Potential impacts to health of harbor, shellfish resources, and commercial shellfishing in Wellfleet Harbor from sea level rise

A summary report

An overview prepared by the

Working group on Climate Change impacts on shellfishing in Wellfleet Harbor

22 July, 2015

Introduction

Shellfish play a vital role in the ecology of Wellfleet Harbor and the economy of Wellfleet. Shellfish help maintain water quality in the harbor and they are an important component to the overall ecosystem. While shellfish have historically played an important role in the local economy, the rise of shellfish aquaculture has given increased importance to this sector. Wellfleet produces approximately 20% of the shellfish harvest in the Commonwealth of Massachusetts, second to Duxbury. Landings in 2014 were valued at roughly $4,500,000.

Climate change will have significant impacts on shellfish resources over the long term, as well as the communities that rely on them (Burkett and Davidson 2012, Horton et al. 2014, Titus et al. 2009). Climate change is predicated to cause changes in sea levels, air and water temperatures, and intensity and frequency of precipitation, and water chemistry.

This report presents efforts of a group in the town of Wellfleet, Massachusetts to characterize the risks and vulnerabilities for the shellfish fishery and local community due to a changing climate – both today and into the future. The Wellfleet Shellfish Working Group is a community-based group with broad representation from the shellfish industry and the Town. The project is funded by the National Oceanic and Atmospheric Administration (NOAA) Climate Program Office through a grant to the Social and Environmental Research Institute in Amherst, Massachusetts.

The purpose of this report is to summarize the Working Group's discussions related to sea level rise, including potential impacts to shellfish and shellfishing in Wellfleet Harbor and adaptation strategies. Information about the Working Group, including its goals and members, can be found in Appendix C and at the project website: www.seri-us.org/content/fisheries-and-climate-Wellfleet. The Working Group used the Vulnerability, Consequences, and Adaptation Planning Scenarios (VCAPS) process to organize its discussions (Webler et al. 2014; an overview is provided in Appendix C).

Sea levels are predicted to rise

Relative sea levels are predicted to rise from several causes. Relative sea level rise in Wellfleet is predominantly a combination of rising ocean waters and land subsidence. Changes in sediment transport within the harbor may also affect relative sea level rise, by changing the amount of sand deposited on the bottom in different locations. An additional factor that may increase sea level rise in the northeastern US compared to other parts of the globe is the slowing of ocean currents (Burkett and Davidson 2012).

In the northeastern US the combination of rising ocean waters and land subsidence is leading to higher relative sea level rise compared to many other coastlines in the US and elsewhere. Since 1900 the rate of sea level rise in the northeast has exceeded the global average by approximately 4 inches to about 1 foot in the Northeast versus about 8 inches globally over the past 110 years. The most recent assessments project a global sea level rise of 1-4 feet by 2100, with the northeast continuing to exceed global averages (Horton et al. 2014). These values are consistent with those reported in a recent report by the Commonwealth of MA, which estimated additional sea level rise of 8 to 16 inches by 2050 and 20 to 55 inches by 2100 (MA EOEA 2011).

General Impacts of Sea Level Rise

Rising sea levels, in combination with more severe storm surges, are associated with changes that can affect shellfish resources, including:

- Increasing salinity in estuaries by extending saltwater penetration upstream. Increased salinity has been linked to higher QPX mortality in clams (Dahl et al. 2012) and MSX infections in oysters (Ewart and Ford 1993).
- Impacting embayments and marshes that support shellfish by degrading and eliminating habitat, including important foraging and nursery habitat for some species (Najjar et al. 2010, Wong et al. 2014). According to the US Climate Science Program "degradation and loss of tidal marshes will affect fish and shellfish production in both the marshes themselves and adjacent estuaries (Titus et al. 2009, pg. 83 Loss of habitat is due in part to submergence of coastal areas and increased erosion of coastlines in areas where the habitat and coastline cannot migrate landward like they would in a natural system (Frumhoff et al. 2007). This is especially important in terms of the loss of intertidal habitat. Loss of habitat will be exacerbated as sea level rises against armored shorelines that prevent the landward migration of intertidal flats and wetlands.
- An increase in the proportion of freshwater runoff into the Harbor from direct stream discharge, versus groundwater discharge, as coastal aquifers rise along with mean sea level. There is an increased risk of septic leachfields become inundated by rising sea and groundwater levels. A larger fraction of freshwater discharge will no longer pass through highly organic, anaerobic and, thus, denitrifying coastal sediments; in this way more nitrogen may be delivered to coastal waters to fuel eutrophication (Masterson and Portnoy 2005, Nuttle and Portnoy 1992).

Flooding caused by storm surge and precipitation from severe storms will be greater as sea levels rise. The IPCC (Field et al. 2012) and US Global Change Research Program (Melillo et al. 2012, pg. 583) predict that flooding associated with severe storms will become more frequent.

Flooding associated with more severe storms, in combination with sea level rise, can affect shellfish resources, including:

- Increasing pollution from run-off, septic systems, and wastewater treatment facilities, which can degrade estuarine water quality (Cocharane et al. 2009, MA EOEA 2011)
- Increasing nutrient loading, which can lead to hypoxia and degradation of coastal ecosystems (Wong et al. 2014), including coastal salt marshes (Frumhoff et al. 2007), mortality of benthic animals (Najjar et al. 2010), and increased incidences of harmful algal blooms (Frumhoff et al. 2007). Larger or more frequent Harmful Algal Blooms can lead to increased closures of shellfishing beds, resulting in economic losses (Frumhoff et al. 2007).
- Reduced salinity in estuaries following high precipitation events, which can decrease biodiversity (Wong et al. 2014).
- Increased freshwater runoff into estuaries, which can lessen the prevalence of MSX infections among oysters (Ewart and Ford 1993) and QPX mortality in clams (Dahl et al. 2012), in contrast to increasing levels of salinity associated with rising sea levels.
- Increased stratification of estuarine waters with respect to salinity and temperature (Wong et al. 2014).

Specific Impacts of rising sea levels on shellfish and shellfishing in Wellfleet harbor

Sea level rise combined with storm surge will lead to loss of vehicle access routes to shellfish grants. Some shellfishermen in Wellfleet are already experiencing difficulties driving to their grants because of erosion, shoreline retreat, and access constraints. Rising sea levels and coastal erosion associated with sea level rise and storm surge will exacerbate this problem. Maps highlighting grant access in relation to sea level rise are shown in Appendix A (maps were produced by Greg Berman, Woods Hole Sea Grant and Cape Cod Cooperative Extension, 2015). In addition, over the long term rising sea levels will shift grants into deeper sub-tidal areas. Vehicle access by land (truck) to grants may be impossible or very restricted because of tides.

In response to loss of vehicle access to grants, more shellfishermen may use boats. Purchase of boats will lead to increased expenses for growers and alter their systems of growing and harvesting. Different gear will be required for aquaculture in deeper waters. Use of boats will also lead to increased demand for infrastructure, including mooring spaces. More boats using infrastructure and more boats on the water can lead to more conflicts among users of the Harbor (e.g., recreational boaters) and more conflicts with marine mammals and sea turtles.

Sea level rise combined with storm surge may increase quahog mortality and decrease quahog growth.

Sea level rise and storm surges can impact quahogs in several ways:

- Sea level rise and storm surge will alter sediment transport. In combination with changes in sediment transport dynamics, bluff erosion can lead to sand being deposited onto quahog beds. This may reduce harvestable areas and harvests of quahogs, but it may also be beneficial by helping to keep water depths from increasing with sea-level rise. However, coastal land uses and coastal features of the harbor are unlikely to allow sedimentation rates to keep up with sea level rise, thus resulting in loss of marsh habitat.
- Sea level rise and storm surge will reduce grant areas in the intertidal zone and increase grant areas in the subtidal zone.
- Sea level rise will result in loss of intertidal zones. Loss of the intertidal zone will impact quahog populations by reducing available marsh habitat and productivity. Again, coastal land uses and coastal features of the harbor are unlikely to allow sedimentation rates to keep up with sea level rise, thus resulting in loss of marsh habitat.
- Sea level rise will increase subtidal habitat relative to intertidal habitat. Quahogs grown in subtidal areas may benefit from the longer period of inundation, but they will also encounter more stress by increased algae growth. Distribution and rates of predation and competition with other species may change as shellfish are grown in deeper waters. Food availability may change, impacting growth rates.

The net effects on shellfish of these interacting changes are very difficult to measure and predict because of significant seasonal and location differences within the Harbor.

Sea level rise may impact growth and disease rates of oysters.

An oyster that is continually submerged has the opportunity to feed longer than an oyster exposed at low tide but that oyster under water is also increasingly subject to burial or sedimentation as well as longer exposure to diseases, pests, and predators. Sea level rise may increase the time that oysters are submerged in deeper water, thus reducing the time they are exposed to heat. Cooler waters may reduce the risk of Vp in oysters, although little research has assessed the potential for

risk reduction. Risks associated with Vp and possible management strategies were discussed further in an interim report of the Working Group (Appendix B).

Sea level rise may result in poorer water quality in Wellfleet Harbor. Septic systems may fail as groundwater level rises to flood septic leachfields further inland. Furthermore, the route of freshwater discharge into Wellfleet Harbor will be altered with an increased surface flow into the Harbor. Consequently, less freshwater will flow through highly organic wetland, and intertidal and subtidal sediments, leading to less denitrification and bacterial removal. Because of development, marshes may not be able to migrate landward as sea levels rise. The consequent loss of marshes, which help to filter water, can exacerbate water quality problems in the Harbor.

As nitrogen removal from freshwater runoff declines and nitrogen loading of receiving harbor water increases, the risk of phytoplankton and seaweed blooms will increase:

- Blooms of phytoplankton can have both positive and negative effects on shellfish. These drift algae are food for bivalves; however, their blooms can include species that are toxic to shellfish (harmful algae blooms).
- Seaweed blooms (e.g. sea lettuce) can reduce growth rates of shellfish by depleting oxygen levels, reduce eel grass by stimulating epiphytic growth, and clog aquaculture nets, smothering contained quahogs.

Sea level rise may increase conflicts among users of the Harbor and marine wildlife. Some gear used for deep water growing, required as growing areas shift to subtidal zones, may lead to new conflicts among different users of the Harbor (e.g., with recreational boaters). Use of gear in deeper water has the potential to cause entanglements of marine mammals and sea turtles.

Sea level rise combined with storm surge can damage infrastructure.

Increased water depth will increase wave heights and current velocities in some shellfish growing areas, damaging gear and displacing shellfish stocks. Flooding caused by storm surge (with more intense storms, also predicted as an impact of climate change) in combination with sea level rise will increase the risk of damage to infrastructure on or near shore, including docks, moorings, and other structures that support shellfishing in the harbor.

Sea level rise will financially impact shellfish-related businesses.

Sea level rise has the potential to impact many aspects of shellfish growing and harvesting. Rising waters can change the productivity of grants, change access to grants, and change the time available for working on grants. Rising sea levels, in combination with other climate change impacts, may negatively impact the health and growth rates of oysters and quahogs. Increasing risks of harmful algae blooms increases the risk of shellfish bed closures.

Such impacts will affect financially shellfish-related businesses, including aquaculture and wild harvesting. Financial impacts may include:

- Lost revenue from increased shellfish mortality.
- Lost revenue from reduced shellfish growth rates.
- Lost revenue from time contraints on harvesting.
- Additional expenses for new gear.
- Additional expenses for new boats and other equipment (e.g., trailer, ice machine).
- Other additional expenses (mooring fees, etc.).

- Additional expenses for more maintenance (algae).
- Costs associated with changing how shellfish can be grown and harvested (e.g., in deep water areas, such as those in Provincetown and Truro).

Opportunities for adaptation

Because sea level rise is expected to increase over many decades, shellfishers will have the opportunity to adapt to changes as they emerge. Shellfishers have the opportunity to plan for changes in how they grow, harvest, and sell their products. For example, overtime they can purchase new equipment for growing oysters in deeper waters. The ability to plan and react to slowly emerging changes may help reduce the financial impacts from sea level rise. Projects to monitor shifts can be implemented, ensuring that important baseline data are gathered. Examples of such projects are already being conducted, including mapping of Wellfleet harbor bottom and monitoring of water quality by the Woods Hole Oceanographic Institute Sea Grant Program and the Provincetown Center for Coastal Studies.

Strategies that mitigate the impacts of sea level rise and promote sustainable shellfishing in Wellfleet Harbor are not solely the responsibility of shellfishers. New policies enacted by the Town or State may be needed. For example, locations of grants could be shifted and additional infrastructure to accommodate more boats could be constructed. To ensure good water quality in the Harbor, which may be compromised as sea levels rise, the town and state can promote modifications to septic systems, ensure opportunities for marsh migration, and promote oyster sanctuaries.

These are just a few of the examples of adaptation strategies that are possible. Additional discussion of adaptation strategies is provided in a separate report of the Working Group, *Adaptation strategies to address the potential impacts of climate change and variability on shellfish resources in Wellfleet Harbor* (July 2015). The critical need is to start discussions of options in the near term so that Wellfleet and its shellfishing sector can be prepared for future changes. Discussions about how to address the impacts of sea level rise should also be integrated with planning for other climate-related threats (e.g., rising water and air temperatures, more intense storms, more severe storm surge) and non-climate-related threats (e.g., nitrogen loading) so that Wellfleet and its shellfishing sector can pursue opportunities that address multiple threats simultaneously (e.g., no-regret actions).

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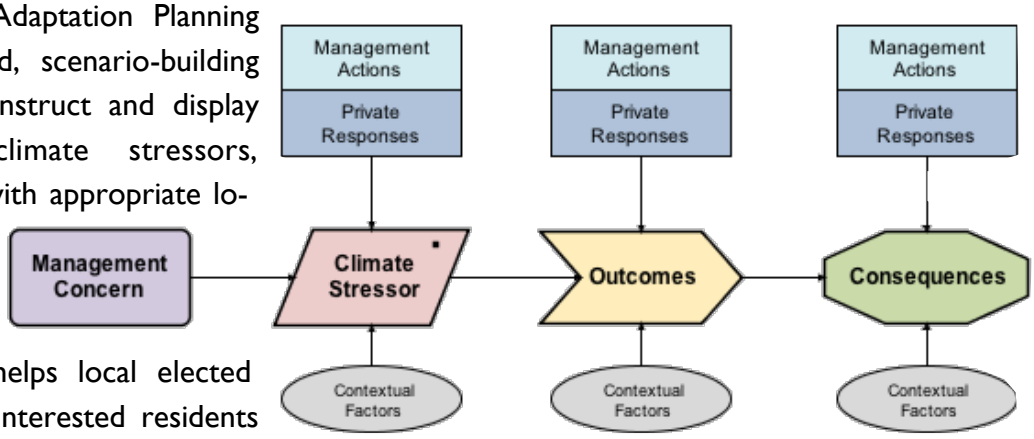
Appendix A

Maps illustrating impacts to grant access

Vulnerability-Consequences Adaptation Planning Scenarios

Overview

Vulnerability and Consequences Adaptation Planning Scenarios (VCAPS) is a facilitated, scenario-building process that enables users to construct and display causal pathways that link climate stressors, vulnerabilities, and consequences with appropriate local adaptation options. These causal pathways are created with an interactive, computer-based diagramming tool. This process helps local elected officials, town staff, planners and interested residents clarify their understandings and assumptions about climate change and adaptation challenges their community will face in the future. During this process, community leaders will be provided with multiple, locally relevant climate scenarios that their community should be prepared for, such as increased rainfall, more intense hurricanes, frequent shallow coastal flooding, drought, or other scenarios that are based upon the best available science. Because climate change could have numerous impacts at the local level, this interactive diagramming process will allow community leaders to define potential climate implications on one or a variety of local management areas (i.e. stormwater management, wastewater management, water supply, beach and waterfront management, building & zoning, emergency management, and public health). Ultimately, the VCAPS process will help local leaders identify and integrate adaptation measures into existing planning activities and the allocation of resources.



The VCAPS Diagramming Framework

VCAPS Objectives

The VCAPS process is intended to help communities improve the process by which they plan and prepare for coastal hazards associated with climate change. VCAPS will:

- **Engage** local decision-makers in an interactive discussion about significant weather and climate threats.
- **Summarize** the wealth of information, knowledge, and experience that exists within a community.
- **Identify** gaps in data, knowledge, or planning that a community may want to further explore.
- **Stimulate** strategic thinking about how to manage consequences through upstream and downstream approaches.

DEVELOPED AND PILOTED BY:

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Sea Grant S.C. Sea Grant Consortium

For additional information on VCAPS, visit the Social and Environmental Research Institute website at www.seri-us.org/content/coastal-adaptation-planning

Key Elements

Management Concern
Identify a single management area of concern, such as building & zoning, beach management, public health, emergency management, stormwater management, etc.

Climate Stressor
Explore how climate change may impact the management concern, for instance, increased heavy precipitation.

Outcomes
Evaluate how the management area of concern will respond to the climate stressor, for example, increased rainfall causes flooding.

Consequences
Determine the potential implications of the outcomes on individuals, institutions, or ecosystems, for instance, flooding damages infrastructure and private property.

Management Actions
Identify actions that public institutions, such as local and county governments, can take to reduce or eliminate the consequences of the stressor, for example, upgrading the capacity of existing stormwater systems.

Private Responses
Identify actions that private individuals or organizations, such as local businesses, can take to reduce or eliminate the consequences of the stressor, like installing rain gardens and rain barrels.

Contextual Factors
Identify site specific characteristics, like impervious cover, that affect the magnitude of the climate stressor, outcome, or consequence.

The Process

The VCAPS process, which can be completed in one or a series of meetings, is lead by a multi-person team, consisting of a facilitator, climate expert, diagramming scribe(s), and note taker. Initially, the team will introduce the local leaders and professionals, including planners, emergency managers, engineers, floodplain managers, administrators, and elected officials, to the computer-based diagramming tool and diagram elements. The facilitator will then guide the group through selecting a management context, deciding on applicable climate stressors, and soliciting the resulting outcomes and consequences to fill out the chains and contextual factors that influence the management concern. Through the diagramming process, community leaders will identify practical management solutions to adapt or mitigate the impacts of short-term weather and long-term climatic stressors, differentiating the solutions from those that are appropriate for the local government to spearhead and those that private individuals and organizations can implement. From there, community leaders can then determine where to allocate funding and resources to mitigate impacts of future threats and disasters.

Where has VCAPS been applied?

In 2011, VCAPS was initially tested and refined through its application in two South Carolina coastal communities. Since then, it has been applied in additional communities with the assistance of research, outreach and extension partners. To date, the following communities have benefited from its application:

- Sullivan's Island, SC
- McClellanville, SC
- Plymouth, NC
- Plymouth, MA
- Boston, MA

McClellanville, SC Waterfront

In addition, training workshops have been conducted to show local planners and extension agents the benefits of using the scenario-building approach to identify climate change adaptation strategies. Upcoming facilitation of VCAPS is slated to occur in New Bedford and Fairhaven, MA and Orange Beach, AL.

For additional information on VCAPS, contact Seth Tuler, Senior Researcher, Social and Environmental Research Institute at SPTuler@seri-us.org

Appendix C: Overview of Working Group and the VCAPS process

The **purpose** of the Working group on Climate Change impacts on shellfishing in Wellfleet Harbor is to identify:

- threats to shellfishing in Wellfleet Harbor from climate change,
- the role of shellfish in mitigating impacts from climate change and other environmental hazards in Wellfleet Harbor, and
- strategies to increase the resilience of Wellfleet and its shellfishery in a time of climate change.

The **outcome** of the working group will be reports summarizing threats and opportunities, including specific actions that the Town and others can consider further to manage threats to the shellfishery in both the short and longterm. Specifically, the Working Group will provide information to inform local planning by addressing these questions:

1. What are anticipated impacts in Wellfleet Harbor and to shellfish from climate change?
2. To what extent do existing plans and proposed actions address impacts in Wellfleet Harbor and to shellfish from a changing climate? (Harbor Plan, Shellfish Management Plan, etc.)
3. What information is needed to understand impacts and how they can be managed (reduce vulnerabilities, adapt, etc.)?
4. What are additional / new actions that can be taken to reduce vulnerabilities and increase resilience of Wellfleet Harbor and its shellfish to a changing climate?

Members of the Working group on Climate Change impacts on shellfishing in Wellfleet Harbor

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This report was prepared by the Social and Environmental Research Institute with funding from the NOAA Climate Program Office (Award Number NA12OAR4310106). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Oceanic and Atmospheric Administration (NOAA).

Further information is available at: www.seri-us.org/content/fisheries-and-climate-Wellfleet

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