**
Vegetation	3	1	0	**4**
Totals	**7**	**1**	**1**	**9**

Table 3-13. Advanced Resilience Practices references by town

Advanced Resilience Practices (Excl. green infrastructure)	Chatham	Newbury	Scituate	Resilience main category
Building permeability	2	0	0	Building & Infrastructur
Pavement permeable or no hardened	1	1	0	Building & Infrastructur
Retreat Move building back	0	0	0	Building & Infrastructur
Property buy-back	0	0	0	Land Use
Relocation	0	0	0	Land Use
Rolling or moveable easement	0	0	0	Land Use
Totals	**3**	**1**	**0**	

Table 3-14. Table of documents reviewed

Document Name	Docu-ment #	Type	Town	Date amended or updated	How enacted, amended, promulgated by	Themes (nodes) coded	References coded	Pursuant to State law or reg. in whole or in part	# of pgs in doc
Protective Zoning Bylaw		Municipal Bylaw	Chatham	13 Oct 2015	Town meeting	41	228	MGL Chps 40A, 40B, 41	90
Wetlands Protection Bylaw	Chapter 272	Municipal Bylaw	Chatham	2015	Town meeting	17	69	MGL 131 §40 Wetlands Protection Act	8
Wetlands Protection Regulations Part 1 General Provisions		Municipal regulations	Chatham	17 Sept 2014	Conservation Commission	14	71	WPA	23
Wetlands Protection Regulations Part 2 Coastal Wetlands		Municipal regulations	Chatham	17 Sept 2014	Conservation Commission	28	251	WPA	23
Stormwater Management and Illicit Discharge and Erosion Control	Chapter 87	Municipal Bylaw	Newbury	2015	Town meeting	12	22	WPA	11
Wetlands Protection Bylaw	Chapter 95	Municipal Bylaw	Newbury	2015	Town meeting	43	254	MGL 131 §40 Wetlands Protection Act, E.O. 181	13
Zoning Bylaws	Chapter 97	Municipal Bylaw	Newbury	2015	Town meeting	57	359	MGL Chps 40A, 21 & others	123
Wetlands Protection Rules and Regulations	Section 30770	Municipal regulations	Scituate	17 July 2012	Conservation Commission	33	131	Title V, State Environmental Code 310 CMR 10.03, 15.00; MGL 131 §40 Wetlands Protection Act	46
Zoning Bylaws		Municipal Bylaw	Scituate	15 May 2015	Town meeting	42	233	MGL Chp 40A	122
Elevation Grant Fact Sheet		Municipal information sheet	Scituate	2015	Information only	6	9	FEMA	3
Natural Hazard Mitigation Plan		Municipal plan	Scituate	2016	Adopted by Board of Selectman, July 2016	35	100	WPA, town bylaws	135

Table 3-15. Case town characteristics

TOWN	Massachusetts Coastal Zone REGION	POPULATION	Coastal structures, linear feet (m)	Cost of structure repair (est. 2009)
Chatham	Cape Cod	6,125	5,600 (1707)	$4.2 million
Scituate	South Shore	18,133	46,000 (14,021)	$33 million
Newbury	North Shore	6,666	2,640 (805)	$1 million

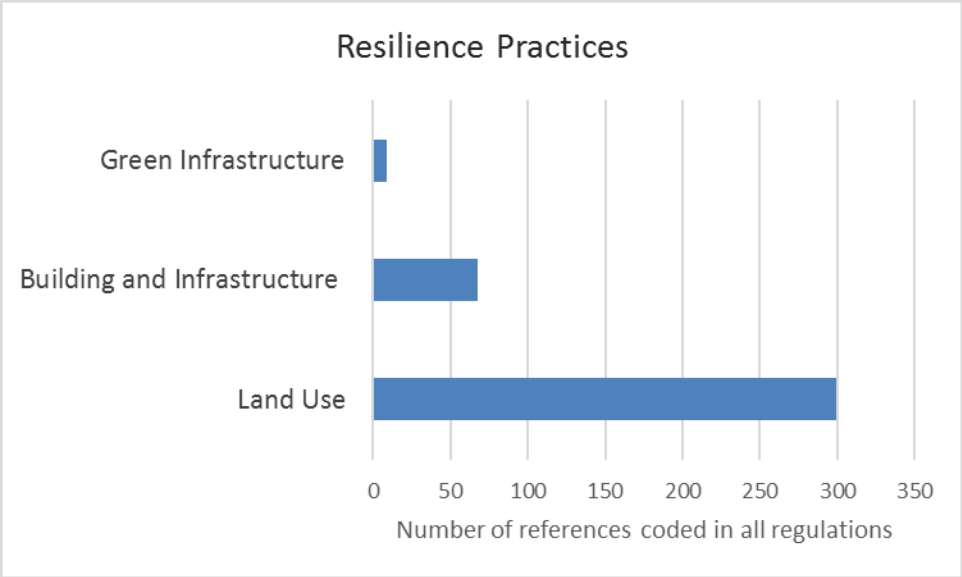

Figure 3-1. Frequency of Resilience main categories references

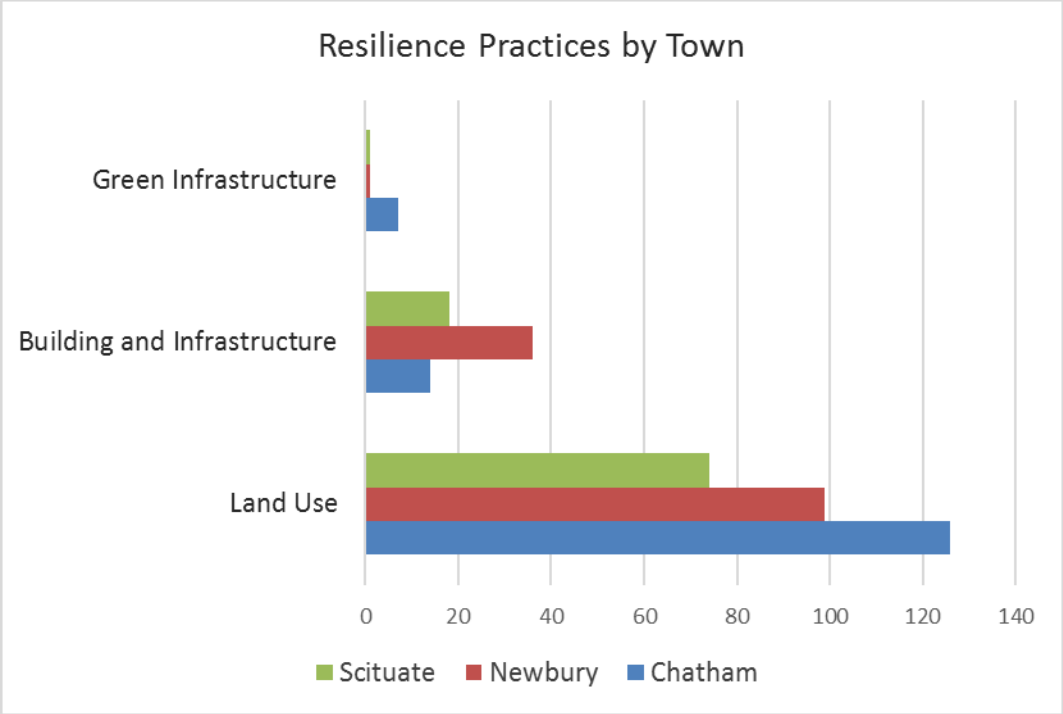

Figure 3-2. Resilience practices references by town

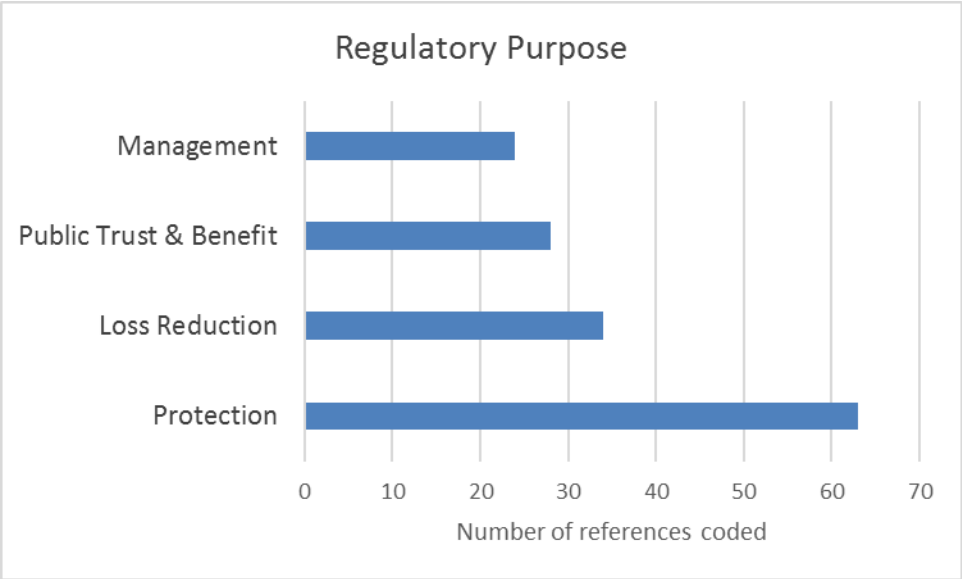

Figure 3-3. Regulatory purpose references by main subcategory

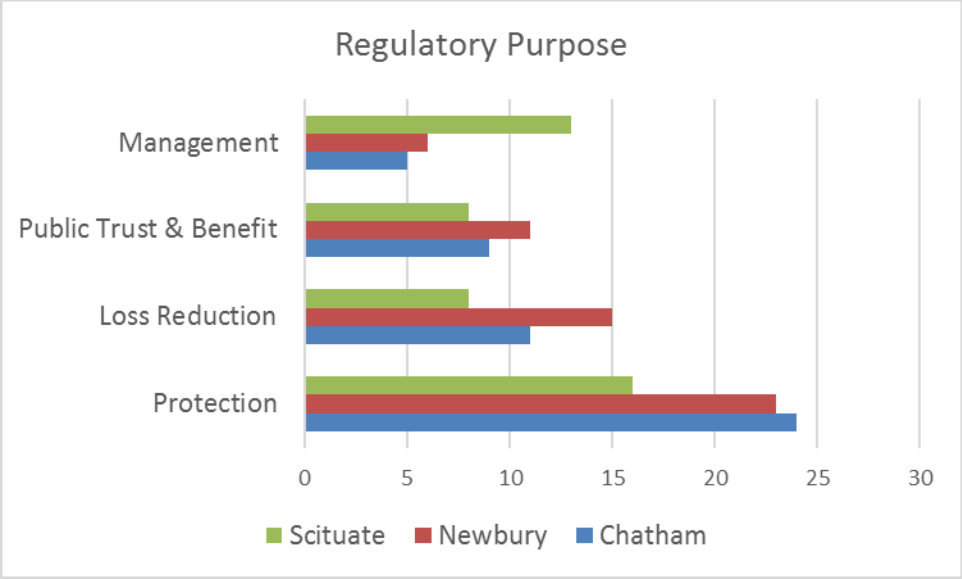

Figure 3-4. Regulatory purpose categories references by town

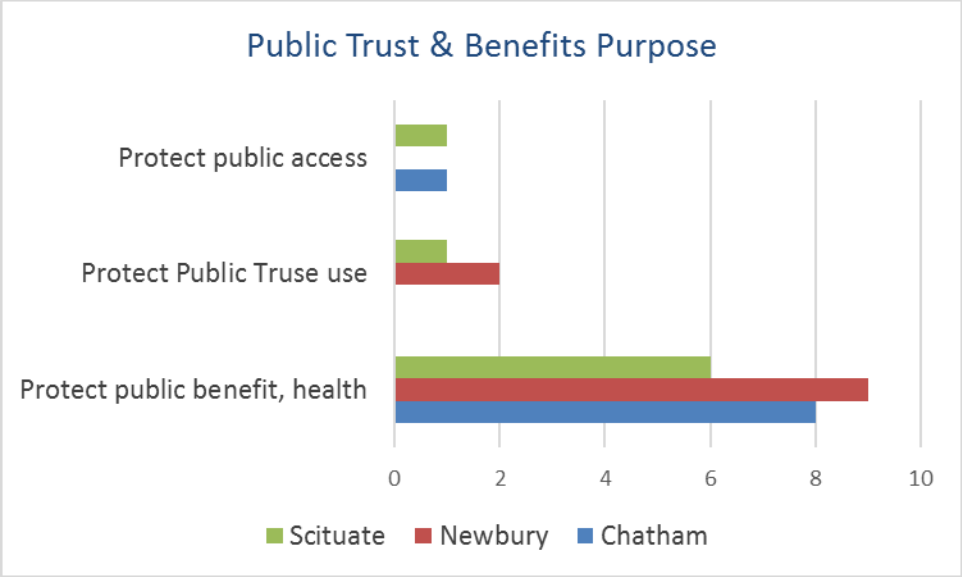

Figure 3-5. Public trust and benefits purpose subcategory references by town

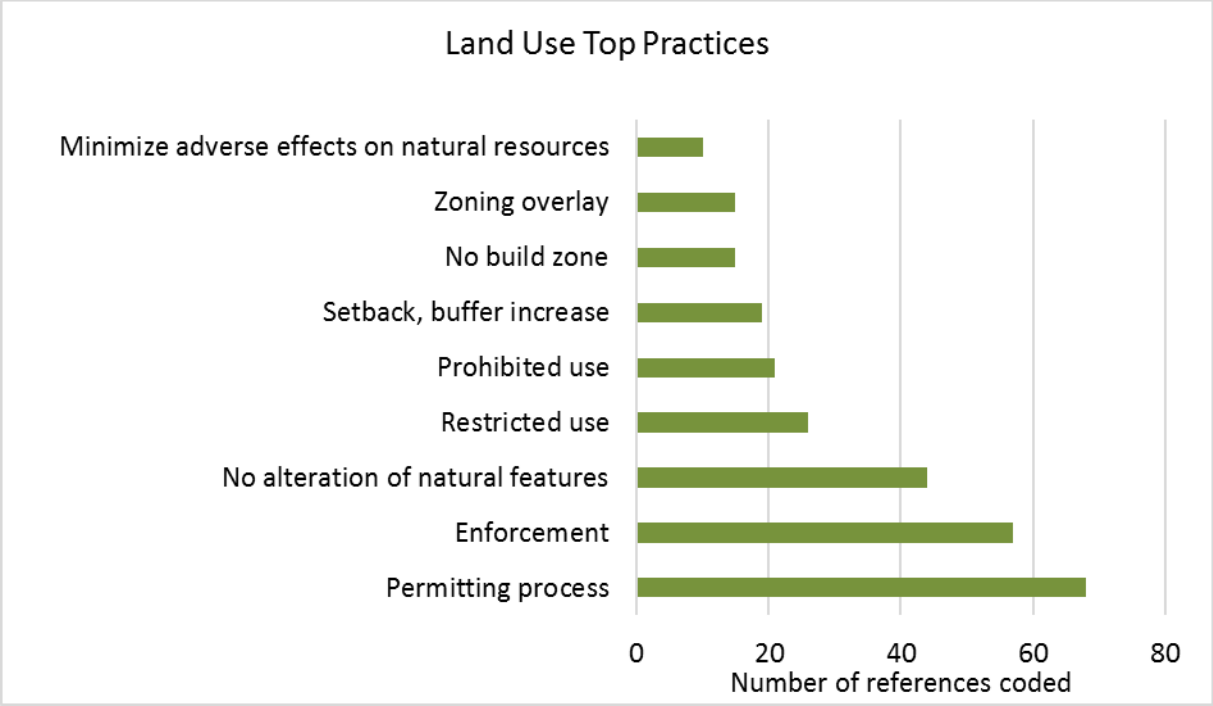

Figure 3-3. Land use categories most frequent references

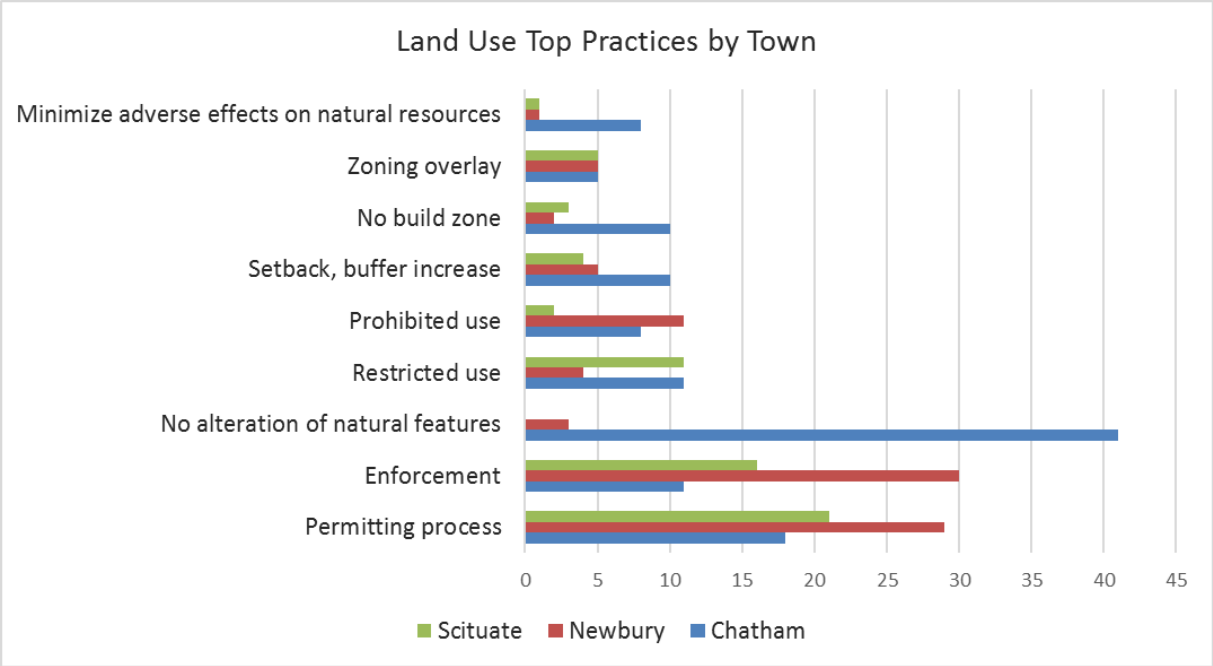

Figure 3-4. Land use categories most frequent references by town

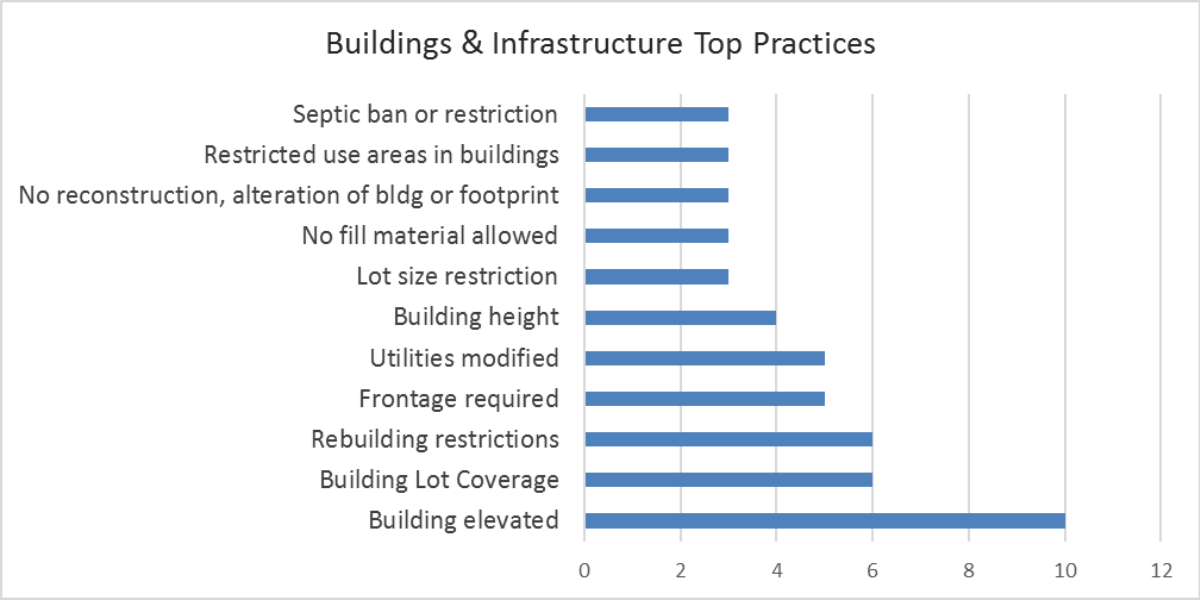

Figure 3-5. Buildings and infrastructure categories most frequent references

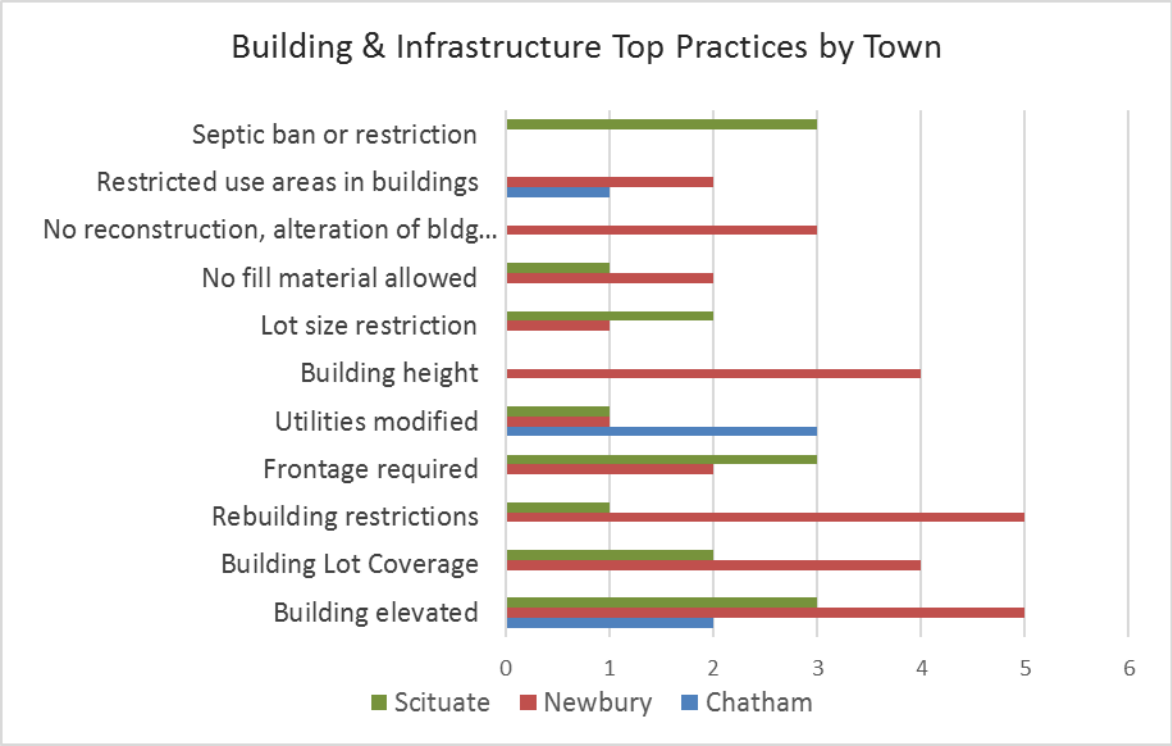

Figure 3-6. Buildings and infrastructure categories most frequent references by town

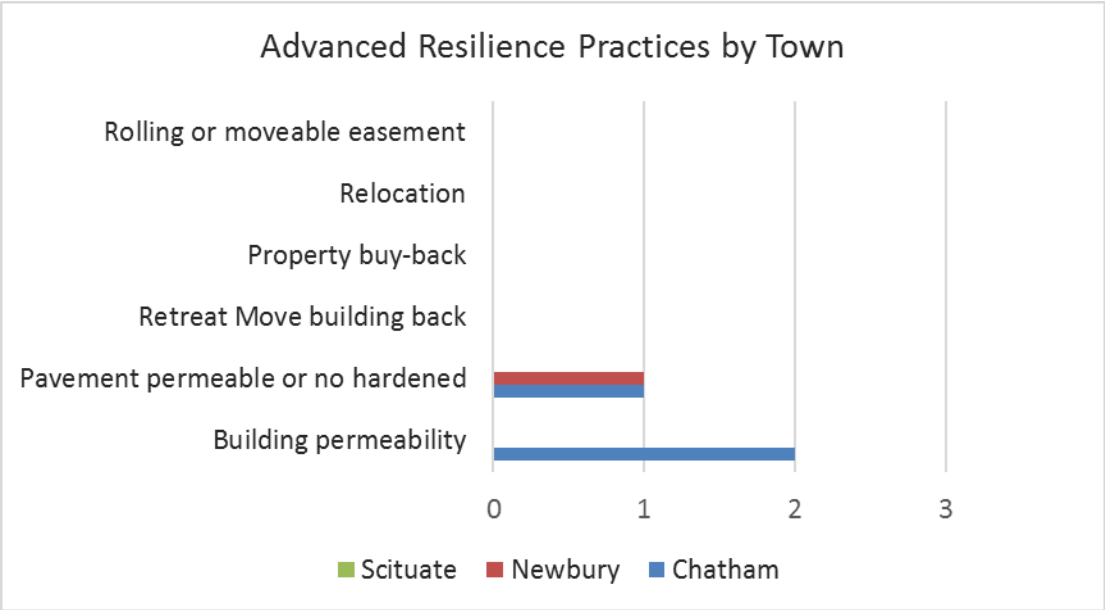

Figure 3-7. Advanced resilience practice categories reference frequency

Chapter 4, Coastal Resource Professionals Speak

Introduction

Qualitative content analysis was used to analyze the transcripts of interviews that were conducted with municipal coastal resource managers and other coastal professionals to ascertain their views on coastal resilience practices and their perspectives about the challenges they face in planning and implementing projects.

Participants responded to a central question of this study: Do municipal regulations and policies facilitate coastal resilience practices? The municipal resource managers were very familiar with their towns' wetlands, coastal, and zoning regulations (discussed in Chapter 3), so felt confident in addressing this question.

They described social and political factors that influence adoption or implementation of coastal resilience practices, and identified and characterized conflicts and barriers to planning and project success. Their responses contribute to understanding the context of the coastal management practice environment. Their recommendations for building adaptive capacity in local governance included moving from a crisis-management environment to more comprehensive and collaborative planning practices aligned with best practice recommendations in the literature (Beatley 2009, p. 5).

Participants viewed local governments as the primary deliverers of the services that build resilience. Their perceptions about the conflicts and barriers to building coastal resilience are captures by Peter Byrne's article in the Vermont Journal of Environmental Law:

> Public officials will have complex incentives and duties: protecting environmental resources (such as dunes and wetlands), securing public rights, promoting economic development, and satisfying constituents, including littoral property owners. But the dramatic changes being brought about by climate change will require rapid developments in rules based upon scientific understandings and the

> balancing of competing interests that legislatures accomplish better than courts. (Byrne 2010)

Summary

Interview participants were not familiar with the term "resilience" practices, but when presented with examples like marsh restoration, elevating buildings, and hybrid shoreline stabilization methods, they all responded that they had or wished they could have been engaging in those practices for years. Discussing the concept of resilience articulated another layer of purpose to what they were already doing. There is a disconnect between what academics and policy makers think practitioners know about building resilience (which is not much). Despite not having heard the term, the interview participants picked up the discussion and began to give examples of how coastal areas could be made more resilient using modifications and combinations of techniques that they had discussed with their peers, and in a few cases, had seen implemented. Only the term was new to them. This confirmed the supposition in this dissertation's introduction that "resilience" is partly a re-packaging of the "adaptation" and "natural resource management" concepts. For, "… once you start thinking about how to incorporate climate change into conservation or management it will seem curiously similar, or at least analogous, to what is already standard practice" (Hansen & Hoffman 2011).

Resilience in the U.S. is not the same as standard practice or adaptation (see discussion about the defining resilience in Chapter 1), but the interview participants expressed the desire that their coastal projects would build resilience instead of being piecemeal projects or quick responses to coastal damage that would be washed away with the next storm. Their recommendations to address the conflicts and barriers they reported to building resilience were consistent with the recommendations in the resilience literature. Now, they have the latest name for it.

Interview Participants

There are six interview participants of five types: two municipal coastal resource managers (2), a municipal conservation agent, a coastal resource manager that works with several towns on the Massachusetts coast, a town resident that advises a resource manager, and a federal agency subject matter expert that conducts coastal hazards research and assists federal and state agencies with coastal project planning and policy development. [39,40,41] He is familiar with all the case towns and their municipal coastal resource managers. All the participants, except the town resident adviser, are employed or contracted by their jurisdictions, are educated in their fields, and have years of professional coastal management experience. These traits were selection criteria and contribute to this study's inference quality that was discussed in Chapter 3.[42]

Purposive sampling based on jurisdiction type, employment and expertise was used to select the interview participants.[43] At least three municipal coastal resource managers from different towns were wanted to provide more diverse experiences and opinions. The towns from which they relate their experiences are Chatham, Newbury, and Plymouth. The coastal manager responding with experiences from Plymouth included experiences from other Massachusetts coastal towns he has worked with.

Chatham and Newbury town profiles are in Chapter 3. Plymouth is in the South Shore Region of the Massachusetts Coastal Zones. Its coast faces Plymouth Bay and the western side of Cape

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[39] All participants but one gave permission for their identities to be revealed in this study.
[40] Northeastern University Institutional Review Board forms and authorization are in the Appendix.
[41] Federal participant is Rob Thieler, Director of the U.S. Geological Survey's Woods Hole Coastal and Marine Science Center in Woods Hole, Massachusetts. https://www.usgs.gov/staff-profiles/rob-thieler
[42] The discussion of inference quality for Chapter 4 is included in the Chapter 3, Method section.
[43] Peter S. Rosen, this project's adviser, was the source of the recommended coastal management experts to approach for participation in the study.

Cod Bay. Plymouth has a working harbor and a long narrow barrier island with some shoreline stabilization structures. This is the town of Plymouth Rock, Plimouth Plantation, and Pilgrim Nuclear Power Station.[44] Like the other case towns, Plymouth faces increased coastal hazard risks.

Method and Interview Transcripts

Semi-structured interviews were conducted in-person with all six participants and digitally recorded with their permission.[45] Each interview was transcribed word-for-word[46] into its own document and then imported into *Nvivo*™. Qualitative content analysis only was used to analyze the transcripts; no findings qualified as data to integrate as descriptive statistics as they did for the regulations in Chapter 3. The resilience practice mentions and references from the interviews add understanding and context to the coastal resilience practice environment.

The interviews included questions designed to elicit yes and no answers supported by examples of their direct involvement with projects in their jurisdictions. For example, whether municipal, state, or federal regulations facilitated or hindered coastal resilience project implementation. Some of the questions did not apply directly to the federal participant.

Some questions were designed to prompt discussion of a specific topic. The main categories of topics covered resilience project implementation, planning, policy and governance issues, their concerns about coastal hazards and thoughts on engineered coastal protection structures. Content analysis of their answers yielded the *in vivo* coding architecture for the main topics.[47]

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[44] Pilgrim Nuclear Power Station is set to close in 2019. Entergy Corporation (2016)
[45] Document with interview questions is in the Appendix.
[46] Transcriptions were not 100% accurate because of occasional inaudible words and some background noise in one interview.
[47] Codebook is in the Appendix.

The main categories specific to the interviews coding architecture that are not shared with the regulations codes are Coastal Hazard Concerns, Engineered Structures, Governance, and Problems (planning, implementation, regulatory, political). A separate set of codes was created for the binary answer questions. Main categories shared with the regulations architecture are Purpose (regulatory) and Resilience Practices. Figure 4-1 shows the distribution of mentions in the six main categories by participant type, exclusive of the binary answer categories.

The "Problems" category was most referenced by those policy implementers, the coastal resource managers; the policy enforcer, the conservation agent; and a beneficiary of municipal services, the town resident. The Problems main category is made up of several sub-categories discussed in the "Conflicts and Barriers" section.

The content analysis of the interviews characterizes the factors that the participants contend with to bring resilience to coastal communities. Their recommendations span the practical to the political and are presented in the "Recommendations" section.

Findings

Discovering whether the participants felt that local, state, and federal regulations helped or hindered the implementation of coastal resilience projects was a main objective of this study. Participants did give "yes" or "no" responses and were eager to provide context and details. They were asked in conjunction with the binary question if political or public opinion factors affected project implementation. The federal participant did not have responses to these questions since he was not responsible for municipal project implementation.

The details and explanations about context were captured in the categories coding architecture described above in the "Methods" section.

Do regulations help?

Perceptions about regulatory effects on project outcomes are presented here. Figures 4-2, 4-3, and 4-5 show the number of responses participants made to the question "Have [local, state, federal] regulations and/or policies helped [coastal resilience/adaptation/restoration/stabilization] project implementation in your town?" The number of responses correspond to the number of examples the participants gave with each yes or no response. Their responses are grouped by the jurisdiction of the respondents. It is important to keep in mind that participants answered this question in an interview setting. They did not refer to project data or otherwise refresh their memories with reports or other writings. Their answers were thoughtful, but spontaneous. It cannot be inferred from their responses that there are overall more or fewer instances of regulatory helpfulness in a town. Generalization from their responses is not possible.

There were fifteen responses that local regulations supported coastal resilience project implementation and ten that expressed hindrance to implementation (Figure 4-2). The Plymouth and Newbury respondents thought first of project successes that had facilitated by their town's regulations. That they did not offer examples of regulatory interference or indifference does not mean that there were none. They did offer examples of these in the open-ended answer portion of their interviews (presented in the "Conflicts and Barriers" section below). The interviewer did not press for examples and did not force the discussion back to the question if the respondents did not provide examples for both cases and indicated they were ready to move on to another question.

In the ensuing open-ended answer interview discussions, participants made recommendations about how regulations could be more supportive. Participants expressed frustration and resignation about the barriers regulations created.

The question about the helpfulness of state regulations and policies elicited more negative responses than for local regulations (Figure 4-2 and Figure 4-3). There were sixteen "no's" and only five "yes's." The Plymouth/regional participant did not offer an example of state regulatory interference. Again, that does not mean that there were none.

The Chatham and Newbury participants perceived state regulations as not helpful to project implementation. These responses included comments like "No, in the project I just talked about for the local question, the state regulations weren't helpful." These responses cannot all be inferred as instances of state regulatory interference, only as "not helpful." This is also the case for their responses about federal regulations in (Figure 4-4).

Political factors (5 responses) and public opinion (15 responses) were not all perceived as negatively affecting project implementation (Figure 4-5). The public opinion and education thread weaved through the entire interview with the Chatham participants. They related situations of uninformed public outcry about projects, town residents clamoring for unsustainable or unrealistic projects, and sometimes fierce resistance to acceptance and compliance with conservation agent's and commission's decisions. A strong recommendation made by all the participants was a need for public education about the coastal zone. They said that once people had an opportunity to learn about options for coastal stabilization and the impacts of human uses of the coast, they became more interested and engaged, less combative with town officials and each other, and even vocal supporters of projects. Not all their responses were about negative effects on projects.

The Newbury and Plymouth participants related the five instances of political influences on project implementation. Again, these were not all negative. They spoke of projects that would never have been funded or considered but for the support of an elected official.

Conflicts and barriers

Responses for all participants are included in this "Conflicts and Barriers" section. The objective of this set of questions was to discover the conflicts and barriers the participants encounter to building coastal resilience. Discussions were prompted by open-ended questions around three main categories, (i) Policy, regulatory, and political factors that have a negative effect on any aspect of efforts to achieve coastal resilience (hereinafter referred to as "poli-regulatory"), (ii) Project implementation conflicts and barriers including why projects fail, and (iii) Planning conflicts and barriers.

The number of mentions was determined by line-by-line hand-coding the interview transcripts using word searches to aid in the identification of mentions. Participant mentions reference situations and issues that were discussed, not merely word counts. These were in-depth interviews about the conditions-on-the-ground framed by the open-ended questions. Participants were free to discuss any related coastal resilience or adaptation situations they had direct experience with, and they were not restricted to events in a given time-period or held to an interview time-limit. Responses for all the participant types are in the Conflicts and Barriers section.

Project implementation conflicts and barriers garnered the most of the 143 mentions (37%), followed by Poli-regulatory (35%), and Planning issues (28%) as shown in Figure 4-6.

The sub-category codes for each of the three main categories were all created *in vivo* from the participants' responses.

Policy, regulatory, political conflicts and barriers

Mentions of legal or liability issues (19%) and property rights conflicts (34%) together were just over half (53%) of all the poli-regulatory conflicts and barriers reported (Figure 4-7).

Property rights conflicts between property owners, between property owners and the town, and a general attitude of "NIMBY" (Not In My Backyard) were reported. The situations covered a range of property rights questions.

For example, objections were made about dredge material being used in town harbor areas that are near private property. Private property owners worried that dredge material would be carried to their beaches and affect their beach quality. There were reports of property owners unfairly blocking public access to the shore. Massachusetts law that gives property owners rights down to the low water line was reported to cause conflicts for the town especially when it was asked to intervene in or advise about property rights conflicts between private landowners. Lack of concern about the general welfare of the shoreline ecosystem was apparent by the attitude that private property protection should always be the priority.

Regulatory and political conflicts often overlapped. For example, when town officials sign a declaration of emergency after a coastal disaster, residents often approach town coastal managers and ask them to issue permits for projects that would not be permissible under normal conditions. According to the interview participants, residents are under the impression that if their properties are threatened, they should be able to do whatever kind of project they want. This can lead to a breakdown in regulatory authority and the kind of street-level bureaucracy described in Chapter 3 about the stand-off between property owners and regulators on Plum Island in 2013.

As related by one of the town coastal resources managers when town coastal managers or conservation agents refuse to issue permits during or after declared emergencies (accompanied the reasons for the refusals), residents typically go right to their legislators to complain.

> "They're [legislators] very susceptible to pressure of that kind from their constituents. So, before you know it they're getting involved in the process and then there's a battle between the legislators and the regulators and you've got the taxpayers and the governor's office involved. Well, let me digress, so 5 people do that. What if it's 50 people? 5000 people? 50,000 people? And you're starting to talk on regional scales. The regulatory authorities can't hold that back. You're not likely to maintain a hold over the regulations with that kind of pressure. Which we can see, based on what has happened." [Referring to the unofficial suspension of regulations that allowed property owners to armor their shorelines on Plum Island in 2013.]

Planning conflicts and barriers

Participants report that the causes of the lack of long-term and comprehensive systems planning are related to funding constraints and a policy culture of crisis management which is perhaps due in part to funding constraints (Figure 4-8). Project funding comes from town budgets and state and federal grants. Budget-funded projects are usually for maintenance items like dredging and beach management. Special projects like a marsh restoration typically are funded by grants. Privately funded projects may not impact town budgets, but they were a factor in participants' planning conflicts responses. Private projects typically have a single-focus, usually property preservation. These projects can create barriers to systems planning and contribute to the number of crisis management decisions.

An example of competing human and natural interests is the need for dune development to assist with property protection and endangered species habitat preservation. The endangered piping plover that breeds on Massachusetts beaches prefers wide flat beaches for nesting. Dune

projects can reduce beach width and disrupt other conditions the plovers need for successful breeding.

The most contentious competing interests issue is human systems demand for a stable shoreline and the dynamic natural coastal processes. Seawalls can stabilize parts of the shoreline, but disrupt wave energy and the sand supply system of long stretches of the shore. This competition plus wetlands preservation versus permit requests for building comprised many of the situations the participants reported.

Implementation conflicts and barriers

Figure 4-9 enumerates the myriad of conditions reported that interfere with resilience, adaptation, and coastal resource management project implementation. Inadequate funding problems were 20% of the reported instances. Overwhelming maintenance expenses and fund mismanagement brought financial barriers to almost one-third (32%) of the total reported instances.

Financing climate mitigation, adaptation, resilience, sustainable development, and renewable energy is a critical global issue (UNFCCC 2017). Municipal adaptation funding problems mirror the international: Creating and accessing funding streams, project prioritization, and cooperative decision-making. Participants did not have funding recommendations, except to comment that an educated public is more likely to understand its importance and engage in these complex discussions.

Project failure due to natural processes overwhelming a project before the end of its expected term of usefulness was another 20% of reported instances. An example of this is a dune stabilization project that was overwashed by storms in the same season. Participants noted that

many of these failures were due to crisis management and lack of long-term systems planning. In other words, many project failures were avoidable.

Time constraints, inadequate tools to execute a project, and structures in disrepair together were 12% of reported instances.

Policy or program failures were another 12% of instances. Examples reported described a failed FEMA property buy-out attempt because of rules changes and unreasonable time-limits; and a situation where a homeowner took advantage of FEMA funding to elevate his home which triggered an insurance policy change, but because of NFIP rules changes that required insurance policies be held in perpetuity, his policy was not grandfathered and his annual rate increased by thousands of dollars. All the situations reported were fraught with frustration and a stinging sense of injustice.

All the conflicts and barriers reported in this category seemed rooted in causes beyond the control of municipal coastal resource managers.

Recommendations of Interview Participants

Interjurisdictional and cooperative resilience projects

Town coastal resource managers discussed types of projects that they saw implemented, types they think would advance comprehensive long-term coastal resilience and might be possible, and some they think are not possible because of prevailing policies and attitudes (Figure 4-10).

One of the latter is coastal land acquisition for purposes like preparing for future marsh migration and open space, “There are a lot of nice goals…to buying low lying homes, but we don’t have the money so that the marsh can migrate into here 50 years from now. That isn’t going to happen.”

Joint town projects were reported to have better success of acquiring funding, especially when projects encompassed an entire natural system like a wetland that crossed or intersected municipal boundaries. Joint private project notice-of-intent applications are reported to have significantly increased in the past 20 years. Property owners band together to pay for a project that will benefit all. These joint projects are easier for conservation commissions or the Commonwealth to approve because the risk of appeals is low from abutting owners that in the past would likely have objected but are now part of a joint solution.

Town-state projects brought state technical and political assistance to larger complex projects. Benefits were reported for all types of interjurisdictional and joint projects.

"Intermunicipal collaboration" can aid "ecological connectivity" as in the case of the wetlands joint town project mentioned above (Bergsten et al. 2014).

Recommended policy practices and adaptive regulations

Political leadership was described as the ability to bring stakeholders to the table, facilitate difficult discussions and help people stay focused on the important issues without resorting to bickering (Figure 4-11). A state senator was named as an example of an elected official with these leadership qualities that had been instrumental in facilitating multi-stakeholder dialogue and problem-solving.[48] Participants recommend seeking these leaders out and engaging them in learning about local coastal issues to prepare them for future involvement.

Multi-stakeholder policy discussions were recommended especially around zoning, building codes, and community aesthetic ordinances that could be tested by adaptation solutions

[48] State Senator Bruce Tarr, Massachusetts First Essex and Middlesex District, https://malegislature.gov/People/Profile/BET0

to sea level rise and intensifying inundation events (Figure 4-11). Elevating homes may conflict with current building height restrictions. Building codes are largely driven by state requirements, so a town may not be able to customize codes. Waterfront homes on stilts may conflict with town aesthetic rules and prompt nuisance complaints from inland property owners that their views are obstructed. Participants observed that municipal officials are not thinking ahead about town access points, shoreline properties, or even municipal infrastructure. They are completely occupied by today's issues with no public pressure to engage in these long-term planning issues.

Much discussion focused on the need for new and adaptive regulations (Figure 4-11). These fell into three general categories, (ii) for built environment projects, (ii) for natural processes projects, and (iii) hybrid shoreline stabilization projects.

As mentioned earlier, the participants agreed that prohibitions are easier to understand, apply, and enforce. Building codes and zoning bylaws are typically clear-cut compared to coastal and wetlands regulations that are designed for site-specific application.

A recommended change in zoning bylaws to allow higher buildings so that waterfront and some landward property owners could build or rebuild according to the latest above-flood-height structure elevation recommendations.

Regional or "whole beach" sand supply issues were used as examples in almost every interview topic discussion in this study. One example of a negative regulatory effect on the natural beach system was of a property owner that was made to do a beach nourishment project for a 200 foot stretch of beach. This "didn't make sense" for the regional sediment supply, but regulations constrained project scope and permitting to that one site. The recommendations were for regulations that would accommodate systems planning and projects. As with all of the participants'

recommendations, this regional sand supply approach is consistent with best practices in the literature (NRC 2014, p. 92).

A discussion about requiring sand mitigation [replacement] for a coastal protection structure (e.g. revetment) that displaces sand, ended in a realization that there was no specific regulation for it, but there should be.

Regulatory barriers to different types of hybrid projects were explained. One participant commented that "regulations limit activities below high tide, so it's easier to do projects [above high water line] than it is to do a more appropriate project that incorporates the whole [beach] profile."

Installing a moveable or non-permanent wave-reflecting structure[49] in the fore- or nearshore until new marsh restoration plantings get established is desirable. The mature marsh would provide upland protection and other ecosystem services. The participants in one town offered this scenario as an example of a regulatory barrier because the "regulations are so stringent that we can almost never get that permit." They recommended adaptive regulations that would consider hybrid projects that incorporated wider coastal areas, including the inter-tidal area.

Recommended planning and implementation practices for building capacity and cooperation

Cooperative planning for comprehensive interjurisdictional projects was a main theme that threaded through the interview discussions, no matter the topic. All participants mentioned intertown and agency planning and policy learning between towns (Figure 4-12). Sharing lessons

[49] E.g. Moveable breakwater, wave attenuation device (WAD)

learned with colleagues in other towns was mentioned as an important factor to project success and professional development.

Increased municipal capacity to fund, plan, staff, and execute coastal resilience projects was hoped for, but not expected. This hopeful skepticism recurred in the national and international literature, "the daunting threats of climate change can result in inert local governments" (Janasie 2014, p. 54).

Conclusion

The conflicts and barriers expressed by these coastal resource professionals were consistent with those found in the literature. Municipal policy and regulatory environments seem to have similar effects on coastal resilience efforts across the nation.[50] Participants' recommendations also aligned with the literature.

Participants stressed "joint knowledge production" as an essential element in building coastal resilience (Hegger & Dieperink 2014). They considered "productive stakeholder engagement" and long-term planning as vital "characteristics of adaptive governance" (Yohe 2009, p. 30).

A regulatory environment that has the agility to accommodate changing coastal conditions, "whole shore" and resilience best practices was recommended. Frustration was evident that coastal processes science and coastal resource management and engineering have toolkits of proven solutions that go unused because of policy decisions made in "political silos" (Moser & Boykoff 2013).

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[50] As found in the literature and as relayed in conversations with the author by coastal resource professionals in municipalities in other U.S. states.

These interview participants demonstrated a depth of knowledge and the expertise that should inspire confidence that they can lead efforts to build community coastal resilience in the current atmosphere of uncertainty of increasing coastal hazards and incomplete knowledge (Soule 1985).

Figures

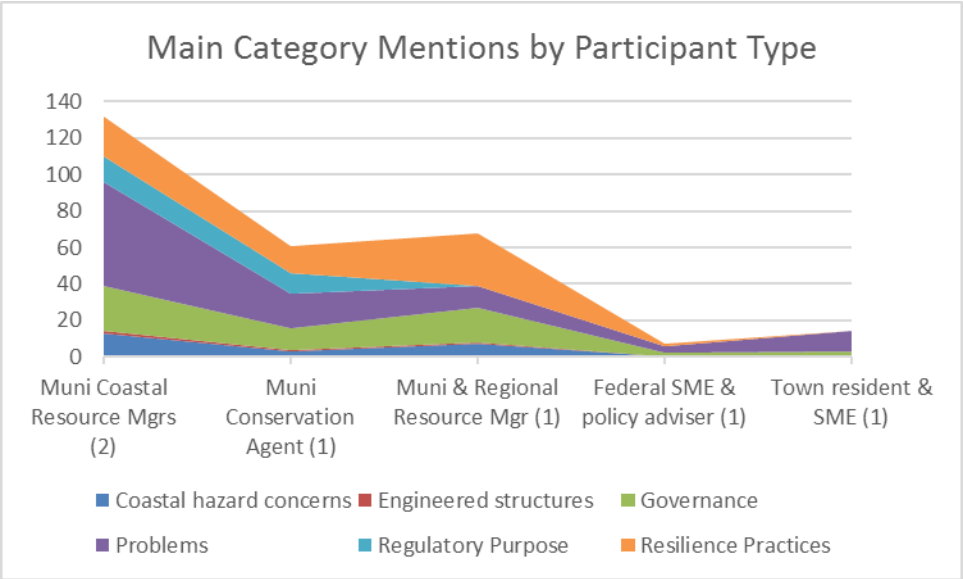

Figure 4-1. Distribution of responses by category by participant type

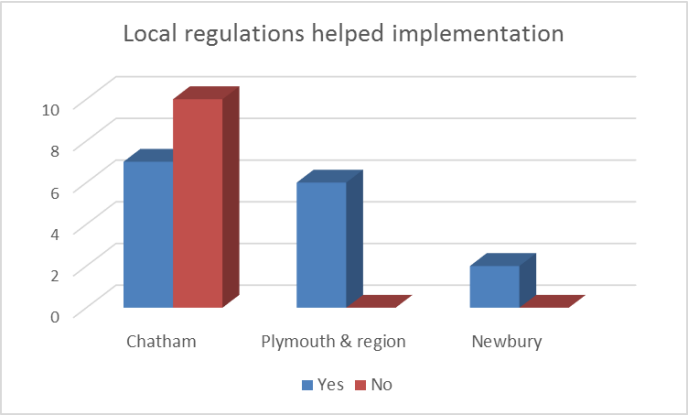

Figure 4-2. Perception of the effect of local regulations on resilience project implementation by jurisdiction of participants

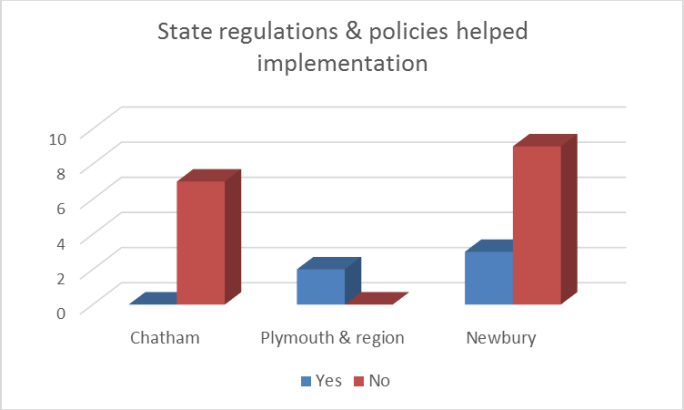

Figure 4-3. Perception of the effect of state regulations on resilience project implementation by jurisdiction of participants

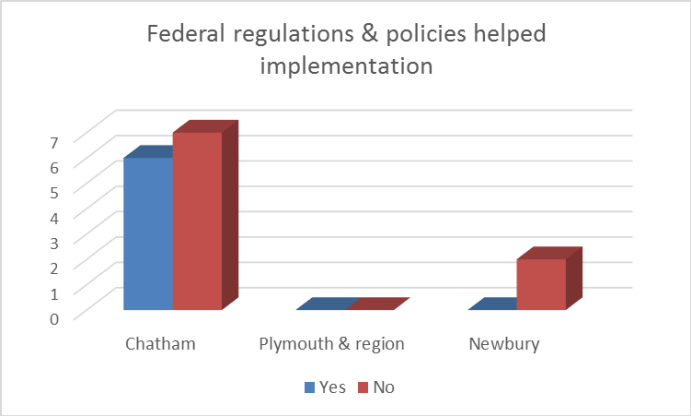

Figure 4-4. Perception of the effect of federal regulations on resilience project implementation by jurisdiction of participants

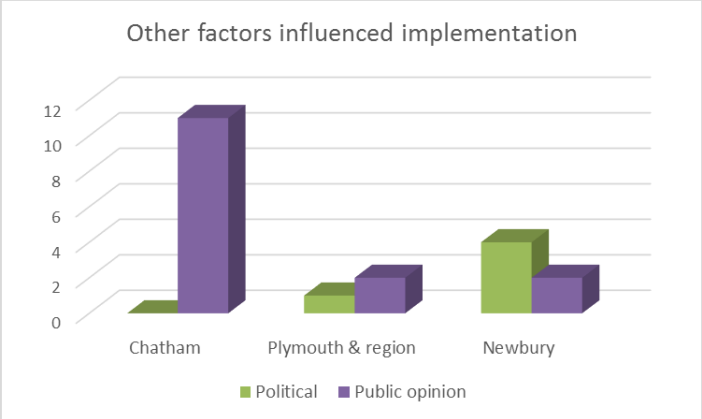

Figure 4-5. Perceptions of the effects of political and public opinion factors on resilience project implementation by jurisdiction of participants

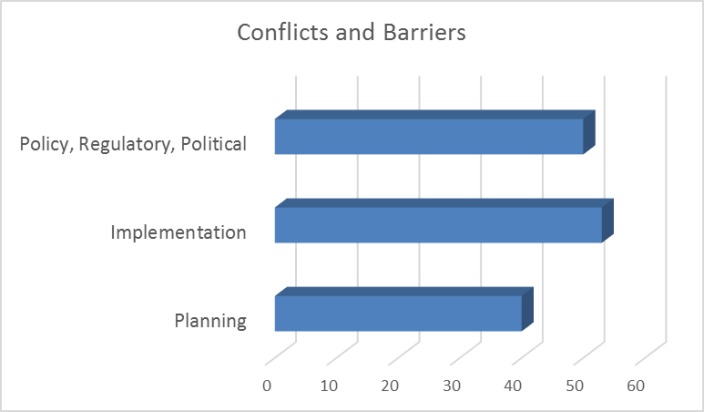

Figure 4-6. Conflicts and barriers mentions by main category

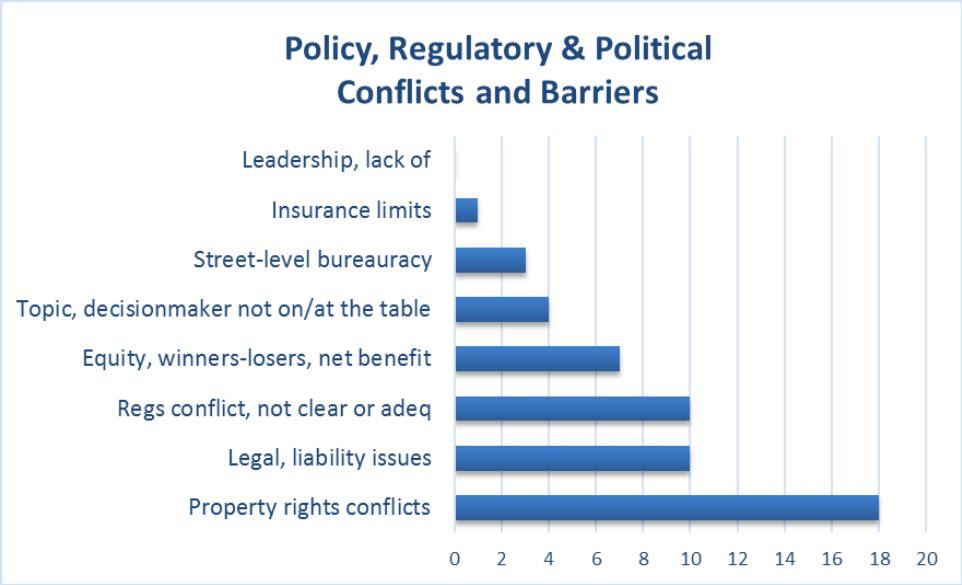

Figure 4-7. Policy, regulatory, and political conflicts and barriers reported by all respondents

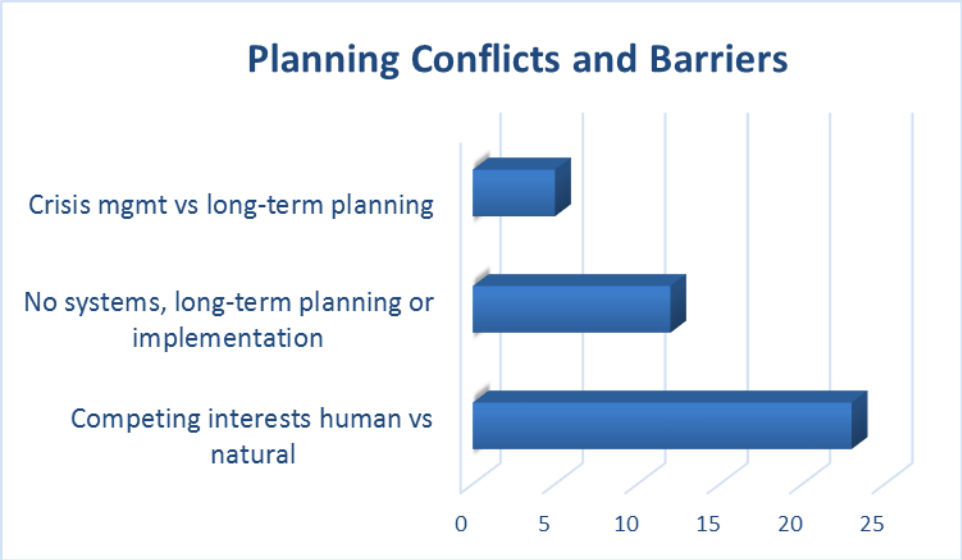

Figure 4-8. Planning conflicts and barriers reported by all respondents

Figure 4-9. Implementation conflicts and barriers reported by all respondents

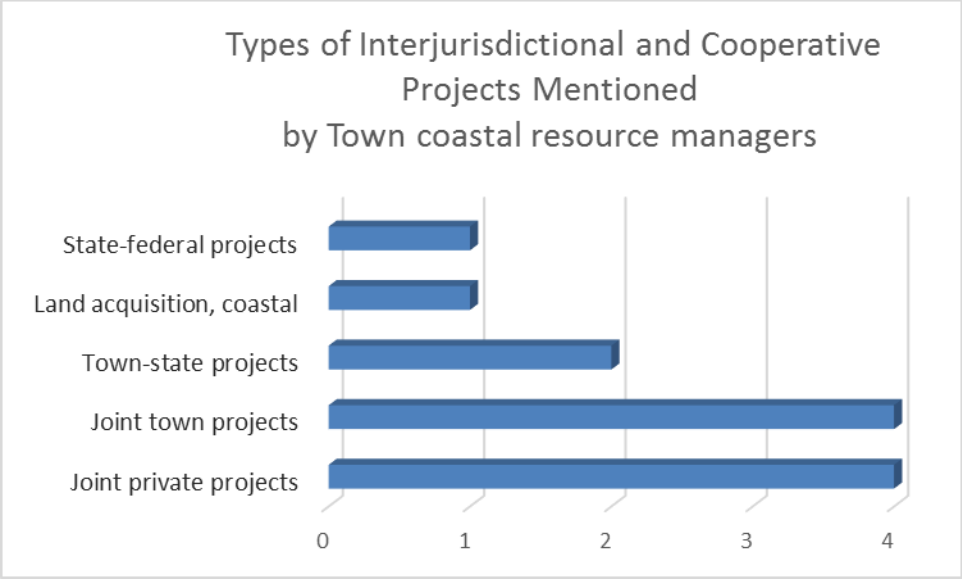

Figure 4-10. Types of interjurisdictional and cooperative projects mentioned by town coastal resource managers

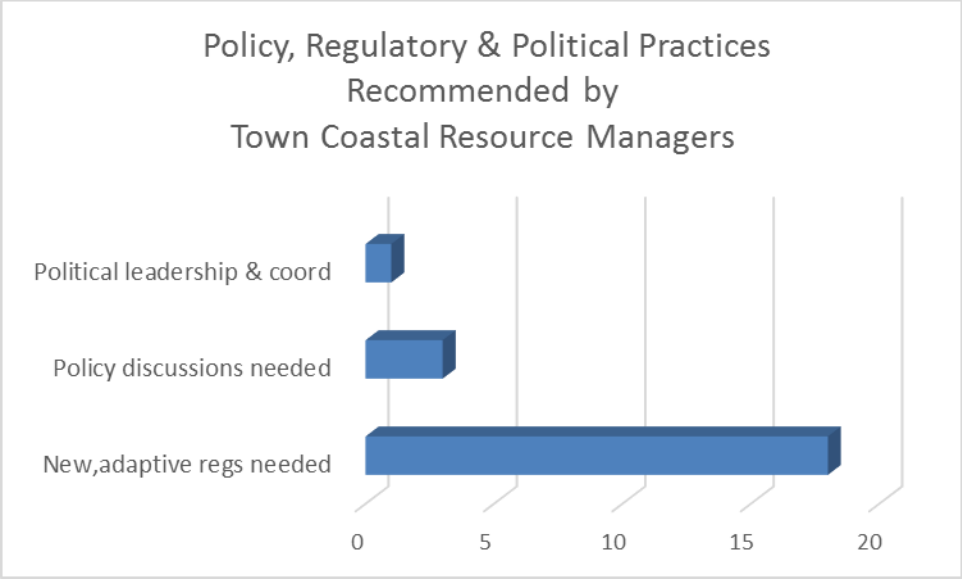

Figure 4-11. Recommended policy, regulatory and political practices

Figure 4-12. Recommended planning & implementation practices

Chapter 5, Erosion as Pollution

Introduction

Coastal property values increase with water views and proximity to the ocean, so when these amenities are put at risk, due to short term events such as storm surges, king tides, or along-shore sediment fluxes, or longer term hazards such as rising sea-levels, property owners often respond by seeking to construct seawalls.[51] In Massachusetts, property owners must appeal to local government conservation commissions ("Con-Coms") to approve the emplacement of seawalls. Within the broad constraints of the Commonwealth's Wetlands Protection Act of 1978 (WPA), municipal decision-makers must make decisions about permitting coastal protection and restoration methods across a wide range of coastal environments.

Coastal armoring by seawalls can lead to accelerated erosion on proximate, downdrift beaches.[52] This accelerated erosion, as a type of negative externality, can decrease property values linked to those beaches. Even in the face of strict WPA rules, seawalls continue to be constructed (Friedman et al. 2002), and as coastal geologists point out, "[w]hile the use of hard shoreline stabilization is discouraged due to adverse impacts on sediment supply to downdrift beaches, this is the approach that many communities will attempt to use, especially in the wake of major coastal storm damage" (O'Connell and Leatherman 1999).

The clear relationship between shoreline protection structures and accelerated erosion demonstrates that this topic is an important one that deserves further research to support decisions leading to more effective coastal adaptation and resilience. At minimum, political and societal

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[51] "Seawall" is used in this study to mean all types of hard engineered coastal protection or stabilization structures.
[52] In some contexts, experts suggest that combinations of low-impact methods may be less damaging, leading to improved coastal resilience RAE (2015), Schneider (2013).

impulses to armor the coast ought to be informed by the results of studies of the inclusive impacts of these structures. With the increased risks to the coastal properties, infrastructures, and livelihoods that are the inevitable results of rising sea levels and growing levels of coastal storm activity and intensity, municipal decision-makers must account more fully for the effects of engineered hard protection structures.

This chapter observes how shoreline erosion rates can change before and after the installation of seawalls in two Massachusetts coastal communities (Figure 5-1). A framework for assessing the external costs of these installations is developed here. This chapter addresses the question of whether the construction of seawalls results in net economic benefits when the adverse external effects of these engineering responses are incorporated explicitly as costs. An argument is advanced that adoption of the framework could lead to improvements in both the efficiency and equity of coastal decisions about protecting the coast with seawalls.

Dynamics of coupled natural and human systems

Human behavior responds to natural and economic events. As individuals lose valuable properties to coastal erosion, they seek to reduce those losses. A traditional solution has been to construct seawalls. A request is made either for the relevant municipality to build one or for a permit for a private installation, but historically the vast majority of coastal structures in Massachusetts were constructed by and belong to municipalities (MCZM 2011b).

Feedbacks exist between the geomorphological processes of the shoreline (the natural system) and waterfront development (the human system). Seawalls are built to stop and slow shoreline erosion, but seawalls simultaneously slow erosion at protected properties and accelerate erosion at downdrift properties. Consequently, property values can be affected adversely, and

communities or property owners may act to try to preclude downdrift erosion by building even more seawalls in front of the remaining unprotected properties.

Municipal officials need to know what the consequences of a structure will be both to a project site and to adjacent beach properties. Issues that should be considered are whether there will be winners and losers, their identities, and if there would be a net economic benefit for a town. Considering recent legal cases, towns must deliberate these questions and address concerns such as their liability for erosion damage caused by town-owned structures.

The elements in this coupled nature-human system are examined next. The concept of "pollution" is defined in ecological, legal, and economic terms. The concept of "net economic benefit" is defined. Finally, the concepts are combined to discuss the idea of "erosion as pollution."

Environmental Pollution

Environmental pollution is a degradation of the quality or characteristics of a natural feature (Bates & Jackson 1987). Water pollution is an obvious example. For Massachusetts residents, the restoration of the previously "un-swimmable" Charles River showed how federal, state, and local regulatory coordination could benefit the environment and restore ecosystem benefits to a community (Toussaint 2016).

In this study, environmental pollution comprises the degradation (erosion) of beaches and their natural processes of sand transport. Coastal erosion is the removal of sand and other material from one place and its natural transport to another place (Davis & FitzGerald 2004, p. 372). Erosion is caused by waves, currents, wind, and gravity (Davis & FitzGerald 2004), but this study does not distinguish erosion by cause.

Legal Pollution

For purposes of legal redress, pollution typically is considered a tort or a nuisance (Percival et al. 2009). In legal cases concerning beach erosion or accretion (the accumulation of sand), takings have usually been at the heart of the tort claims (*Lucas v. South Carolina Coastal Council, 505 U.S. 1003 (1992), Stop the Beach v. Florida EPA, 560 US 702 (2010)*).

Recently, private property owners prevailed in their case for the right to sue the Town of East Hampton, New York (on Long Island) claiming that the damaging effects of coastal erosion that led to water damage to properties caused by neglected town-owned jetties constituted both public and private nuisance and trespass (*Cangemi v. United States, 939 F. Supp. 2d 188 EDNY 2013*). With evidence that their homes were in significant danger of washing away, the Supreme Court of New York ruled that property owners could sue their municipality for nuisance on the basis that the town had interfered the use and enjoyment of their properties. The court also ruled that they could sue the town for trespass because water entered their land as a consequence of the town's neglect to repair the jetties.

Legal pollution adds another dimension to how erosion is perceived in the public mind. It also could provide an avenue to redress for property owners that experience catastrophic or damaging erosion near seawalls. Towns should account for these legal risks and responsibilities during shoreline stabilization planning.

Economic Pollution

Pollution is considered an external cost of a particular activity (Viscusi et al. 2005). It can be either unintended or purposeful, but in all cases the individual, firm, or government entity causing the negative outcome or side-effect does not bear the relevant costs.

In the coastal context, a property owner might construct a seawall to protect against the loss of her property due to erosion. The seawall acts to restrict erosion at the location where it is constructed but, at the same time, leads to accelerated erosion of properties downdrift. The accelerated erosion and consequent devaluation of downdrift properties constitutes a negative externality.

If the impacts of human systems on ecological systems can be quantified in economic terms, damaging outcomes might be mitigated through regulations that require reductions in the offending activity, technological fixes, or taxes or tradeable permits that force the polluter to bear the external costs. The costs of the external effects would then be internalized to business or municipal planning decisions.

Net Economic Benefit of Protection

This chapter addresses a central question of whether there is a net economic benefit when a seawall is put in place. Net economic benefit is defined as the difference in property values measured before and after the installation of a coastal protection structure (seawall). More specifically, the sum of annualized changes in the values of properties at a seawall site and downdrift of the seawall are compared before and after the seawall's installation. Importantly, the flows of annualized values are affected by the changes in the risks of inundation due to coastal erosion.

The rationale behind this method is to provide insight into the question of what happens to shoreline erosion and the values of properties affected by erosion both with and without the construction of a seawall. This study uses historical shoreline change data to answer that question in retrospect. The application of the framework to decisions made in the future would require

additional data, estimates, or assumptions about geomorphological changes and characteristics of the housing market.

Distributional Effects of Pollution

Regardless of whether there is a net economic benefit as perceived from the accounting stance of a municipality or region, some individuals might gain and others might lose from the construction of a seawall. This distributional question also likely influences community decisions about seawall construction or maintenance.

Policies that include negotiated solutions may be needed to address such distributional issues. Analysts have begun to explore the social benefits of negotiated solutions such as the sharing of costs by waterfront and near-waterfront property owners (Griggs et al. 2014, Jin et al. 2015).

Erosion as Pollution

Humans build on coasts as if they will never change. At the same time, coastal property owners are aware that beach profiles can change quickly and frequently from one storm to the next or from one season to the next. In terms of private property rights in Massachusetts, property lines shift with the mean low water line (Ducsik 2008).

The accelerated erosion of beaches downdrift of hard structures is a well-recognized phenomenon in coastal geology (Davis & FitzGerald 2004, p. 385, MCZM 2013, Pilkey & Wright III 1988). Coastal engineers typically plan for it (Coastal Lab ERDC 2007).

Depending on the type and scope of the project, guidance and authorization are required from the municipal or regional Conservation Commission (ConCom), state agencies, including the

Massachusetts Office of Coastal Zone Management (MCZM) and the Department of Environmental Protection (DEP), and federal agencies (the Army Corps of Engineers). In addition to the technical assistance provided by state agencies and the Corps, municipal officials should determine whether a seawall would provide an overall net benefit to the town. The ConCom and other town officials should consider whether the effects of erosion caused by town structures would cause harm to nearby properties and the shore.

Erosion affects beach width, and as a beach erodes, the time-to-inundation, or the point at which a physical structure such as a residence is inundated, shortens. A framework for simulating the effects on property values was used to answer this question for two case sites along the South Shore of coastal Massachusetts, one in Plymouth and one in Scituate.

Methods and Data

Analytical Framework

In order to understand the effects of shoreline erosion on waterfront property values, an analytical framework was designed to simulate changes in property values. The results of a hedonic price model (HPM) specified for a nearby municipality (Sandwich) on the South Shore of Massachusetts (Eberbach 2007; Eberbach and Hoagland 2011) were used to demonstrate the feasibility of using the framework. For each case, the framework comprises two spatial scenarios, the updrift site where a seawall emplacement is under consideration and a proximate downdrift site, and two temporal scenarios, before and after the installation of the seawall at the updrift site.

Assume that an "updrift" property owner situated on a coastal beach observes the rate of erosion of the beach fronting her property and estimates the time-to-inundation of her residence.[53] She decides that it would be sensible to construct a seawall if the property value, net of the costs of seawall construction,[54] exceeds the property value without a seawall:

$$B^U(SW) - C > B^U(0) \tag{1}$$

where B is the capitalized property value, U indexes the updrift property, SW indicates that a seawall has been constructed, and C constitutes the costs of construction and the discounted stream of future maintenance costs for the seawall.

A downdrift property owner is negatively impacted by the updrift owner's action if:

$$B^D(SW) < B^D(0) \tag{2}$$

where D indexes the downdrift property.

Ceteris paribus,[55] the municipality would decide to permit construction of the seawall if:

$$B^U(SW) - B^U(0) - C > B^D(0) - B^D(SW) \tag{3}$$

or the benefits, net of construction, to the updrift property owner should equal or exceed the external costs to the downdrift property owner. Expressed differently, the benefits with the seawall in place should equal or exceed the benefits without it:

$$B^U(SW) + B^D(SW) - C > B^D(0) + B^U(0) \tag{4}$$

To implement the framework, benefits are assumed to comprise capitalized property values as estimated by a hedonic pricing model (HPM). An HPM relates a measure of capitalized property

[53] When implemented in practice, updrift and downdrift properties would be aggregated.

[54] Construction also could encompass the reconstruction or restoration of a seawall that is not serving its intended purpose of forestalling erosion at the location where it is emplaced.

[55] This framework abstracts, for the moment, from regulations under the Massachusetts Wetlands Protection Act that may preclude local authorities from permitting coastal property owners to build a seawall.

values, typically either observed property sales prices or property assessments, to attributes of properties that may affect their values:

$$B = f(S, N, E) \tag{5}$$

where the capitalized value of a coastal property is a function of vectors of characteristics of the built structure (including the attached land), S, the neighborhood characteristics, N, and the environmental characteristics, E. Environmental characteristics include, among other factors, a time-to-inundation measure (sometimes referred to as "geotime") that represents the risk of inundation due to coastal erosion. In the context of empirical tests of the relationships between property values and property attributes in an HPM, if the effect of time-to-inundation on property values is positive and significant, then it could be used to simulate the effects on property value of changes in coastal erosion risk (Heinz Center 2000).

Erosion rates occurring both prior and after the construction of a seawall were used to determine the changes in time-to-inundation at both the updrift and downdrift locations. An increasing time-to-inundation at the updrift site implies a reduction in coastal erosion risk, which can be measured by the sum of annualized property values that are realized over the time period of the extended time-to-inundation. This sum constitutes $B^U(SW) - B^U(0)$. Analogously, decreasing time-to-inundation at the downdrift site implies an increase in coastal erosion risk, which can be measured by the sum of annualized property values that would be lost over the time period of a contracted time-to-inundation. This sum constitutes $B^D(0) - B^D(SW)$.

Coastal Structure Attributes

To demonstrate the implementation of the framework, the existence of a hard-engineered, shore-parallel, coastal protection structure with a downdrift adjacent sandy beach was required. The structure's construction date also was required. Qualifying structure types included seawalls,

stone revetments, and bulkheads. No hybrid or combined types were considered. Structure attribute data was collected from an unpublished Massachusetts coastal structures dataset, used by permission (MCZM 2011b).[56]

All coastal municipalities in the Commonwealth of Massachusetts were considered, except the City of Boston. Two sets of historical shoreline data were needed for each structure, one set before and one after the structure was built. These criteria revealed gaps in both historical shoreline measurements and in the coastal structure dataset.

The case study sites also required the presence of waterfront residential properties with houses that were protected by (located "behind" or landward of) the structure, and waterfront residential properties with houses located immediately downdrift of the structure, but not protected by the structure. Structure and shoreline data were exported to ArcMap©. The Massachusetts coast was visually scanned in Google Earth for combined structure/sandy beach candidates. The candidate sites were then examined for the relevant property attributes by a visual inspection in Google Earth.

Shoreline data attributes

The next phase of site selection required two sets of two historical shoreline transect measurements from the Massachusetts shoreline change dataset for each candidate site: one consisting of continuous transects in front of (seaward of) the structure and with at least 150ft of continuous transects on both the updrift and downdrift sides of the structure, for a total of four shoreline measurements (*Shoreline Data Layers*, 2013). The earlier set required one set of two

[56] Portions of this unpublished dataset were subsequently published in the Massachusetts Shoreline Change Project MCZM (2011 - 2015).

continuous transects, each dated before the build date of the structure; the latter set dated after the build date of the structure. These measurements yielded two erosion rates, one before the structure was built and one after. The final selections comprised a site in Plymouth with a stone seawall built ca.1959 (Figure 5-2, Figure 5-3) and a site in Scituate with a stone seawall built ca. 1958 (Figure 5-4).

Shoreline measurements

The long-term erosion rates before and after the installation of a seawall were calculated using Massachusetts historical shoreline measurements. Two sets of historical shoreline transect coordinate points for each case were collected from the Massachusetts historic shoreline change project (*Shoreline Data Layers*, 2013). The transect points (T_n) were plotted in ArcMap©, and then shorelines were constructed by connecting transect points: two sets of shorelines for each case site, one set before the seawall was installed (Plymouth 1909 to 1952; Scituate 1858 to 1952) and one set after installation (Plymouth and Scituate 1978 to 1994). Finally, shorelines were exported to Google Earth Pro.

Erosion rates

Two sets of erosion rates, as average feet per year, were calculated for each case site (one before seawall installation, ER_0, and one after installation, ER_{SW}), by taking the difference in distance between corresponding shorelines (SH_{yr}), using Google Earth's measuring tool. The distance was divided by the difference in number of years between the year of the earlier and later shoreline measurement sets.

For Plymouth: $ER_0 = (SH_{1909} - SH_{1952})/(1952 - 1909)$

$$ER_{SW} = (SH_{1978} - SH_{1994})/(1994 - 1978)$$

For Scituate: $$ER_0 = (SH_{1858} - SH_{1952})/(1952 - 1858)$$

$$ER_{SW} = (SH_{1978} - SH_{1994})/(1994 - 1978)$$

Erosion rates were compared to visualize the changes in rates before (ER_0) and after (ER_{SW}). Superimposed erosion rate bar graph sections on a Google Earth projection of the Plymouth site provided a view the erosion rates located on the actual shoreline.

Time-to-inundation

Inundation is assumed to occur when a shoreline intersects a built structure, such as a residence. Time-to-inundation was calculated using the Google-Earth distance of a structure to the erosion feature, such as a shoreline or a seawall, divided by the erosion rate for the property's corresponding shoreline transect. This yielded specific time-to-inundation data for each case property. The gain or loss of time-to-inundation determined the effect on assessed property values.

Property characteristics

Structural (S) and environmental (E) property characteristics were independent variables in the HPM. All properties were in the same neighborhood (N), so the categorical value of N=1 was input for each of the simulations. Data for all residential properties were collected from the two towns' public online property records databases. The data for each variable were sorted into two spatial scenario datasets for each town, comprising the updrift site (properties protected by a seawall), and the proximate downdrift site (properties not protected by a seawall), resulting in four datasets.

The structural independent variables constituted a property's living area (*ln*SFLA), lot size (*ln*LANDSZ), age of the building (AGEBLT), and the number of years since its most recent sale (AGESALES). The environmental independent variables were a property's distance to the seawall (*ln*DIST_ERF), its time-to-inundation (*ln*GEOTIME, *ln*(GEOTIME)^2), and the property's beach width (*ln*BEACHWDT). Three categorical (0,1) variables were used: waterfront property (WATERFRONT); the existence of a reconstructed dune between the house and the water (DUNERECON); and location in the FEMA coastal high hazard V-Zone (INVZONE). The V-Zone was determined for each property by referencing its location on the redrawn 2014 FEMA maps (FEMA 2016b). FEMA V-zone codes were cross-referenced in the FEMA map index to find the FEMA zone for the properties in that code area.

The means of each variable except time-to-inundation, which was varied from 0 to 100 years, were used in the simulations.

Hedonic Pricing Model

A hedonic pricing model (HPM) developed by Eberbach and Hoagland (2011) for Sandwich, Massachusetts was used to estimate the benefits or costs of changes to erosion rates and therefore time-to-inundation due to the construction of an updrift seawall. This model was motivated to fill a gap left by an earlier effort to develop a national model that did not include observations of the risks of erosion along New England coasts (Heinz Center 2000, Kriesel et al. 2000). The application of this model to Plymouth and Scituate is a form of "benefits transfer," where a model of environmental amenity values and erosion risk in one context is adapted for use in another.

The estimated Sandwich HPM was:

$$lnP = 10.12 + 0.38 * lnSFLA + 0.70 * lnLANDSZ - 0.002 * AGEBLT - 0.0006 * AGESALES - 0.8 * lnDISTERF + 0.15 * lnGEOTIME - 0.01 * \ln GEOTIME^2 + 0.02 lnBEACHWIDT + 0.10 * DUNERECON + 0.47 * WATERFRONT + 0.01 * INVZONE \quad (6)$$

Where *lnP* is the natural logarithm of the capitalized value (its sales price or its assessed value) of a coastal property. Simulations involving modifications of the time-to-inundation variable were conducted to develop estimates of $B^i(j)$ for $i = U, D$ and $j = SW, 0$. When the Sandwich model was developed, most of the estimated coefficients were found to be significant at the one percent level or less ($p << 0.01$), except for *lnBEACHWIDT* ($p = 0.03$). (Two variables, *lnSFLA* and *INVZONE* in the Sandwich model were found to be insignificant.) All variables were left in the model to simulate changes in annualized value with decreasing time-to-inundation for the different cases.

Eight simulations were conducted, using the four spatial scenario variable sets (two for each town) applied in the two temporal scenarios (before and after the installation of the seawall at the updrift site).

A diagram of the framework concept with expected results of the simulations is in Figure 5-5. Negative effects were expected for times-to-inundation and property values downdrift of the seawalls, as reported in previous studies on which this framework was based (Kriesel et al. 2000; Eberbach & Hoagland 2011). There were no *a priori* expectations for what the framework would reveal about the distribution of risks and benefits from the effects of the seawalls.

The elements of the simulation model are shown in Figure 5-6: The simulation co-efficients borrowed from the Sandwich HPM, and the Scituate values for the independent variables are shown to illustrate how they are used in the simulation.

Net benefits

Net benefits were estimated for each site where the capitalized values of updrift (B^U) and downdrift (B^D) properties are functions of the simulated Average Assessed Values and Average Annualized Assessed Values from the model.

Construction costs are relevant to decisions about whether to build a seawall and whether it would yield a net benefit. Construction costs were not available as many of the structures in Massachusetts, including the two in this study, were built before adoption of legislation (1978 Wetlands Protection Act)[57] that required better recordkeeping. Net benefit estimates should include the construction and ongoing maintenance costs of a seawall. (Note that construction and maintenance costs are not always borne completely by a municipality.)

Repair costs were estimated using 2009 repair estimates included in the Massachusetts unpublished coastal structure dataset (MCZM 2011b). If a repair estimate was not assigned to a seawall, then the total of the town's structure repair estimates[58] was divided by the town's total linear feet of structures for an estimated repair cost per linear foot. The 2009 repair estimates reflected the costs to return structures to states of good repair.

Beach type (generally eroding, accreting, or stable) affects the net benefit evaluations at the town and state-wide scales. Beach function varies by its location in the broader coastal sand supply system (Davis & FitzGerald 2004). This is the reason that beach width is not static. In Massachusetts, there are significant areas of accretion and hotspots of erosion (Mass EEA 2015). The net of these areas taken at larger scales could cancel out the net benefits or losses of individual beach sites.

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[57] WPA (1978, updated 2012)
[58] 2009 total estimated repair costs for all structures: Plymouth $28 million, Scituate $32 million.

The entity that builds or owns the seawall does not affect the results of the model. The erosion rates, time-to-inundation, and effects on property values operate independently of a seawall's ownership. Construction and ownership may be relevant to community net benefit considerations. Real estate taxes and neighborhood amenity values may also be relevant, but are not considered in this study. Town decision-makers typically have ready access to those numbers, but should also consider the hidden economic impacts of accelerated erosion effects from seawalls that this study's analytic framework could provide.

Results

Simulation estimates were compiled from all four scenarios for each town's case site, and discussion of them accompanies their graphic representations for each town site (figures are at the end of the chapter).

Plymouth

As expected, erosion rates accelerated on the shoreline in front of the properties downdrift of the seawall after its installation (Figure 5-7). Zero linear feet (on the abscissa) marks the location of the downdrift end of the seawall. The greatest erosion acceleration was downdrift of the structure on the shoreline to within 200ft of the end of the seawall.

Average annual updrift erosion rates before the seawall was built (ca. 1959) for the 43 years from 1909 to 1952, averaged 2.5ft/yr. for the entire 180ft stretch of shoreline that the seawall would occupy from its updrift end (beginning at 180ft) to its terminus (at zero feet) as shown on the abscissa (Figure 5-7).

The seawall emplaced in 1959 served a purpose of reducing updrift erosion rates for the landward properties. Average annual updrift erosion rates decreased after the seawall was built for

the 16 years from 1978 to 1994. The rate directly in front of beginning of the seawall (at -181ft in Figure 5-7) decreased by 44%, from 2.6 to 1.4ft/yr. Rates for the next 150ft of updrift transects to the terminus of the seawall decreased by 71% (2.4 to 0.7ft), 79% (2.7 to 0.6ft), and 76% (2.3 to 0.6ft), respectively. Immediately after the terminus, the rate began to climb and, at that transect point, exceeded the pre-installation rate by 56% (0.9 to 1.3ft) (Figure 5-7).

Average annual downdrift erosion rates before the seawall was built for the 43 years from 1909 to 1952, ranged from just under 1.0ft/yr. immediately downdrift of the seawall, and then averaged 1.8ft/yr. for approximately the next 150 feet downdrift (Figure 5-7). Properties on this downdrift shoreline were not protected by the 1959 seawall.

Average annual downdrift erosion rates increased after the seawall was built for the 16 years from 1978 to 1994.[59] The rate immediately downdrift of the seawall increased by 56%, from 1.0 to 1.3ft/yr. The three transects for the next 150 feet downdrift increased by 81% (2.1 to 3.8ft), 73% (1.7 to 3ft), and 17% (1.6 to 1.9ft), respectively (Figure 5-7).

Accelerated erosion was the greatest immediately after the terminus of the seawall where wave energy was deflected downdrift with the greatest force. The accelerated erosion effect lasted from this point for almost 200ft downdrift of the terminus at which point the rate began to approach pre-installation rates (Figure 5-7).

It is startling that, after the seawall was built, the erosion rates for the unprotected downdrift properties accelerated to rates even higher than those experienced by the protected updrift properties before the seawall was installed. Those pre-installation updrift rates prompted the request for the seawall in the first place. This was an example of a redistribution of erosion risk

[59] It should be noted that the unprotected properties on this Plymouth shoreline are located just downdrift from another section of seawall.

from one group of updrift properties to neighboring properties downdrift. Clearly, the redistributed erosion effects could be considered a polluting nuisance, a scenario ripe for litigation.

After the seawall was installed, the updrift properties landward of the sea-wall gained an average of 49 years before the expected year of inundation compared to the case in which the seawall had not been built (Figure 5-8). This timeframe covered the term of a typical residential mortgage, showing that the seawall achieved its purpose for those properties.

The slopes of the curves in Fig. 6 begin their precipitous drops about 6-10 years before inundation, when properties lose their value completely, a finding that is consistent with the Kriesel et al. (2000) and Jin et al. (2015) models.

Coastal risk expressed as the average expected years until inundation for all updrift or downdrift properties is plotted on the abscissa in Figure 5-8 and Figure 5-9. Kriesel et al. (2000) label the time-to-inundation as the "expected years away from the shoreline" in their model. Property value expressed as the accumulated average annualized assessed values (AAAV) of all protected or unprotected properties in dollars (2014) is plotted on the ordinate in Figure 5-8 and Figure 5-9.

Time-to-inundation for the unprotected downdrift properties would occur on average 135 years earlier than it would have if the seawall had not been built (Figure 5-9). The time-to-inundation for these properties is longer compared to the protected properties because they are located on the top of an embankment that is between 64-97ft high in places.

It would have been ideal for the study if a section of shoreline had been found without an embankment that met all the selection criteria. This shoreline feature does not invalidate the simulation, however. The accelerated erosion risks were transferred to the downdrift shoreline and properties in the simulation, in any case. An embankment does not always take longer to erode

than a sandy beach. Indeed, it may collapse in sections as the beach beneath it erodes (Davis & FitzGerald 2004).

The benefits of extended times-to-inundation provided by the seawall accrued to the up-drift shoreline and properties (Figure 5-8). The increased erosion risks and compressed times-to inundation were transferred to the downdrift shoreline and properties (Figure 5-9). The net economic benefit or loss of this seawall project was calculated retrospectively with the actual shoreline change data and property values for the study area.

Net benefits were calculated by taking the difference of the AAAV of all the properties from each time scenario (before and after installation of seawall) for the year range 0-50 years. This range was used because it covers the term of a typical 30-year mortgage plus 20 years to account for the transfer of property ownership to a second generation or to another owner. The year range starts at zero dollars AAAV and zero years left until time-to-inundation. This is the point in time at which the shoreline would have reached a house, inundating it and reducing its value to zero.

Figure 5-10 shows a $1.2 million (2014 USD) accumulated benefit for the protected properties and a $3.6 million accumulated loss for unprotected properties. The 2009 estimated one-time repair cost is approximately $76,000. This results in a net loss of almost $2.5 million over 50 years for the Plymouth site.

Scituate

Erosion rate changes for Scituate show a pattern similar to that of Plymouth's. Accelerated erosion occurs downdrift of the seawall after its installation (Figure 5-11). The Scituate shoreline has a very different physical profile than that of Plymouth. There is no bluff or embankment, and

the entire study area is relatively flat (Figure 5-4). The 316 ft.-long seawall that was built in 1958 is the most downdrift in a series of seawalls. Part of the last seawall in the updrift series is pictured in the aerial view of the study site in Figure 5-4.

Average annual updrift erosion rates before the seawall was built for the 94 years from 1858 to 1952, ranged from 3.0-5.8ft, averaging 5.4ft/yr. for the 316ft stretch of shoreline that the seawall would come to occupy in 1958 from its updrift end (beginning, at -316ft) to its terminus, as shown on the abscissa of Figure 5-11. This beach eroded and accreted sand at high annual rates, indicating that it was an important area of sand transport for nearby sections of coastline.

The seawall served its purpose to reduce updrift erosion rates for the 316ft of shoreline it protected and the properties landward of it, decreasing the average annual erosion rate by 42% (2.3ft/yr). The average decrease was 43% (2.3ft) for the 316ft of protected updrift shoreline. The rate directly in front of northern end of the seawall (located at -316ft in Figure 5-11) decreased by 26%, from 4.2-3.1ft/yr. Rates for the next 300 feet of updrift transects to the terminus of the seawall decreased by 48% (5.8-3.0ft), 44% (5.7-3.2ft), and 48% (5.7-3.0ft), respectively. Immediately downdrift of the seawall's terminus, the erosion rate began to climb, and, at the first downdrift transect point marked at 103ft, the erosion rate was 6.7ft/yr. nearly equal to the pre-installation rate of 6.9ft (Figure 5-11).

The average annual downdrift erosion rates for the 94 years from 1858 to 1952, before the seawall was built, were considerably higher (34%) than the updrift rates. The downdrift average was 7.2ft/yr. versus updrift average of 5.4ft/yr. (Figure 5-11). The point of building a seawall is to slow erosion in the most vulnerable places, so it is curious that the seawall was not installed on the shoreline with the higher erosion rates. A possible explanation lies in Scituate's beach and intertidal profile (Figure 5-4). The updrift houses are close to the beach, so property owners would

feel an imminent threat from the eroding shoreline. The downdrift homes are much farther away from the high water line with a wetlands area between. The faster erosion rate was not perceived as a threat (if it was noticed at all by homeowners) because time-to-inundation would have seemed remote. This behavior is consistent with the findings of this study and previous studies (Kriesel 2000, Eberbach 2011) that impending inundation can motivate behavior to construct hard protection.

The accelerated erosion effect on the beach downdrift of the seawall after its installation was less dramatic than in the Plymouth case. The wide flat profile of the Scituate beach may account for the extended reach of the accelerated erosion down the shoreline compared to Plymouth (Figure 5-7). Beach profile plays an important role in how far beyond a seawall accelerated erosion can occur (Davis & FitzGerald 2004). Only the transects marked at 227ft and 342ft from the end of the seawall in Scituate showed accelerated erosion (3% and 8% increases respectively) after its installation (Figure 5-11). The accelerated erosion effect disappears beyond 500ft downdrift of the seawall's terminus. At the transect marked at 564ft, the rates approached those for the updrift properties protected by the seawall (Figure 5-11).

Average annual downdrift erosion rates after the seawall was built for the 16 years from 1978 to 1994 were similar to the rates before the seawall was built. The only noticeable difference is an 11% increase at 342ft. Because of the beach profile here, it is not possible to be certain that rate changes this far downdrift are from the effects of the seawall.

The rate for the 100ft immediately downdrift of the seawall's terminus (0-103ft on the abscissa in Figure 5-11) increased from 3.0 to 6.7ft/yr. returning this section very near to its pre-seawall rate of 6.9ft/yr. (Figure 5-11). Because of the dramatic decreases in the updrift erosion

rate, it is reasonable to assume that the downdrift rate for this 100ft is caused by the seawall's wave energy deflection to the downdrift shoreline.

Farther downdrift at 564ft the rate decreased 58% from the pre-seawall rate, from 8.5 to 4.9ft/yr. This probably indicates that the shoreline at that point is well outside the study area and nothing can be inferred using the study's parameters. It is interesting though that there is such a significant change compared to the rate that would have occurred if the seawall had not been built.

Updrift protected properties gained eight years until time-to-inundation compared to that expected if the 1858-1952 erosion rates had continued unimpeded by a seawall (Figure 5-12). Eight years seems like a short respite, but it is about a quarter of the life of a typical mortgage. The sharp decline in property value begins approximately 6-10 years before properties are inundated. The updrift average long-term erosion rates were cut almost in half (Figure 5-11).

Downdrift unprotected properties would be inundated 35 years sooner, about the term of a typical mortgage, than they would have been if the seawall had never been built (Figure 5-13). This pattern demonstrates the cumulative effect over time of what seemed like a modest 2% average increase in erosion rates to the unprotected properties downdrift of the seawall (Figure 5-11).

Modest benefits of extended times-to-inundation provided by the seawall accrued to the updrift shoreline and properties (Figure 5-12), but these benefits were less than what is observed in the Plymouth case (Figure 5-8). Some increased erosion risks and decreased time-to-inundation were transferred to the downdrift shoreline and properties (Figure 5-13).

There was a $154,000 benefit for the updrift protected properties and a $605,000 loss in accumulated average annualized assessed values (AAAV) for downdrift unprotected properties

(Figure 5-14). The estimated one-time repair cost was approximately $380,000. The estimated net loss over 50 years was $450,000 for the Scituate site.

Discussion and Conclusions

Coastal erosion and accretion are the processes that provide beaches, dunes, and marshes with sand. Increasing population concentration and the expansion of the built environment along the coast interfere with these natural processes. This coupled nature-human dynamic intensifies erosion problems, triggering humans to respond by stabilizing the shoreline.

Coastal communities face increases in storm frequency and intensity with inevitable associated inundation and erosion. The costs of preventing damage to buildings can be daunting. Whether seawall construction is privately or publicly funded and maintained, decisions to build seawalls should include analyses to forestall economic losses when the full social costs are considered.

The simulation framework presented here could be applied to a variety of shorelines with similar physical characteristics to evaluate proposed new seawall construction or repair. The framework could be refined further by incorporating estimates of shoreline changes due to sea-level rise and values of nonmarket ecosystem services that are put at risk. With appropriate modification, the framework also might be applied to evaluate coastal resilience options like salt marsh restoration, low-impact hybrid systems, or other types of living shorelines. It is critical for the long-term health of coastal systems that the impacts of proposed stabilization projects be accounted for and considered in project decisions.

A traditional practice of granting permits to construct seawalls to "squeaky-wheel" property owners without careful consideration of the potential external effects can lead to

unnecessary litigation. A good example is the Massachusetts case, *Woods* v. *Brimm* (2010)[60], a legal dispute between coastal property owners over the damages caused by seawall constructed by updrift property owners. In this case, the downdrift property owner sued both the updrift property owners and the engineering firm that built updrift seawalls. The dispute involved a negative social consequence (an externality) that the town could have analyzed more completely during the permitting process, using the framework suggested in this chapter. Now that property owners are becoming more aware that seawalls lead to accelerated erosion to downdrift properties, cases like *Woods* might be expected to be occur more frequently in the future, potentially including municipalities as defendants, as has occurred in the *Cangemi*[61] case mentioned above.

Municipal Conservation Commissions and other agencies involved in deliberations over permit requests for new seawall construction, replacement, or repair would need projected estimates of future erosion rates to use in the framework. Coastal geologists will need to be relied upon to provide such projections. Investment in local expertise at onset of deliberations could mitigate the technical, labor, and legal expenses of disputes that arise from a seawall that ultimately does more harm than good.

All parties involved in shoreline stabilization project planning should be cognizant of the distribution and transfer of risks and benefits using a framework like the one presented here. If seawall construction is allowed, any transfers of risks and benefits should be resolved in such a way that those who benefit are obliged to compensate those who bear the increased risks. This study's framework could potentially provide estimates to develop formulas for negotiated solutions to these distributional outcomes.

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[60] *Woods v. Brimm, 27 Mass L. Rptr. No. 20, 389 (2010)*
[61] *Cangemi v. United States, 939 F. Supp. 2d 188 EDNY 2013*

Figures

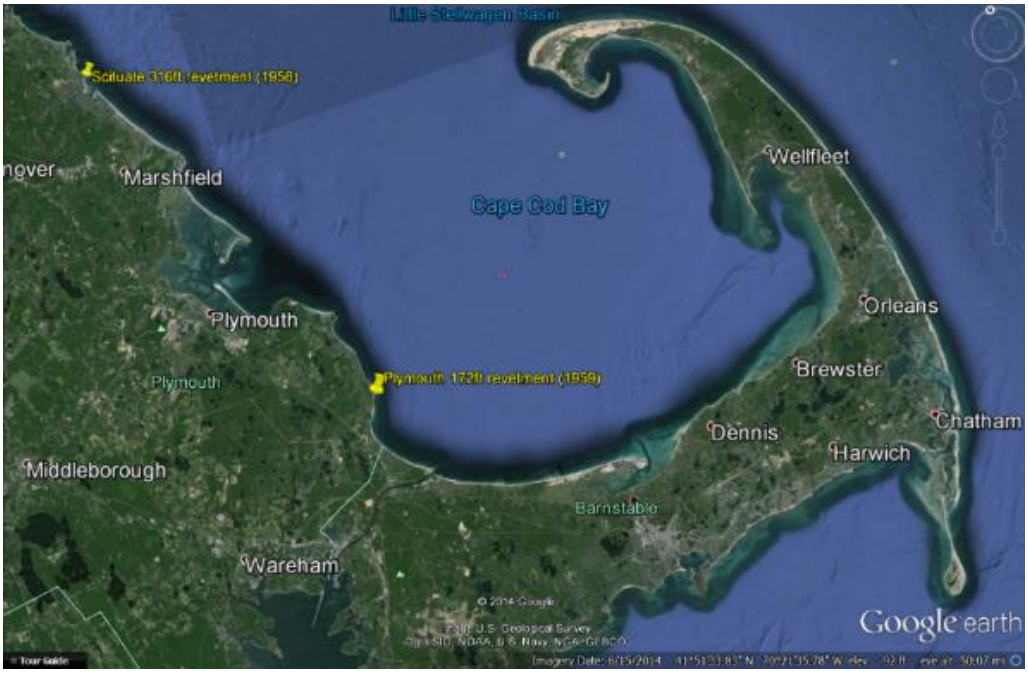

Figure 5-1. Location of Plymouth and Scituate case sites on Massachusetts coast (Google Earth image)

Figure 5-2. Plymouth 172ft stone revetment with downdrift embankment, installed circa 1959 (Google Earth image)

Figure 5-3. Plymouth site, closer updrift view (Google Earth image)

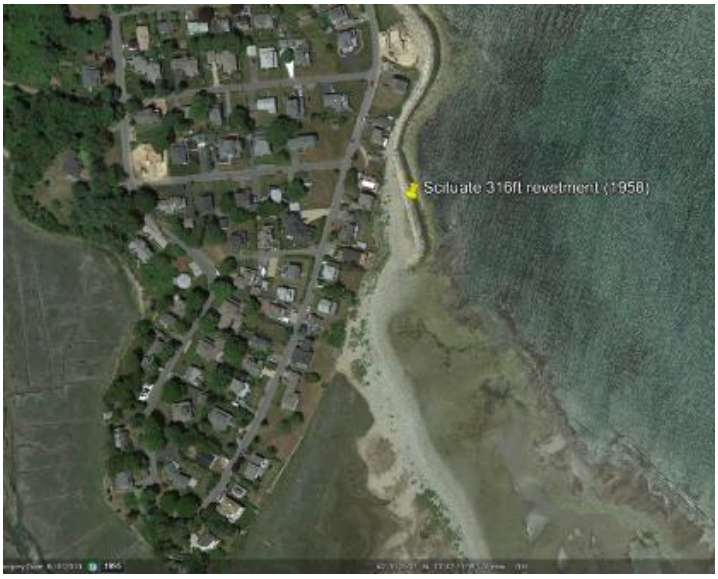

Figure 5-4. Scituate, 316 ft stone revetment, installed in 1958 (Google Earth image)

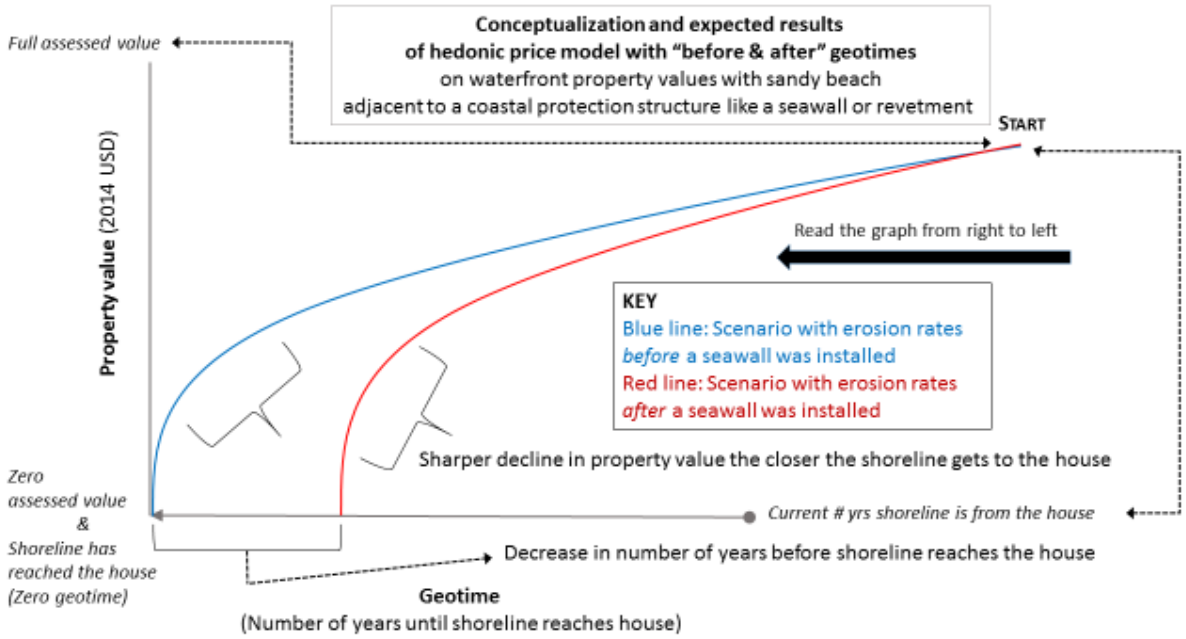

Figure 5-5. Framework concept diagram with expected results (geotime is time-to-inundation)

	Sandwich Coefficients	Independent Variables Property Attributes	SCITUATE means Pre Seawall Updrift	Pre Seawall Downdrift	Post seawall Updrift Protected	Post seawall Downdrift Not Protected	Products for 4 scenarios
Structural	10.1159	Intercept	1	1	1	1	10.1159
	0.3846	ln(Sq Ft Living Area)	7.537	7.303	(same)		*p*
	0.7022	ln(Lot Size)	0.174	0.171			*p*
	-0.0024	Age of building	84.333	59.750			*p*
Environmental	-0.0006	Years since last sale	11.667	15.500			*p*
	-0.1791	ln(Distance from Erosion feature)	3.933	4.903	3.529	4.095	*p*
	0.1475	ln(Time-to-inundation)	3.366	4.122	3.599	3.295	*p*
	-0.0062	ln(Time-to-Inundation)2	11.381	17.010	13.001	10.889	*p*
	0.023	ln(Beach Width)	3.645	4.758	2.956	3.754	*p*
	-0.0988	Dune reconstruction	0	0	(same)		0
	0.4738	Waterfront	1	1			*p*
	0.0054	Located in FEMA V-Zone	0	0			0
Framework results		Years to inundation	29	62	37	27	
		Difference in Years to Inundation			8	-35	
		% Gain or Loss in Years to Inundation			26%	-56%	

Figure 5-6. Elements of the simulation model

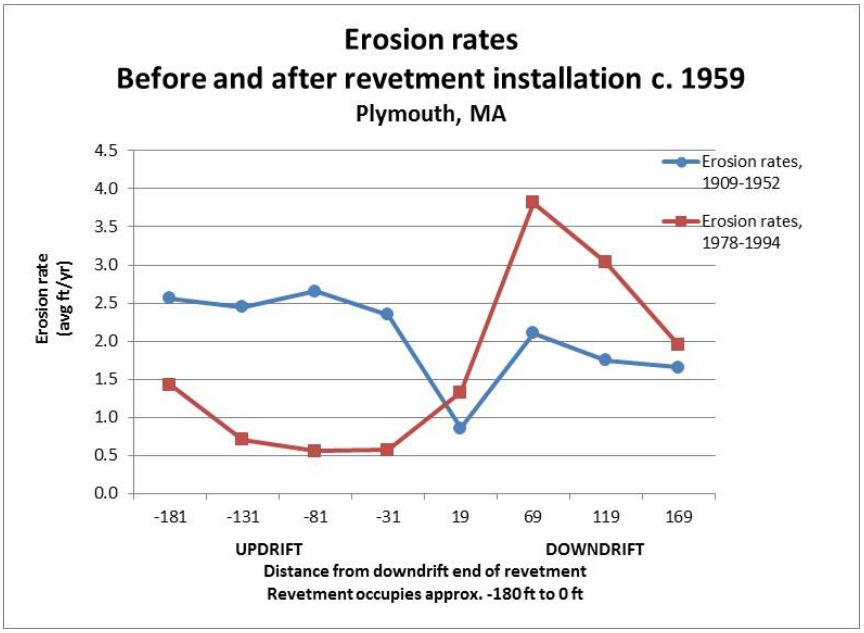

Figure 5-7. Plymouth updrift and downdrift historical erosion rates, 1909 to 1952, and 1978 to 1994

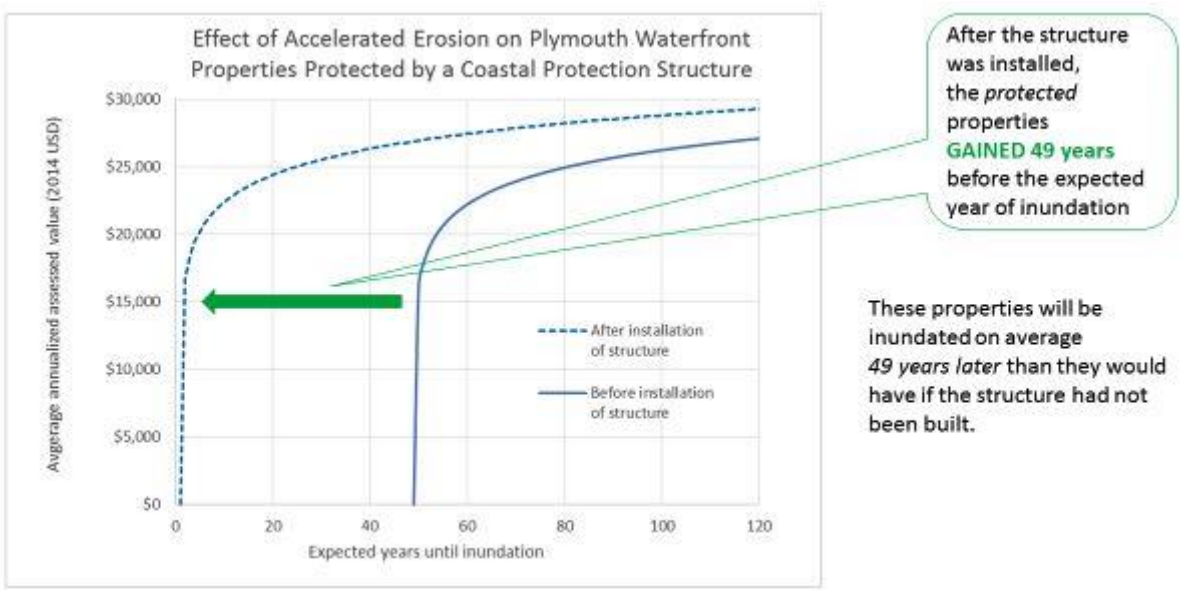

Figure 5-8. Plymouth seawall accelerated erosion effects on updrift time-to-inundation and property values

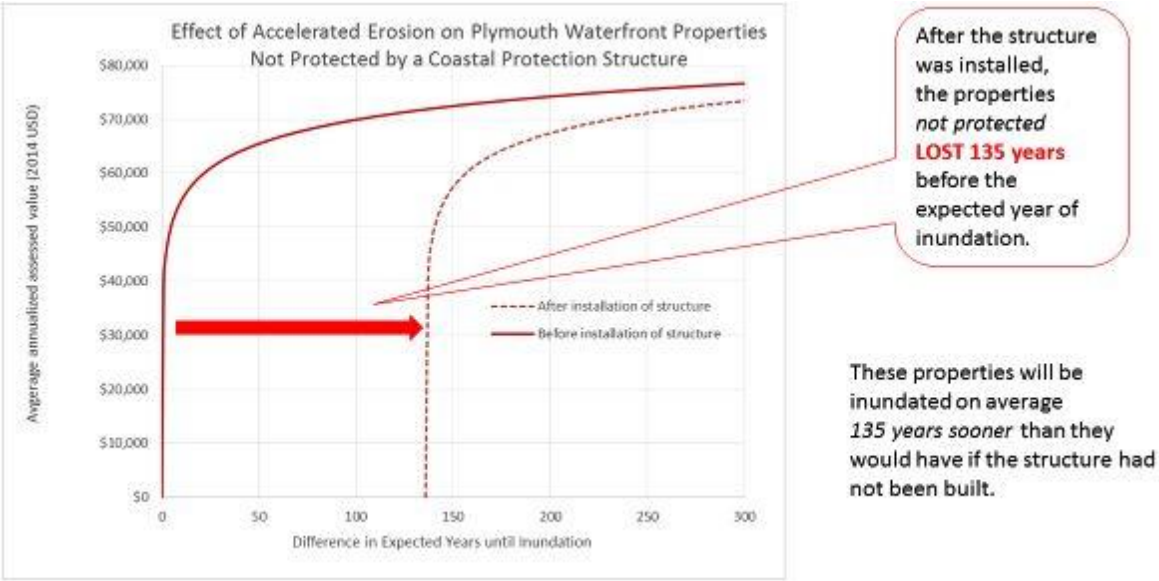

Figure 5-9. Plymouth seawall accelerated erosion effects on downdrift time-to-inundation and property values

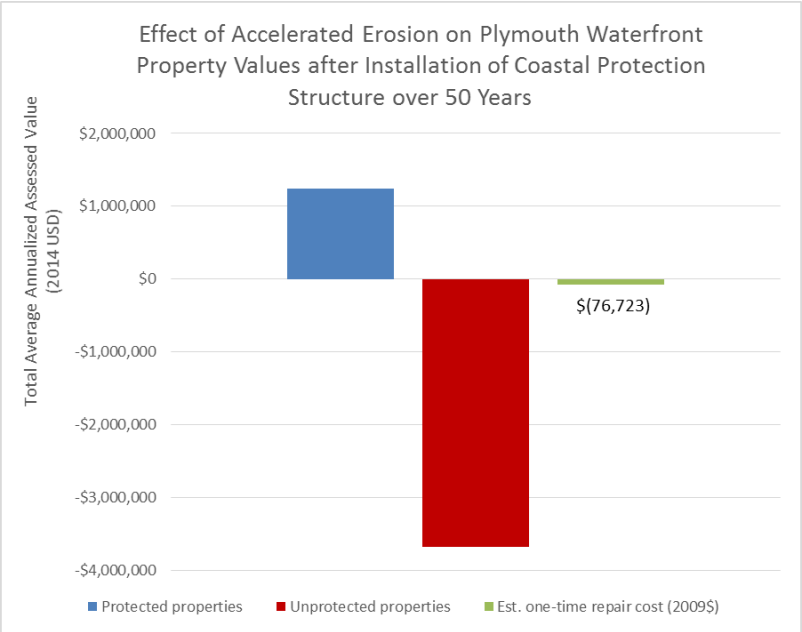

Figure 5-10. Plymouth est. net benefit of total accumulated average annualized assessed property values plus estimated repair cost

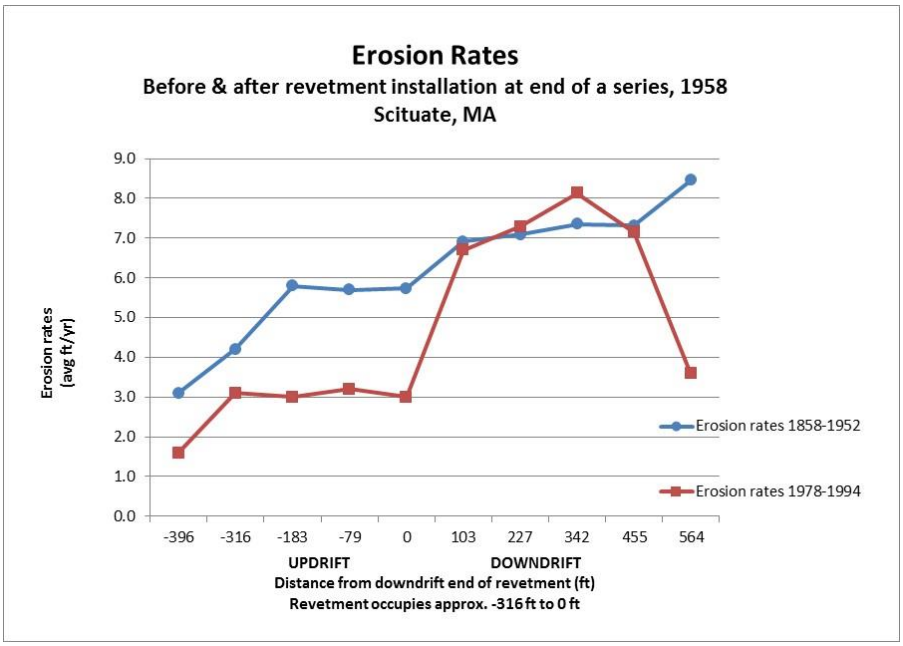

Figure 5-11. Scituate updrift and downdrift historical erosion rates, 1858 to 1952, and 1978 to 1994

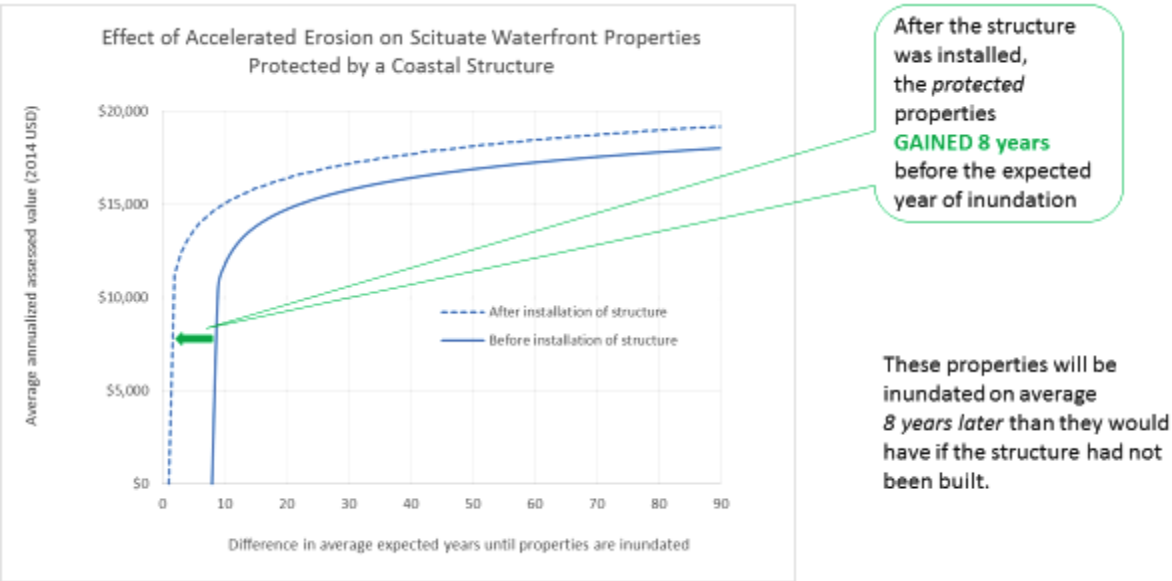

Figure 5-12. Scituate seawall accelerated erosion effects on updrift time-to-inundation and property values

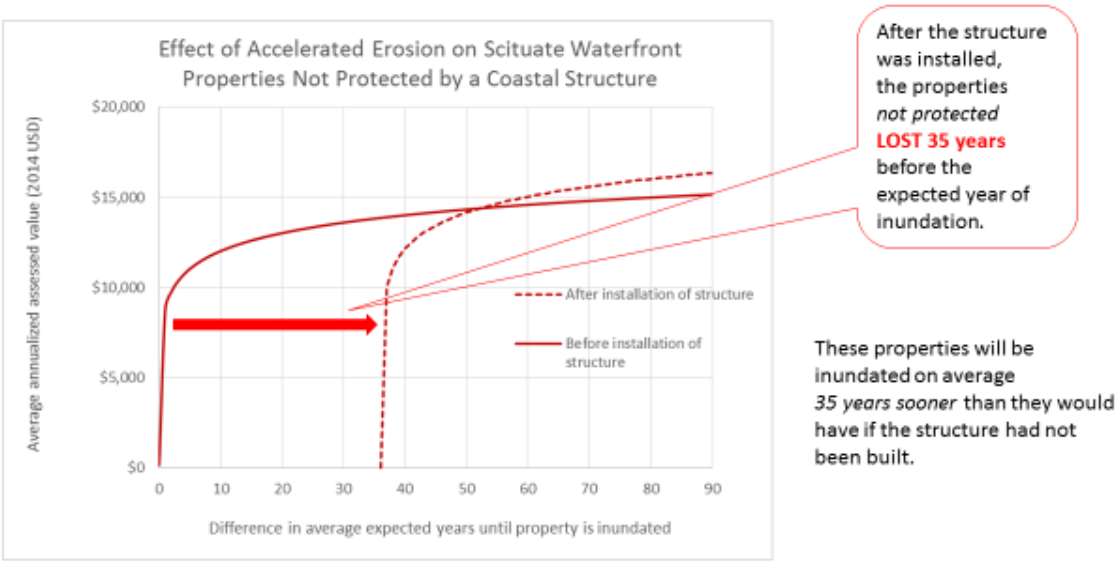

Figure 5-13. Scituate seawall accelerated erosion effects on downdrift time-to-inundation and property values

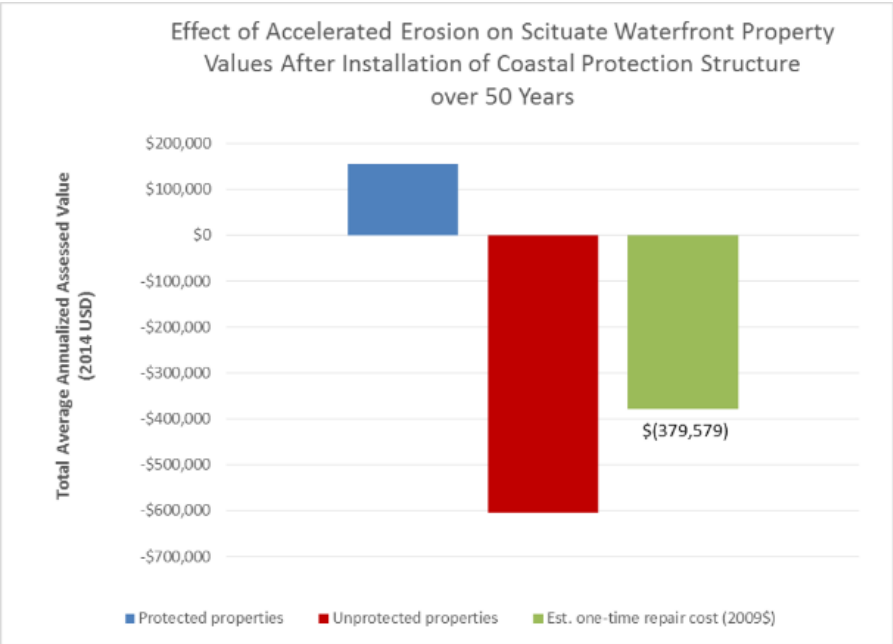

Figure 5-14. Scituate est. net benefit of total accumulated average annualized assessed property values plus estimated repair cost

Chapter 6 Summary and Policy Implications

"American political institutions are ill-suited to the indeterminacy and elasticity of nature"

(Dean 2001)

Conclusions

The conclusions that emerged from the three studies in this dissertation revolve around the need for adaptive regulations and governance to build municipal coastal resilience.

We must adapt the way we manage coastal natural resources and the built environment to meet the challenges of intensifying effects of climate change. Business-as-usual governance that produces one-size-fits-all policies does not rise to challenges of the dynamic nature of coastal ecosystems and the uncertainties of coastal hazards.

The concept of adaptive regulations and governance methods requires policymakers to anticipate conditions and society's needs. It is true that legislation is often in response to acts and situations that have already occurred: air and water pollution, for example. Regulations are enacted to rectify practices that have already caused harm or confusion. Anticipatory governance may seem unrealistic, but global policy learning, practice sharing, multi-jurisdictional planning and project collaboration, and technology networks provide platforms to make it possible (Boyd et al. 2015).

Summary of resilience practices in municipal regulations

Coastal resilience principles from the literature were used as benchmarks for the integrated content analysis with descriptive statistics undertaken in Chapter 3 that revealed references to coastal resilience practices in the regulations of all three case towns. Their presence in municipal regulations indicates that they have been used in practice, since regulations are legislative responses to actions. The interview participants confirmed their application in the field. Whether

the regulations facilitated coastal resilience practices was addressed by the interviewees, but regulations can be interpreted as signals of policy priorities.

Chatham, Newbury, and Scituate all experience frequent and challenging coastal inundation and shoreline change events. The analysis revealed legislative intent to address loss reduction and property protection from coastal hazards and erosion.

Land use practices and building and infrastructure references dominated the mentions of resilience practices. There were a few references to green infrastructure practices like marsh restoration, beach renourishment, dune stabilization, and using vegetation to prevent erosion, but beach dewatering, an effective and promising practice, went unmentioned.

Some innovative resilience building and infrastructure practices, including permeable pavements and buildings, were mentioned in the regulations.

The land resilience practices that have been moving to the forefront of the adaptation literature also were unmentioned, including retreat, relocation, rolling easements, and property buy-backs. These practices are now at the frontier of land use policy, and they could be interpreted by property owners as interfering with their perceptions of private rights. As sea levels rise and coastal damages intensify, and as the effectiveness of strategies of adaptation begins to plateau, these frontier strategies may yet find a place in the resilience policy toolbox, even in US municipalities where property right concerns still predominate.

Building resilience into coupled human and natural systems can be a complex undertaking. Comprehensive planning across systems is necessary, but implementation solutions often require site- and situation-specific customization. Present regulatory frameworks make this difficult.

The absence of references to some of the more innovative coastal resilience practices implies some clear opportunities through which towns can continue to expand upon and improve coastal resilience.

Summary of practitioners' recommendations

To build lasting coastal resilience, interview participants in Chapter 4 called for collaborative long-term planning for comprehensive solutions that incorporate whole nearshore ecosystems and social environments. They issued cautions that business-as-usual reactions and crisis management piecemeal projects do not build resilience and in some cases, are detrimental to it.

They described characteristics of adaptive co-management (discussed below) in their comments and recommendations, though none used that term. Remarks about the importance of bringing diverse stakeholders into policy discussions and project planning were accompanied by expressions of frustration that this was often difficult to manage. They emphasized the importance of annual funding of public education and outreach efforts to project success and neighborhood harmony.

Joint and interjurisdictional project descriptions highlighted cooperative planning and successful project outcomes. Engaged and informed political leaders used their influence to advance these projects. Joint town projects were reported to have better success of acquiring funding, especially when projects encompassed an entire natural system like a wetland that crossed or intersected municipal boundaries.

Adaptive regulations were called for in three categories, (ii) for built environment projects, (ii) for natural processes projects, and (iii) hybrid shoreline stabilization projects. Practitioners

realized that the institutional constraints on municipal regulatory authority and lack of awareness about the barriers erected by the current regulatory environment to effective coastal resource management make regulatory improvements difficult.

Despite their direct experience with the conflicts and barriers to building coastal resilience, they are optimistic that growing public awareness of resilience and their engagement with elected officials will motivate positive changes.

Summary of the effects of seawalls

A simulation framework for assessing the external costs of seawall installations was applied to the question of whether the construction of seawalls results in net economic benefits when the adverse external effects are incorporated explicitly as property costs. The adoption of the framework could lead to improvements in both the efficiency and equity of coastal decisions about protecting the coast with seawalls.

The temporal-spatial simulations for sites in Plymouth and Scituate showed that there can be a negative effect on the average accumulated assessed property values from accelerated erosion rates related to the installation of seawalls. In terms of municipal coastal resilience, seawalls may not be the most effective or equitable solutions for beach ecosystems and all waterfront property owners.

Shoreline armoring with seawalls is prevalent on the Massachusetts coast. Armoring alone and incorporated with hybrid shoreline resilience projects will continue to be "perhaps an inevitable [coastal] management tool" (Pranzini et al. 2015, p. 446). The presence of seawalls does not mean that building coastal resilience in those areas is impossible. Resilience can be enhanced by employing customized green infrastructure and hybrid practices in the nearshore environment

like marsh restoration, living shorelines, and beach dewatering; and by deploying shore-parallel strategies just seaward of the surf zone like moveable breakwaters and wave attenuation devices (WADs). "The nearshore region is vital to our national economy" (The Nearshore Processes Community 2015, p. 31).W

The simulation framework could be applied to a variety of shorelines with similar physical characteristics to the case sites to evaluate proposed new seawall construction or repair. The framework could be refined further by incorporating estimates of shoreline changes due to sea-level rise and values of nonmarket ecosystem services that are put at risk. With appropriate modification, the framework also might be applied to evaluate coastal resilience options like salt marsh restoration, low-impact hybrid systems, or other types of living shorelines. It is critical for the long-term health and resilience of coastal systems that the impacts of proposed shoreline stabilization projects be accounted for and considered in municipal project decisions.

Policy implications

"The sea, every day she moves the sand. Every night we push it back."

- Foreman, beach restoration night crew, Cancun, Mexico[62]

Traditional coastal management strategies have been and will be overwhelmed by the forces of nature and are inadequate to address whole ecosystem resilience (Burroughs 2011). Reports of major inundation events are commonplace. Sea level rise has already displaced coastal and island

[62] 2008. Author's conversation with the foreman while the crew operating bulldozers, front loaders, and dump trucks performed their nightly routine of beach restoration to preserve the economic vitality of Cancun's coast. Tourists expected the beaches to look the same each day, unaware of the efforts taken while they slept to make it so.

communities around the world. A paradigm shift toward resilience provides a way for coastal communities to survive and thrive.

Coastal resource managers, engineers, and scientists develop, deploy, and share information about adaptation and resilience strategies. The key to adopting these tested resilience planning approaches and practices lies with governments; in the context of this study, municipal governments. The results of this study, especially the recommendations of the interview participants, suggest that adaptive governance principles have the characteristics to facilitate adoption.

Adaptive governance uses principles from several governance approaches. Adaptive co-management "emphasizes collaboration among diverse actors, functions across scales and levels, and fosters learning though iterative feedback" (Plummer 2013). These are activities highly recommended by the interview participants.

Public education, engagement, and facilitating joint projects that reduce legal conflicts were deemed vital to coastal resilience by the interviewees. These types of social processes that accompany ecosystem management are called social-ecological systems (Olsson et al. 2004). Incorporating social-ecological systems in coastal management is a feature of adaptive governance.

How are U.S. municipalities going make a policy paradigm shift and form adaptive governance? A good model for this long-term process comes from the Municipality of Kristianstad in southern Sweden (Olsson et al. 2004).[63] The policy and governance shifts in Kristianstad were accompanied by the creation of a "new municipal organization that played a key role in the

[63] The organizational and governance changes in Kristianstad took place over the course of about decade. Olsson et al. (2004)

adaptive co-management of the area's ecosystems" (Olsson et al. 2004). It is possible that existing town and regional conservation commissions could adjust to perform the role of lead facilitator of adaptive co-management. They are already placed and organized to engage the diverse group of stakeholders with sometimes competing interests in the coast.

The Cape Cod Commission,[64] established by the Massachusetts legislature (MA Legislature 1989), has in its mission features of adaptive co-management: ecosystem protection, comprehensive planning approaches, socioeconomic system awareness, and partnership building (CCC 2017). A newly created organization similar in structure to the Commission, but with a mission to advance resilience and adaptive co-management may help local U.S. coastal communities replicate the policy and governance shifts of Kristianstad.

Massachusetts coastal communities do have the regulatory, practice, and governance foundations to build coastal resilience. As related by this study's coastal resource practitioners, citizens wield the power to influence local policy.

> "They [property owners on Plum Island] think from the heart and they think with their wallet. You don't really tell the people down there when it's time to quit [fighting to keep their properties from being consumed by the sea]. When their wallet gives out, sometimes that's enough for some of them. When their heart gives out that's enough for everybody. If their hearts aren't in it anymore, they're going to leave. But the threshold is different for every single person. So, it's a huge issue to try and educate them and get them to agree on a process. What's likely to happen is it's going to be so difficult at the state level and so difficult at the federal level that they're going to make us do it through home rule petition down here. And that will set up a huge fight, even between the parties that want to cooperate. They'll say, 'When you're on my back, pushing me to do this to the people that I live with, and those people don't want do it how hard am I going to push? How hard do you expect me to push?' And I think that's going to be huge for all of us." Interview participant, Doug Packer, Conservation agent, Newbury, MA.

[64] http://www.capecodcommission.org/

Persistent public pressure can create the political will to build resilience for the long-term health of our coastal ecosystems and for the common good of future generations.

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Appendix A: Interview participation consent form

Note: Title of Project listed here is the original title. Final title is The Characteristics and Conflicts of Municipal Coastal Resilience in Massachusetts

Northeastern University, the Law & Public Policy Program in the School of Public Policy and Urban Affairs

Name of Investigator(s): Principal Investigator: Peter S. Rosen, PhD, Associate Professor of Marine and Environmental Sciences, Northeastern University; Student Researcher: Lisa Granquist, PhD candidate, Law & Public Policy, Northeastern University

Title of Project: "An analysis of the capacity of local regulations to support the adoption and implementation of coastal resiliency practices in Massachusetts coastal communities."

Informed Consent to Participate in a Research Study

We are inviting you to take part in a research study. This form will tell you about the study, but the researcher, Lisa Granquist, will explain it to you first. You may ask her any questions that you have. When you are ready to make a decision, you may tell the researcher if you want to participate or not. You do not have to participate if you do not want to. If you decide to participate, the researcher will ask you to sign this statement and will give you a copy to keep.

Why am I being asked to take part in this research study?

We are asking you to be in this study because you are involved in making decisions about coastal resources and/or coastal land use in your town. You have been identified through a review of personnel of municipal department online listings, and/or are known to the researchers.

Why is this research study being done?

The purpose of this research is to learn about your professional opinions about coastal resiliency practices and the local regulations and land use ordinances that could affect the implementation of coastal resiliency practices in your town. The study will use several methods to produce an integrated analysis of the capacity

and potential for Massachusetts coastal communities to employ coastal resiliency best practices given their existing regulations and policy environments. This research study will focus primarily on the four towns of Plymouth, Scituate, Chatham and Newbury.

What will I be asked to do?

If you decide to take part in this study, we will ask you to ***respond to a series of questions and discuss your opinions*** about the potential implementation of coastal resiliency practices in your town and local land use ordinances or coastal regulations that might affect adoption or implementation.

Where will this take place and how much of my time will it take?

The interview will take place at your office, or another public location convenient to you and at a time convenient to you and will take about 60-90 minutes for the main interview (or 30-60 minutes for a pre-analysis interview). If needed, and if you consent, a follow-up phone call may be made to you in order to clarify information from your interview, or to ask you an additional question(s). A follow-up call would be of significantly shorter duration than the original interview.

Will there be any risk or discomfort to me?

The possible risks or discomforts of the study are minimal. You may feel a little *uncomfortable* answering *what may be politically sensitive* questions.

You may decline to answer any question or stop the interview at any time. Your identity will not be disclosed in the study report, and your responses will not be attributed specifically to you.

Will I benefit by being in this research?

There are no direct benefits to you for participating in the study. However, your answers may help us to learn more about the potential applications of and inform future policy discussions about coastal resiliency practices and whether these practices might be beneficial to Massachusetts coastal towns.

Who will see the information about me?

Your part in this study will be confidential. Only the researchers on this study will see the information about you. No reports or publications will use information that can identify you or any individual as being of this project or will state that you are a participant in this study. There is a small risk that individuals interviewed in this research could be identified through a thorough search of personnel of municipal departments and committees in Massachusetts towns by people who are very familiar with these issues. While we cannot anticipate all situations, these interviews should not pose any foreseeable risks or discomforts. We will protect your identity and confidentiality to the best of our abilities. The specific methods we will use are listed below.

With your permission, we will digitally record your interview(s). The digital recordings will be destroyed as soon as transcription is completed.

Your personal information will be protected. Transcripts of recorded interviews will not include your personal information. Your interview will be assigned an alphanumeric code that will not include any clues to your identity.

The following are more ways that will be used to protect your identity and confidentiality:

- Your name and title will not be used in the study publication (report) or linked to your town.
- No demographic data will be collected about you.
- Your interview will be assigned a code that is not your name and that has no identifying characters in it that could be linked to you.
- Information from your interview will be grouped together (aggregated) with information from all the other interviews in the study and will be analyzed and reported as aggregated data.
- You will not be quoted directly. No specific statement or quotation in the report will be able to be linked to you or any other specific participant.
- Analysis of interview data will be reported in a separate publication chapter from the case study town chapters. The towns that interview participants are from (work or reside in) will not be identified in this chapter or any other chapter of the publication.
- It will be stated in the study publication and any subsequent documents or publications that use or refer to the study data that the interview participants in this study were selected from Massachusetts coastal communities and were not necessarily employed or affiliated with the case study towns. The case study towns will be identified in the

publication.

- If during the course of an interview if you mention the name of another official or stakeholder, a unique event or situation, those name(s), event(s) or situation(s) will be de-identified in the record of the interview. A generalized title or name will be used. For example, "Conservation Agent" might be recorded as "senior or mid-level administrator."
- Interview analysis and reporting will be reported in a separate dissertation chapter that is not part of any of the case study town chapters.

You will have the opportunity to review and ask questions about these procedures before you agree to participate in the study.

During the interview, you may skip answers to any questions or stop the interview at any time.

In rare instances, authorized people may request to see research information about you and other people in this study. This is done only to be sure that the research is done properly. We would only permit people who are authorized by organizations such as the Northeastern University Institutional Review Board [**or if applicable** the sponsor or funding agency e.g. NIH, NSF, FDA, OHRP] to see this information.

NOTE: If you would like to speak "on the record" and be quoted directly and identified in the publication, that possibility can be discussed with the researchers. However, the main objective of the study is to collect and analyze aggregated interview data that is not attributed to a specific interview participant. If you choose to have your name attributed to your comments, your own identifying information such as name, occupation and location may be included and quoted in reports and publications based on this research. I will provide you with a draft copy of the transcript of the interview so that you can review its content and add any clarifications and corrections that you feel are necessary.

Can I stop my participation in this study?

Your participation in this research is completely voluntary. You do not have to participate if you do not want to and you can refuse to answer any question. Even if you begin the study, you may quit at any time.

Who can I contact if I have questions or problems?

If you have any questions about this study, please feel free to contact me, Lisa Granquist, the person mainly responsible for the research, at the Northeastern University Law & Public Policy Program (617-373-2891 or email Granquist.L@husky.neu.edu). You can also contact Professor Peter Rosen, the Principal Investigator, at the Northeastern University Department of Marine and Environmental Sciences (617-373-4380, or email P.Rosen@neu.edu).

Who can I contact about my rights as a participant?

If you have any questions about your rights in this research, you may contact Nan C. Regina, Director, Human Subject Research Protection, 960 Renaissance Park, Northeastern University, Boston, MA 02115. Tel: 617.373.4588, Email: n.regina@neu.edu. You may call anonymously if you wish.

Will I be paid for my participation?

No special arrangements will be made for compensation solely because of your participation in this research. Your participation in this research is completely voluntary. Coffee, tea, or lunch will be offered during the interview.

Will it cost me anything to participate?

It is not anticipated that you will incur any costs to participate in this study. However, if any nominal costs are incurred, e.g. parking, you will be reimbursed.

SIGNED CONSENT: Please place a check in each box to indicate your consent, then sign, date, and print your name on the lines below.

☐ **I agree to take part in this research.**

☐ **I agree to be contacted for follow up or clarification.**

☐ **I agree to be audio recorded.**

My preference regarding the use of my name is as follows:

☐ I wish **NOT** to be identified by name in any transcript or reference to the information contained in this interview.

☐ I agree to be identified by name in any transcript or reference to the information contained in this interview.

_____ _____

Signature of person agreeing to take part **Date**

_____

Printed name of person above

_____ _____

Signature of person who explained the study to the participant above and obtained consent **Date**

_____

Printed name of person above

Appendix B: Interview recruiting email and phone script

Recruiting email and phone script

Lisa Granquist

PhD candidate

Law & Public Policy

Northeastern University

April 2013

Recruiting email Template:

Dear (Name of Potential Participant),

My name is Lisa Granquist. I am a doctoral candidate at Northeastern University. I am conducting a study of how local regulations might affect the adoption of coastal resiliency practices in Massachusetts coastal communities.

I would like to interview you about your professional opinions on this topic. The interview is expected to last about 60 minutes. I am willing to meet with you at a time and place of your convenience.

Please let me know if you are interested in meeting with me. Do not hesitate to ask me any questions, and feel free to contact me at the email or phone number below.

I look forward to hearing from you.

Sincerely,

Lisa Granquist

PhD Candidate

Law & Public Policy

Northeastern University

granquist.L@husky.neu.edu

617.823.0014 mobile

Recruiting phone script

Hi, my name is Lisa Granquist. I am a doctoral candidate at Northeastern University. I am conducting a study of how local regulations might affect the adoption of coastal resiliency practices in Massachusetts coastal communities.

I would like to interview you about your professional opinions on this topic. The interview is expected to last about 60 minutes. I am willing to meet with you at a time and place of your convenience.

[conversation answering questions, providing contact information, setting up date and time]

Thank you so much for your help. I look forward to meeting with you.

Recruiting follow-up email Template:

Dear (Name of Potential Participant),

This is a follow-up email about participating in a doctoral dissertation study about municipal coastal resiliency.

I sent you an email inviting you to participate in this study on [day, month]. Since I haven't heard back from you, I wanted to follow-up and find out if you would like to participate or had some questions before you decided, but hadn't had a chance to reply.

Here is the text of the original invitation to participate:

"My name is Lisa Granquist. I am a doctoral candidate at Northeastern University. I am conducting a study of how local regulations might affect the adoption of coastal resiliency practices in Massachusetts coastal communities.

I would like to interview you about your professional opinions on this topic. The interview is expected to last about [60] minutes. I am willing to meet with you at a time and place of your convenience.

Please let me know if you are interested in meeting with me. Do not hesitate to ask me any questions, and feel free to contact me at the email or phone number below."

I look forward to hearing from you. However, if you do not respond to this email or a follow-up phone call to your office and/or voicemail, I will assume that you cannot or do not wish to participate and will not contact you again about participating in this study.

Thank you for your consideration,

Lisa Granquist

PhD Candidate

Law & Public Policy

Northeastern University

granquist.L@husky.neu.edu

617.823.0014 mobile

Appendix C: Semi-structured interview questions

Lisa Granquist

PhD candidate

Law & Public Policy

Northeastern University

617.823.0014 mobile

Granquist.L@husky.neu.edu

Peter S. Rosen, PhD

Principal Investigator

Assoc. Professor, Marine & Environmental Sciences

Northeastern University

p.rosen@neu.edu

July 2013 - January 2014

Thank you for being willing to participate in this doctoral dissertation research.

The following are questions that we will discuss in our interview.

The open-ended discussion questions at the end are designed to help identify some of the non-regulatory factors that may have affected or might affect projects in your town.

Your participation in the research is greatly appreciated.

Interview questions:

Q1a) Are you familiar with coastal resiliency practices (CRP)?

Q1b) Which ones?

Q2a) Have CRP been used in your town?

Q2b) Which ones?

Q2c) For what application or to address what problem? (This question to be repeated for each application.) Note that if there are several or many applications, you may comment on similar types or categories of applications instead of each individual application.

Q2d) How did you initially decide to use a particular practice for an application?

For example:

- Was the practice used successfully to address a similar situation in another Massachusetts town or in an international jurisdiction?
- Did you become familiar with the practice by attending a conference or reading a journal article?

Q3a) What local regulations or ordinances facilitated that implementation?

Q3b) How did the regulation or ordinance facilitate the implementation? (This question to be repeated for each category of regulation or ordinance.)

Q4a) What local regulations or ordinances inhibited that implementation?

Q4b) How did the regulation or ordinance inhibit the implementation? (This question to be repeated for each category regulation or ordinance.)

Q5a) What state regulations facilitated or funded that implementation?

Q5b) How did the state regulation facilitate or fund the implementation?

Q6a) What state regulations inhibited that implementation?

Q6b) How did the state regulation inhibit the implementation?

Q7) Of the local regulations that you mentioned, are there themes that you use to categorize them when considering projects in the coastal zone? For example, wetlands restoration, freeboarding or elevation, hybrid natural-engineered systems.

Q8) Are there now or have there been federal programs that have funded or facilitated coastal resiliency projects in your town?

Q9a) Has your town worked together with other towns on coastal resiliency projects?

Q9b) Project title/s

Q9c) Project area

Q9d) Project term

Q9e) Town role in project

Q9f) Was project performed under a state or federal program

Q9g) Has your town ever worked on this or other projects with another town/s in which the collaboration has been initiated by local officials and not part of a larger state, regional, or federal program? Please describe.

Open-ended discussion questions:

D1) Were there, or do you anticipate any political factors that affected or may affect implementation of coastal resiliency projects?

D2) Were there, or do you anticipate any public opinion factors that affected or may affect implementation of coastal resiliency projects?

D3) Were there, or do you anticipate any budget or cost factors that affected or may affect implementation of coastal resiliency projects?

D4) What changes in your town's regulations or policies do you think would facilitate implementation of CRP?

D5) Are there any reasons that particular proposed practices might be detrimental, either ecologically or economically?

D6) Are there any practices that you think would benefit the town right now?

Appendix D: Codebook for Chapters 3 and 4

Nvivo 11 Pro

Name	Description	Sources	References
Coastal hazard concerns of interviewees		3	44
barrier breach		2	6
erosion, shoreline change		3	8
flooding		3	6
incr storm freq,intensity		1	4
infrastructure damage		1	1
navigational hazard		1	3
overwash		0	0
property damage		2	2
Resource sharing inter-town		1	1
sea level rise		2	9
storm surge		2	3
wind, waves		1	1
Comments on engineered structures		3	3
Breakwater stationary	shore parallel wave attenuator made of timeber, rock, or concrete. Larger and farther offshore than sills [see Table 1,11, p 18, Living Shorelines, 2015, RAE.]	0	0
Bulkhead		1	1
Gabion		0	0
Groin		0	0

Name	Description	Sources	References
Jetty		0	0
Revetment (US style)	Built of concrete or rock against a sloped bank. Protects land from erosion and absorbs wave energy without reflecting waves. {Living Shorelines, Table 1.11, p18, RAE, 2015]. European coasts define revetments as interlocking blocks (Pranzini et al 2015, 448) made of stones, concrete blocks, gabions. They would call US-style revetments riprap.	0	0
Seawall	Includes gravity walls for purpose of this study. Shore parallel, vertical, watertight built of timber, steel, rock, or concrete (reinforced) to hold back land. [Living shorelines, Table 1.11, p 18, RAE, 2015]	2	2
Governance		4	71
Planning		4	29
Communication		1	1
Planning comprehensive	includes human, natural systems together	1	1
Planning interagency		3	13
Planning inter-town		2	6
Policy learning btwn towns		3	7
Training		1	1
Policy Reg Political		3	15
Leadership coord, political		1	1

Name	Description	Sources	References
New,adaptive regs needed		3	10
Policy discussions needed		1	4
Programs, Implement		4	27
joint private projects		1	4
joint town projects		2	6
Lack of inter-town projects		1	4
Land acquisition, coastal		2	2
Need more muni capacity	admin, planning, implementation town resources	2	6
state-fed projects		1	1
town-state projects		2	4
Interview Questions		4	137
Q1 Familiar with CRBP	Familiar with coastal resilience practices? If so, which ones?	3	12
Q10 cost factors		2	3
Q11 want to implement	particular resilience practices	2	14
Q12 Don't want to use a practice		1	2
Q2 CRBP in town		3	23
Q3 local regs helped		3	15
Q4 local regs barrier		1	10

Name	Description	Sources	References
Q5 state regs help		2	5
Q5.1 fed regs help		1	6
Q6 state regs,policy barrier		2	16
Q6.1 fed regs barrier		2	9
Q7 local regs purpose		1	2
Q8 political factors		2	5
Q9 public opinion factors		3	15
PROBLEMS		4	138
Planning (probs)		3	39
competing interests human v natural		3	22
crisis mgmt vs long-term planning	reacting to crisis vs	2	5
no systems L-T planning, implementation	human-natural systems	3	12
Policy Reg Political (prob)		3	49
equity, winners-losers, net benefit	free-riders	2	7
insurance limits		1	1
leadership, lack of		0	0
legal, liability issues	no one will take responsibility, e.g. federal or state built structure on private land on Plum Island	3	10

Name	Description	Sources	References
property rights conflicts		3	14
regs conflict, not clear or adeq		3	10
street-level bureauracy		1	3
topic,decisionmaker not on the table		2	4
Program Implem (prob)		4	50
bldg in sensitive areas	like Humarock	2	5
disrepair, state of structures		1	1
elevation		1	4
failure of policy, program		2	6
failure of structure, nature rules	failure of coastal structure to do what it was designed and built to do	2	10
fund mismanagement		1	1
mainten expense overwhelming to town	eg seawalls	2	4
no action, did plan		1	1
no,inadequate funding	not enough to go around, cities get it all	3	10
repetitive loss		1	1
SLR		1	2

Name	Description	Sources	References
time constraints for projects		2	3
tools inadequate	maps, eval, FEMA	2	2
Purpose		11	184
Loss Reduction		9	41
Building loss reduction		3	4
Flooding, stormwater loss reduction		7	17
Hazard mitigation		8	14
Infrastructure loss reduction		3	4
Sea level rise loss reduction		2	2
Management		7	40
Adaptation	to climate change, sea level rise, increase in storm events, flooding	2	2
Development management	includes growth control	4	16
Educate the public	about adaptation, shoreline management, building on the coast (development), etc	3	6
Emergency, disaster management		1	2
Regional cooperation	Coordinate, cooperate, plan, act with nearby municipalities	1	1
Shoreline management		4	13

Name	Description	Sources	References
Erosion control		3	6
Sand supply		3	6
Sea Level Rise mgmt		0	0
Protection		11	74
Economic activity protection		2	3
Ecosystem, habitat, services protection	Ecosystem services and habitat protection	11	54
Pollution prevention		2	2
Property protection		5	8
Recreation activity protection		3	4
Stricter than State	explicitly states stricter than state	3	3
Public Trust		8	29
Protect public access		2	2
Protect Public benefit, health	Protect or Preserve Public benefit, public health and safety	8	24
Protect Public Trust Use	fishing, fowling, navigation	2	3
Resilience Practices	Coastal resilience best practices	16	469
Building and Infrastructure		11	78

Name	Description	Sources	References
Building elevated	For the purposes of this study this code includes raised or elevated utilities to the building.	5	10
Building Floor Area Ratio		1	1
Building fortification		1	1
Building height		1	4
Building Lot Coverage		3	6
Building permeability	Automatic equalization of hydrostatic flood forces on exterior walls by allowing for the entry and exit of flood waters using openings at prescribed heights equipped with screens, louvers, or other devices. (Chatham)	2	3
Building stories		1	1
Building systems elevated	Building systems elevated or floodproofed	2	2
Drainage around structures	to guide floodwaters away from structures	2	2
Frontage required	Street frontage	2	5
Lot size restriction		2	3
Manufactured home, RV limitations	and restrictions	1	2
No fill material allowed		2	3
No municipal services provided	No municipal services or infrastructure will be required, requested, or provided	1	1

Name	Description	Sources	References
No reconstruction, alteration of building or footprint	or structure. Usually in a special district or overlay zone. If reconstruction is allowed, the change shall not be substantially more deterimental than the existing structure.	1	3
Pavement permeable or no hardened	Permeable pavement or no permanently hardened surfaces	2	2
Rebuilding restrictions		2	6
Subject to Wetlands Law, Regs	Rebuilding governed by/subjected to Wetlands Law, Regs	1	2
Time restriction	Typically must be rebuilt within 2 years of destruction or demolition	2	2
Rebuilt town infrastructure		1	3
Repetitive loss rules	Special rules, restrictions for repetitive loss properties	0	0
Restricted use areas in buildings	Restricted use areas in elevated sections of buildings that can be used only for parking vehicles, building access, or storage.	2	3
Retreat Move building back	landward on same lot (as opposed to relocation)	3	5
Septic ban or restriction		1	3
Utilities modified	Utilities and facilities modified: location, construction to minimize or eliminate flood damage	3	5
Walkways elevated		1	2

Name	Description	Sources	References
Water and sewer modifications	Water system and sewer modifications	2	2
Funding		3	13
Fed grants	eg. Grants FEMA pass through, EPA	3	5
Innov funding		1	2
Insur incentives		1	2
State grants		2	4
Green Infrastructure		6	35
Beach renourishment	with marine or terrestrial aggregates (sand, gravel)	3	9
Dewatering	Beach dewatering: the artificial lowering of the water tables within beaches by pumping or drainage to facilitate accretion and shoreline stabilization (from Turner and Leatherman, JCR, 1997)	0	0
Dune stabilization or development	reconstruction, construction	3	6
Living Shorelines	Includes marsh restoration & replication that is used in conjunction with other green, hybrid, and hard structure solutions. Includes native vegetation planted on the shore.	1	1
Marsh restoration	Marsh restoration and replication. Includes restoring marsh areas and installing new marsh areas.	3	8
Sediment recycling	tires, dykes, wires	0	0
Vegetation	Can be onshore (e.g. spartina, but differentiated from marsh restoration) or submerged like a seagrass meadow (e.g. posidonia in the Mediterraean Sea)	5	11

Name	Description	Sources	References
Land Use		12	305
Conservation general	General conservation measures NOS of soil, water plants and wildlife, including wildlife management shelters	1	1
Deed restrictions		1	1
Enforcement		8	59
Civil		4	6
Criminal		4	5
Deny cert of compliance	Deny certificate of compliance	3	3
Fines	Fines for violations	5	9
Increased flood insurance rates		1	1
Inspect, Assess deviation, violation. compliance		5	9
Issue enforcement order		5	5
Monitoring after, during project completion	usually at petitioner's expense	4	5
Project instead of fine		1	1
Public hearing additional	Commissions or permitting bodies can order additional public hearings AFTER a permit has been issued and after a project is underway or completed if that body determines that there is a significant	1	1

Name	Description	Sources	References
	change in the impact or scope of the project.		
Restore to original condition	by forced order	1	1
Revoke, modify cert of compliance		3	3
Security Land restriction	to assure performance; usually as a conservation easement or covenant (with permission of the land owner).	1	1
Security money, performance guarantee	Deposit of money deposit to assure performance or the guarantee of funds available to guarantee performance	3	3
Stop work order		2	3
Time limits	on duration of order, permit, project	2	2
Town directly remedies violation	Town can enter property and remedy violation if property owner does not remedy properly or in a timely manner.	1	1
Limitation on further development		1	1
Minimize adverse effects on natural resources		4	10
No adverse effects	like increasing flood heights	2	4
No alteration of natural features	No alteration of natural features or structures like dunes, no alteration of natural habitats, no adverse effects. There is at least one bylaw clause (Newbury Chp 95 Wetlands, Plum Island, 95-4 (H) that	5	44

Name	Description	Sources	References
	allows alteration that must comply with specific performance standards previously stated in the regs. This was coded as 'No alteration' because regs are so strict that in all practicality, it results in no alteration or at least virtually no alteration.		
No build zone		7	15
No coastal structures	Prohibited: Engineered coastal structures like groin, jetty, seawall, revetment EXCEPT those permitted to prevent storm damage to buildings constructued prior to August 10, 1978 (see additional language in Chatham Wetlands Regulations) per MGL131 section 40	1	1
No encroachment	No encroachment of floodways, floodplains, natural barriers or features	3	4
Open space requirement	usually found in zoning development regulations	1	1
Permitting process		9	68
Consultants fees, restrictions		2	2
Deny, delay permit		2	4
Emergency permit restrictions	Emergency permit restrictions and conditions	2	2
Investigations	Investigations by Conservation Commission or the permitting body. Can enter onto private land to conduct. Subject to Mass and US Constitutions.	1	1
Precautionary Principle,	Presumption is that the natural feature or environment plays a significant	5	10

Name	Description	Sources	References
burden of proof	ecosystems services or habitat role or is significant to the interests of these. The burden of proof that they are not is on the petitioner that would alter or impact the area(s).		
Public hearings, notice to abutters		2	12
Special permits required	Conditions can include: bonds, fees, time limits, expiration dates	6	25
Variances, waivers special process, restrictions	Special or more restrictive procedures to apply for and obtain variances. Or can be a Con Comm waiver if the proposed work will not adversely affect or will improve the area	5	12
Pollution prevention, reduction		2	3
Prohibited use		5	21
Property buy-back		1	1
Relocation	relocation plan and/or assistance	0	0
Restricted access	buffer area	0	0
Restricted number of structures	Restricted number of structures on a land parcel or per acre	2	2
Restricted use	buffer area	6	26
Restrictive more regulations	Regulations are more restrictive than regular local or state requirements. "Most restrictive"	4	7
Rolling or moveable easement		1	1

Name	Description	Sources	References
Setback, buffer increase	Setback or buffer increase	8	20
Zoning overlay	Can be environmental, building code, special zone classification	4	15
Outreach		3	14
Professionals now support resil		2	5
Public education		3	5
Public supportive		1	4
Partnerships		3	8
Public-private		3	5
Public-public		2	3
Planning		1	3
natural systems plans		1	3
Shoreline practices resilient		3	13
Breakwater, stationary or moveable, emerged or submerged	emerged or submerged; can be moveable	0	0
Bulkhead with sill		0	0
Composite	aka hybrid, eg: from Paul Shea: y build a free standing stone wall – no mortar at all or anything – but to then cover it with sand and revegetate it as a sand dune because once you you get the vegetated sand dune in there it will hold in place against a pretty good dose of storm activity but eventually it will start	1	4

Name	Description	Sources	References
	breaking down and then if you get vulnerable points it can just open right up and the water come in. But if you have the hard solution underneath could that work almost like a mast solution.		
Dredging		1	1
Geotubes		3	6
Marsh with sill	"...a protective sill (typically made of rock, shell, or wood) to absorb wave energy." [see Living Shorelines, From Barriers to Opportunities. 2015. Restore America's Estuaries, p. 17.]	0	0
Nourisher berms		0	0
Removal, abandon of structures		1	2
Wave attenuator	W.A.D.	0	0