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CO-EVALUATION OF SUCCESS COMPONENTS IN SALT MARSH RESTORATION AND THE SHELLFISH INDUSTRY ON OUTER CAPE COD, MA

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BY

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ABSTRACT

Salt marshes in their natural form provide innumerable ecologic, economic, and aesthetic benefits to coastal communities. Salt marsh restoration projects have been implemented along coastal landscapes in an attempt to reclaim their original ecosystem services. The ecological and social components of restoration, like its connection to the shellfish industry, are well understood, but the inherent linkages between the components are not. Through the co-evaluation of these components, social and ecologic linkages are identified and assessed.

This project explores the shellfish industry of five outer Cape Cod towns containing salt marshes that have undergone restoration: Orleans, Eastham, Wellfleet, Truro, and Provincetown. Salinity data was used to determine the ecologic success of Hatches Harbor (Provincetown), East Harbor (Truro), Herring River (Wellfleet), Sunken Meadow (Eastham), and Namskaket Creek (Orleans). Annual town harvest reports were used to determine trends in quahog (*Mercenaria mercenaria*), soft shell clam (*Mya arenaria*) and oyster (*Crassostrea virginica*) populations. Shellfish constables, experts in marsh restoration, and shellfishermen were contacted to determine ecologic and social variables in the explored linkage.

This project determined the robust social link between salt marsh restoration and the shellfishing industry. The hypothesis that restoration and associated ecosystem services augment shellfish harvest is lacking. The sense of community and culture that rallies around both salt marsh restoration and shellfishing, however, proves that the link between ecologic and social understanding is important, since both play a valuable role in the community.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

The retreat of the Laurentide Glacier during the late Pleistocene deposited the sediment necessary to create Cape Cod and with it, the very landforms that make Cape Cod what it is today. As sea level rise slowed, sediment accumulation along the coast formed salt marshes as unique interfaces between land and sea. Numerous inlets and bays formed along the coast, providing ideal habitats for shellfish. The local culture of outer Cape Cod, Massachusetts, therefore, is intrinsically linked with its geologic history. From raking for oysters to digging for quahogs, shellfishing remains an integral part of the outer Cape culture and economy. Though salt marshes have been ditched, diked, and filled from the early twentieth century in the interest of reduced mosquito populations and increased development, more recent research has emphasized the importance of the link between healthy salt marshes and healthy shellfish populations. This project documents the current relationship between salt marsh restoration and the shellfishing industry on the outer Cape.

Salt marshes in their natural form provide innumerable ecologic, economic, and aesthetic benefits to coastal communities. Human alterations to salt marshes restrict water flow, which leads to decreased salinity and significant changes in vegetation and biodiversity (Smith and Warren, 2012). After enough time, what was a marsh habitat may become a woody forest, completely diminishing the ecosystem services it once provided (Smith and Warren, 2012). Salt marsh restoration projects have been implemented along coastal landscapes in an attempt to reclaim their original ecosystem services.

Research on salt marsh restoration ranges from science-based hydrologic, biogeochemical, and biotic responses to policy-based community responses. Though arguments exist that the value of restoration should be based solely on ethical grounds (Brennan and Lo, 2008), Chmura et al. (2012) assert that an understanding of the economic benefits of salt marshes offer the strongest motivators for restoration. In particular, salt marshes have substantial economic benefit in the ecosystem services of recreational uses (Day, 2009), flood and storm protection (Barbier et al., 2008; Morgan et al., 2009), climate regulation as carbon sinks (Chumra, 2009), waste treatment (Giblin et al., 1983), and nutrient filtering (Valiela et al., 2002). For a comprehensive breakdown, please see Table 2.1. Even with these benefits, however, implementation of restoration projects is often a long and difficult process. Among other concerns, property built on what was originally coastal floodplain prior to tidal restriction is at risk of flooding post restoration—encroachment is one of the largest threats to restoration projects (Portnoy, 2012). Portnoy (2012) concedes that restoration, particularly on a large scale, would change almost a century of familiar landscape and thus must follow a slow and incremental process in terms of reaching public consensus.

The inshore shellfish industry (soft shell clam, northern quahog, blue mussel, and oyster) of Massachusetts was valued at $27.3 million in 2011 (MA Department of Marine Fisheries, 2011). Previous research has established salt marshes as important habitats for shellfish. The substrate of the marsh is ideal for settlement of spat and juvenile commercially-harvested shellfish, though research has focused largely on mussels, which will not be included in this study (Heck et al., 1995; Roman et al., 2000). Johnston et al. (2002) found that respondents in Rhode Island highly favor salt marsh plans that increase shellfish habitats. Commercially-significant quahogs and soft-shelled clams recolonized East Harbor, a restored marsh in Truro, MA, only two years after restoration (Fraser, 2004). This is a good example of the provisioning and cultural ecosystem services that salt marsh restoration may provide.

The individual social and ecologic components of salt marsh restoration's anticipated impact on the shellfish industry are well documented. The linkages between these components, however, have not yet been explored. A successful restoration considers both major components and their interactions (Hopfensperger, et al., 2006). This project looks to determine if the linkage between salt marsh restoration and the shellfishing industry on the outer Cape exists on social and/or ecologic levels (Fig. 1.1). Increased connectivity, arguably, will have positive implications for current and future restoration projects.

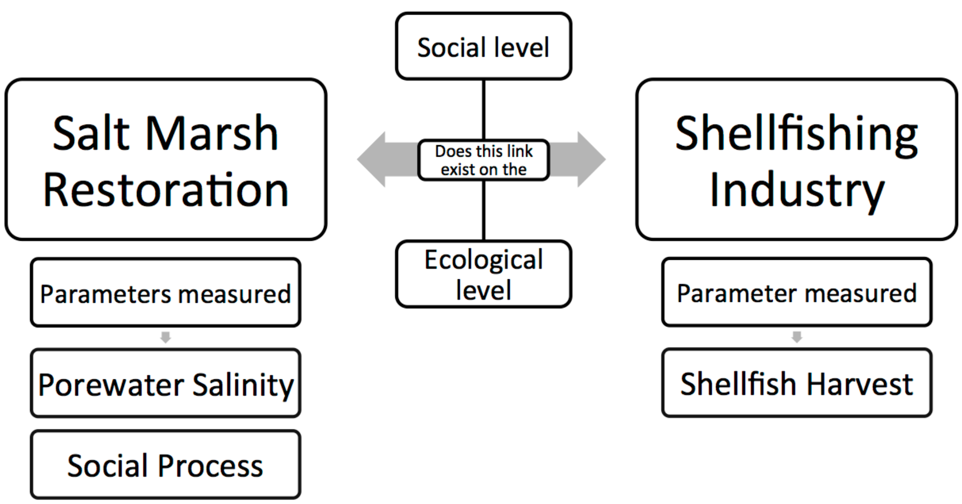

Figure 1.1. Graphical representation of the various components evaluated in this project.

Current research on outer Cape Cod salt marshes includes analyses of both individual marshes and broader geographic areas. Hydrologic and biogeochemical conditions of the Herring River system, a once 1100-acre Wellfleet marsh diked in 1909, are well documented (Roman et al., 1995; Portnoy and Giblin, 1995). Restricted marshes have been compared to unrestricted marshes on a one-to-one basis (Roposa et al., 2001). On a broader scale, satellite imaging has been used to determine shifts in vegetation indicating the effects of tidal restriction on the outer Cape (Smith, 2009). Additionally, salt marsh dieback, the largely unexplained loss of marsh vegetation, has been studied extensively in recent years (Smith and Warren, 2012; Holdredge et al., 2009; Bertness et al, 2009). A previous master's thesis in the marine affairs program at the University of Rhode Island has addressed the impacts of community valuation on the forward movement of the Herring River Restoration Project, suggesting that increased emphasis on community values could benefit the implementation of a project (Dominguez, 2007). Another marine affairs master's thesis has addressed the potential impact of salt marsh restoration on fishery resources in New England, suggesting that restoration projects positively impact important pelagic fish industries (Minton, 1997).

Hatches Harbor (Provincetown) is largely considered the prototype for a successful restoration (Portnoy et al., 2003), and has been considered successful on ecological, social, and economic levels (Hopfensperger et al., 2006). Other salt marsh restoration projects, such as East Harbor (Truro), have not been as successful in meeting their goals post restoration and have turned to significant adaptive management techniques to increase their success. The ecological and social components of restoration, like its connection to the shellfish industry, are well understood, but the inherent linkages between the components are not. Through the co-evaluation of these components, social and ecologic linkages will be identified and assessed. It is hypothesized that the link between salt marsh restoration and the shellfishing industry hinges largely on the ecosystem services that salt marsh restoration provides to the shellfishing industry. It is also hypothesized that the link will be robust on both social and ecologic levels.

2. BACKGROUND

This chapter will first situate the project firmly on the interface of social and natural science by discussing the role of social ecology in both marsh restoration and the shellfishing industry. The importance of ecosystem services in this context will be explored. These concepts will then be applied to outer Cape Cod. The shifting values that have led to the current social environment on the outer Cape will be assessed, as well as the various governance and supporting agencies that influence salt marsh restoration projects in the area. The shellfishing industry of the outer Cape will also be assessed, including its generalized history and an overview of commercially important species. Finally, the varying definitions of “success” will be explored and its context in this project will be defined.

2.1 The role of social ecology

This project exists on the interface of social and natural science, documenting the current relationship between salt marsh restoration and the shellfishing industry on the outer Cape. Both salt marsh restoration and the shellfishing industry have strong social and ecologic components—the ecologic process of restoring a degraded salt marsh ecosystem could not occur without social support, and the social process of shellfishing could not occur without ecologic processes required to maintain a healthy shellfish population. Previous research has grappled with the task of understanding the complex interplay that exists between ecological and social systems.

Preister and Kent (1997) describe this complex interplay generally as social ecology. A social ecosystem, therefore, is defined as a “culturally-defined geographic area within which people manage their lives and resources” (Preister and Kent, 1997).

The concept of social ecology was largely spearheaded by Bookchin (1990), under the term "dialectical naturalism." Social ecology has its roots in productive harmony, a concept based on the National Environmental Policy Act (NEPA) of 1969's Section 101(a). Preister and Kent (1997) visualize the concept of productive harmony as a combination of both permanence and diversity in both social and ecologic arenas (Fig. 2.1).

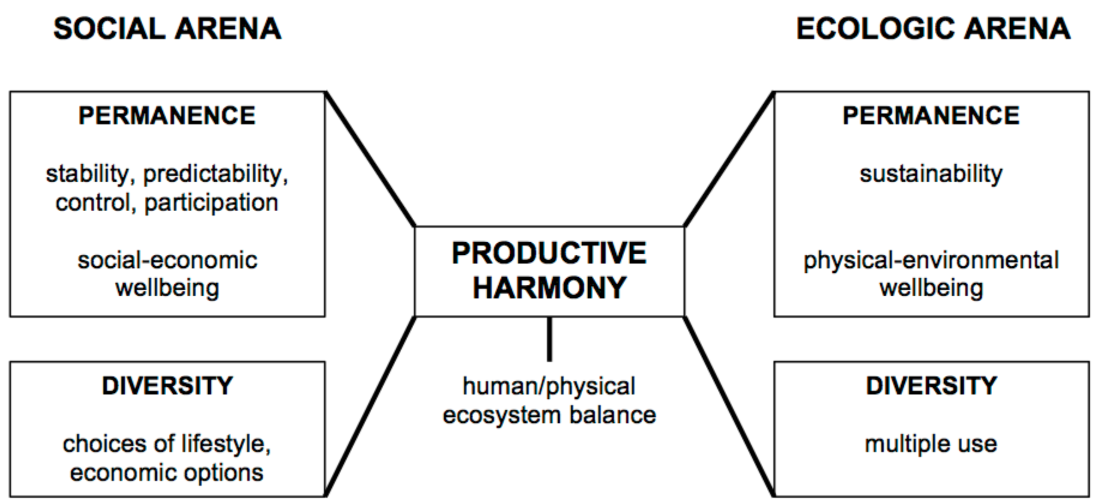

Figure 2.1. Model of productive harmony. Modified from Preister and Kent (1997).

In the NEPA model, productive harmony occurs when social stability in a resource (through participation in a decision-making processes and the cultivation of a sense of control over the resource) is paired with ecological stability in a resource (through long-term sustainability of the resource). The permanence aspect is paired with a concept of diversity in both social and ecologic arenas. The concept of social diversity is exemplified by choices in networks, settlement, work, support services, and recreation (Preister and Kent, 1997). Ecologic diversity is exemplified by the availability of a variety of natural resources (Preister and Kent, 1997).

Preister and Kent (1997) define a social ecology approach to problem solving as recognizing "the existence of the social ecosystem as an equal partner to the physical ecosystem." Indeed, several authors have explored the impact that the social ecosystem has on the physical ecosystem and vice versa. Gual and Norgaard (2010) have devised an initially-daunting depiction of the complex interplay between the two systems—a testament to the complexity inherent in the concept of social ecology (Fig. 2.2).

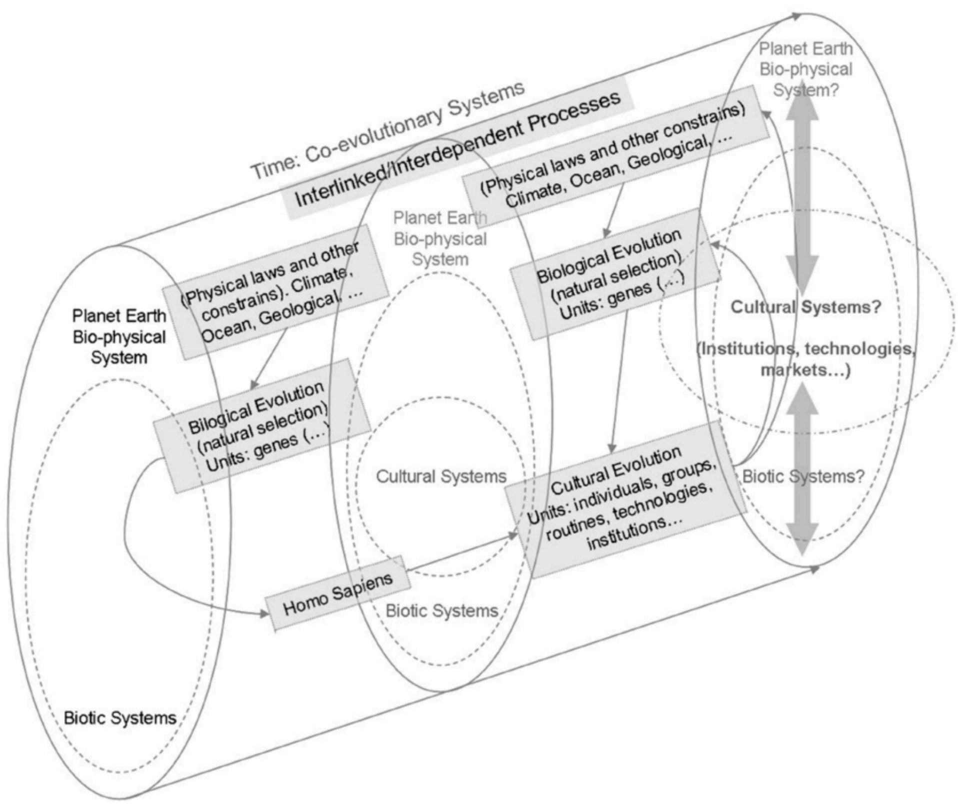

Figure 2.2. Model of complexity of social ecology interactions. From Gual and Norgaard (2010).

Gual and Norgaard (2010) assert that biotic, biophysical, and cultural systems weave together to form a complex form of coevolution. Evolution in both ecologic and social areas is reciprocal and accelerating. Gual and Norgaard (2010) distinguish three different modes of coevolution: coevolution through systemic influence, direct cultural selection forces, and genetic manipulation. For the purpose of this project, only the first two modes will be discussed.

Social-ecological coevolution has four main steps:

1. Cultural systems influence the biophysical arena and change its dynamics.
2. Changed environmental conditions change how biological selection forces operate.
3. One or several species (or populations of species) experience differential evolution.
4. Cultural system evolves, responding (or not responding) to the evolutionary change. (Gual and Norgaard, 2010).

The classic example of coevolution through systemic influence is the evolution of *Biston betularia*, crytic moths. Kettlewell (1973) noted the presence of "industrial melanism," where predominantly light-colored moth populations began to select for darker-colored phenotypes (*steps 2 and 3*) as soot from the European industrial revolution darkened tree trunks (*step 1*). As clean air laws were passed in the 1970s (*step 4*), moth populations began to select for lighter-colored phenotypes (*steps 2 and 3*). As seen in this example, where steps 2 and 3 of the coevolutionary process are repeated, the process often snowballs, as a human response to an environmental change will invariably cause another environmental change.

The classic example of coevolution through direct cultural selection forces is the pesticide-pest relationship. Farmers switch to largely one-crop plots in an attempt to capitalize on a competitive market (*step 1*), which pests can easily decimate (*step 2*).

Farmers use pesticides to eliminate the pest problem (*step 1*), but the pests evolve to become resistant to the pesticides (*steps 2 and 3*). Farmers must then find pesticides that are effective against the evolved pest (*step 4*), and the process continues (Gual and Norgaard, 2010).

This understanding of social ecology has given rise to the concept of adaptive management. Adaptive management has been defined by the Herring River Restoration Project Conceptual Restoration Plan (2009) as:

> A systematic management paradigm that assumes natural resource management policies and actions are not static but are adjusted based on the combination of new scientific and socio-economic information in order to improve management by learning from the ecosystems being affected. A collaborative adaptive management approach incorporates and links knowledge and credible science with the experience and values of stakeholders and managers for more effective management decision-making.

Folke et al. (2005) explore the importance of adaptive management as a way for social systems to respond to uncertainties or surprises in ecological systems, while recognizing that the human dimension of the coevolution means that the social aspect of adaptive management is just as important as the ecologic aspect. Folke et al. (2005) even go so far to declare that any delineation between social and ecologic systems is "artificial and arbitrary." The authors assert that the ability of a society to implement adaptive management in the face of change is imperative to its resilience as a culture. Successful adaptive management, however, requires collaboration among the various levels of stakeholders, from individual users of a resource to federal decision-making agencies. This adds an additional level of complexity—not only are decisions being made across stakeholder scale but also in a constantly dynamic system. The critical factors Folke et al. (2005) identify as necessary for dealing with these dynamic, cross-scale issues in social ecology include:

- Learning to live with change and uncertainty
- Combining different types of knowledge for learning
- Creating opportunity for self-organization toward social-ecological resilience
- Nurturing sources of resilience for renewal and reorganization

A major way to deal with the social ecology considerations of both salt marsh restoration and the shellfishing industry is through the understanding of the role ecosystem services play in each. Social ecology informs this analysis through providing a framework for ecosystem services—ecosystem services are determined based on human valuation of the service.

2.2 The ecosystem services argument

Ecosystem services are a convenient way to synthesize the social and ecologic aspects in this project. Ecosystem services are defined broadly as "the benefits people obtain from ecosystems" (Butchart et al., 2005). Barbier et al. (2011) summarize the interplay between ecosystem goods and services and human drivers of ecosystem change as largely affected by human values and ecosystem processes, effectively creating a way to value the social-ecologic linkage inherent in salt marsh preservation and restoration (Fig. 2.3).

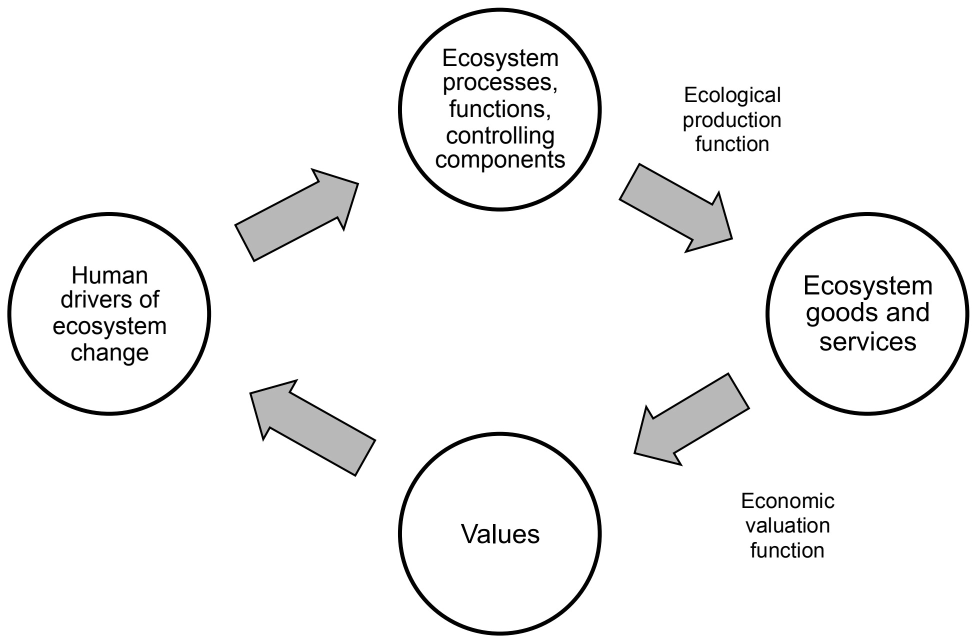

Figure 2.3. Key interrelated steps in ecosystem service valuation. Modified from Barbier et al. (2011).

The 2005 Millennium Assessment distinguishes four main categories of ecosystem services of salt marshes and, generally, wetlands: provisioning, regulating, cultural, and supporting. Increased shellfish production largely falls under the provisioning and cultural ecosystem services categories. A summary of the major ecosystem services discussed in this project can be found at the end of this chapter (Table 2.1).

Though many of the studies discussed explore the ecosystem services of extant, healthy salt marshes, it is also important to understand that many, if not all, of the ecosystem services of a healthy salt marsh will be regained from the restoration of a degraded salt marsh. The traditional measure of ecological success of a restoration project, increased tidal range and salinity, has many overarching effects on the surrounding environment. The Herring River Technical Committee, responsible for spearheading the restoration of the Herring River in Wellfleet, MA, has developed a conceptual model connecting the various ecosystem services both heightened and obtained when a degraded marsh is restored (Fig. 2.4).

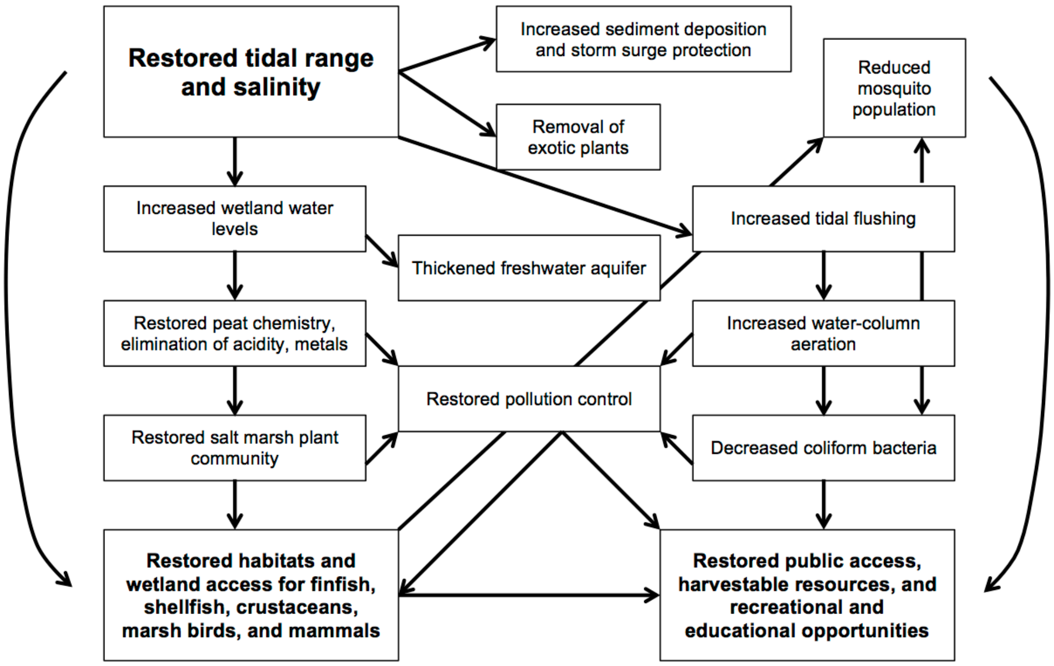

Figure 2.4. Conceptual model of the ecosystem services anticipated with the Herring River restoration project in Wellfleet, MA. Modified from HRCRP (2007).

2.2.1 Provisioning ecosystem services

Provisioning ecosystem services are services that directly provide goods to the social arena, including food production, fresh water, fiber and fuel, biochemical services (including medicines), and genetic materials. For the purpose of this paper, only the food production provision service will be discussed. Though environmental protection regulations generally prohibit direct harvest of food from a salt marsh, some plants are legally harvested for human use. These may include *Spartina patens*, for livestock fodder and mulch; *Plantago maritima*, for food; and *Salicornia maritima*, for salads (Chmura et al., 2012). Gallagher (1985) classified several salt marsh plants as valuable for agricultural use due to their salt tolerance, which could become more useful as sea-level rise salinizes more soils (Chmura et al., 2012).

Secondary food production—through habitat support for game birds, fish, shellfish, etc.—is of particular importance to the social arena, which values these goods for both sustenance and cultural/recreational purposes. Primary production (in the form of dead and decaying vegetation) enters into a "detrital food chain," providing nutrients to detritivores, which provide nutrients to small predators and transfer the energy further from the source (Turner, 1977; Chumra et al., 2012). The small predators transfer their energy to larger predators, such as birds and large fish (Kneib, 2002), which are fit for human consumption. Studies have shown that the rates of secondary production in estuarine habitats rival the highest rates recorded in other aquatic habitats (Fredette et al., 1990). Additionally, Valiela et al. (1978) found that nearly half of the dissolved inorganic nitrogen transported from groundwater into the Great Sippewissett Marsh in Buzzards Bay, Massachusetts, was converted to particulate nitrogen. Nitrogen in particulate form becomes accessible to a variety of shellfish with both economic and ecologic importance (Valiela et al., 1978).

Salt marshes provide an important habitat for shellfish. Though the results have been seen more profoundly in warmer climates (Weinstein 1979), the substrate of the marsh is favorable for the settlement of spat and juvenile commercially-harvested shellfish (Heck et al., 1995; Roman et al., 2000). A study of Cape Fear River, North Carolina, established tidal creeks and portions of fringe marsh as primary nursery habitats for juvenile and postlarval shellfish (Weinstein, 1979). Though Roman et al. (2000) identified eelgrass beds as a primary area for spat settlement of commercially-harvested blue mussels and bay scallops in the Northeast, the hydrologic connectivity extant in the relatively small Cape Cod Bay system suggests that the nutrients from the detrital food chain of the salt marsh plays a role in this preference. A study based in the Newport River Estuary, North Carolina, found that commercially-important shellfish had yet to be recruited to a restored salt marsh after the duration of the 27-month study, though similar species were found in a nearby natural marsh (Levin et al., 1996). From this, the authors determined functional equivalence had yet to be reached between the study and control marshes (Levin et al., 1996).

Though an explicit link between shellfish populations and salt marsh restoration has not been illustrated, extensive research has revealed explicit links between pelagic fish populations and salt marsh restoration (see *Coastal Wetland Restoration and its Potential Impact on Fishery Resources in New England*, University of Rhode Island Master's Thesis, Minton, 1997). Dibble and Meyerson (2012) explored the physiological condition of the mummichog (*Fundulus heteroclitus*) at restricted and reference marshes, including this project's study sites, Hatches Harbor (restored reference) and Herring River (restricted). Their findings showed that fish populations in restricted marshes are at a significant disadvantage to those in restored marshes, suggesting that restoration can improve the physiological condition of the mummichog, among other neckton.

2.2.2 Regulating ecosystem services

Regulating ecosystem services are services that temper natural processes, including atmospheric gas and climate regulation, disturbance and storm regulation, water purification, and waste treatment.

Salt marsh soils sequester significant amounts of carbon dioxide from photosynthesis, effectively aiding in climate regulation. Chmura et al. (2003)

estimated the average value of carbon sequestration as 210 grams per square meter of salt marsh per year. Further, Chmura (2009) hypothesize that salt marshes are "some of the world's most valuable natural carbon sinks," as they will continue to store carbon as they continue to accrete with rising sea levels, whereas terrestrial soils will not. An analysis of restored marshes shows that they store carbon at rates comparable to natural marshes, particularly in marshes dominated by *Spartina patens* (Ainsfeld et al., 1999). Chmura et al. (2003) go as far to determine a market value of the carbon retained in marsh soils. Though extremely variable, the authors value the soil carbon in a salt marsh annually at $0.77 to $138 per hectare (Chmura et al., 2003).

Several studies have described the utility of salt marshes for coastal protection and disturbance regulation. This is largely due to the sedimentological properties that salt marshes possess. Sedimentation directly affects marsh elevation, which can help determine the salt marsh's ability to act as a buffer for storm surges, wind-generated waves, or elevated water levels (French, 2006; Möller, 2011). Input of sediment supply (from wave action or vegetation death) adds to the overall soil volume, which increases elevation (French, 2006). The root zone of the marsh vegetation encourages sedimentation, prevents erosion, and stabilizes shorelines (French, 2006; Shepard et al., 2011). Smaller, more frequent waves are often attenuated by marsh vegetation (Shepard et al., 2011). Additionally, flooding in coastal areas is often reduced because floodwaters can be stored in the soil volume (Shepard et al., 2011).

To illustrate the potential wave attenuation utility of salt marshes, Möller (2012) explored the relationship among wave height, water depth, and distance from a marsh in Tillingham, Dengie, UK. The study found that the study salt marsh suggested a "rapid, non-linear reduction in wave energy landward of the marsh edge," largely dependent on water depth and wave energy (Möller, 2012). As waves encounter the marsh edge, they reduce substantially in height. Additional studies found that wave attenuation was also due to the surface friction of the marsh (Barbier et al., 2008; Morgan et al., 2009). Unfortunately, though tidal restrictions are associated with flooding events (Diers and Richardson, 2012), property built post-restriction may also be at risk of damage once the restriction is removed, since the property will be on an area that would naturally be salt marsh and thus naturally attenuate storm surge (Portnoy, 2012).

In addition to regulation of disturbances, wetlands and salt marshes are renown for their nutrient filtering and water purification capacities. In terms of water purification, salt marshes act as the "final filter" for runoff before it enters an estuary (Gedan et al., 2009). The nutrient filtering capacity of a marsh is a function of both its sediment composition and its species distribution. Jordan and Valiela (1980) found that a population of ribbed mussels (*Geukensia demissa*) in Great Sippewissett Marsh in Buzzards Bay, MA, filtered a volume of water larger than that of the entire marsh during each tidal cycle. We can assume, therefore, that other filter-feeding bivalves (including commercially-important species of shellfish) in the salt marsh also play a role in water filtration. Salt marshes also provide an organic-rich, often-anoxic environment at the interface of land and sea, ideal for denitrification (Stefanson, 1972; Seitzinger, 1988; Groffman, 1994; Nowicki et al., 1999). As such, they act as important buffer zones for anthropogenic sources of nitrogen (Wigand et al., 2004). To quantify this importance, Piehler and Smyth (2011) used the North Carolina nutrient offset program to calculate the value of nutrient regulating services as $6,128 per hectare. There is conflicting evidence to the effects of eutrophication (a direct result of nitrogen-loading) on salt marshes, and some research suggests that eutrophication may actually accelerate marsh loss (Deegan et al., 2006). This suggests that increasing nitrogen loads to the salt marsh is not "an acceptable compromise to better management of pollution sources from watersheds or human activities" (Chmura et al., 2012).

The final regulating ecosystem service to be discussed is waste treatment. Chmura et al. (2012) describe waste treatment as the "trapping of heavy metals in marsh soils, from direct uptake from sewage to sequestration in relatively pristine areas." Marsh sediment has a great capacity to retain toxic substances in a biologically unavailable form (Giblin, 1983), and studies have shown that heavy metal sequestration (Pb, Ni, Cr, As, V, Zn, Cu) and mercury accumulation was comparable between restored and natural marshes (Hung and Chmura, 2006).

2.2.3 Cultural ecosystem services

Cultural ecosystem services include recreational uses and sources of cultural value, such as spiritual and inspirational value, aesthetic value, and educational value. Conservation lands often have trails and boardwalks, which can be utilized by area residents and tourists. These lands can act as a source of recreation and education, particularly if the conserved land is adjacent to an education center. Chmura et al. (2012) suggest that restored marshes may even have greater cultural value, since the history and restoration process can increase interest in the area. Nature tourism activities can also become a part of the local economy, drawing income from the cultural ecosystem service of the marsh (Day, 2009). Since shellfishing is also a major recreational activity on the outer Cape, increased shellfish populations (traditionally considered a provisioning service) may also act as a cultural ecosystem service.

2.2.4 Supporting ecosystem services

Supporting ecosystem services are largely encompassed within provisioning ecosystem services and regulating ecosystem services and include biodiversity support, nutrient cycling, and soil formation. These topics have been discussed in length above. Biodiversity support in the form of habitat and refugia for different species aids in secondary production. Nutrient cycling is an imperative process in waste and water filtering. Soil formation, as discussed above, supports the disturbance regulation function of the salt marsh.

2.2.5 Valuation

Attempts have been made to quantify ecosystem services, most notably by Costanza et al. (1997), who determined that the total annual value per hectare of salt marsh was \$9,990 (1994 US dollars, or approximately \$15,768 today). Though economists have since determined flaws in the study's valuation of ecosystem services (Bockstael et al., 2000), further analysis of multiple sources revealed that the value proposed by Costanza et al. (1997) was within an acceptable range of values (Chmura et al., 2012). A summary of the generalized valuation of ecosystem services of salt marsh ecosystems is included below (Table 2.1).

Table 2.1. Comprehensive breakdown of salt marsh ecosystem services.

Ecosystem Service (per Costanza et al., 1997)	**Value** (2014 US $ ha^{-1} yr^{-1} [1])	**Supporting studies**	**Examples** (per Butchart et al., 2005)
Provisioning			
Food production	736	Turner, 1977 Gallagher, 1985 Kneib, 2002	Production of fish, game, grains, fruit
Biodiversity support	267	Heck et al., 1995 Levin et al., 1996 Roman et al, 2000	Habitat/refugia for variety of species
Regulating			
Disturbance regulation	2,903	Barbier et al., 2008 Morgan et al., 2009	Flood control Storm protection
Climate regulation	--	Chumra, 2009	Carbon sink Temperature regulation
Waste treatment and nutrient cycling	10,569	Giblin et al., 1983 Valiela et al., 2002	Water purification Removal of excess nutrients Retention of pollutants
Cultural			
Recreational uses	1,039	Day, 2009	Recreational activities: kayaking, canoeing, fishing, etc.
Cultural value	2,780	Ehrlich & Ehrlich, 1992	Spiritual and inspirational impacts Aesthetic beauty/value Educational opportunities
Supporting			
Nutrient cycling/filtering	--	Valiela et al., 2002	Nutrient storage, recycling, processing, acquisition
Biodiversity support	267	Heck et al., 1995 Levin et al., 1996 Roman et al, 2000	Habitat/refugia for variety of species

[1]Values converted from 1994 US dollars to 2014 US dollars using Bureau of Labor Statistics inflation calculator (bls.gov/data/inflation_calculator.htm). Original values from Costanza et al. (1997). Values for climate regulation and nutrient cycling not included.

2.3 History of restoration on the outer Cape

2.3.1 Shifting values

Salt marsh restoration on the outer Cape represents centuries of shifting values. In colonial times, salt marshes were highly valued for their agricultural purposes (Casagrande 1997). Common marsh vegetation includes *Spartina patens*, salt marsh hay, which could be dried and used as livestock feed. With the rise of industrialism, however, it became easier to dike, ditch, and fill salt marshes, which were increasingly seen as "breeders of disease" borne by mosquitoes (Peck, 1889). By the early 1900s, mosquito eradication was considered "a mission of moral rectitude," making salt marshes a prime target for a similar eradication (Casagrande, 1997).

With the start of the environmental movement in the 1960s, salt marshes began to be valued more for their intrinsic properties. Research in the late 1950s and early 1960s connected salt marshes with marine fishery productivity (Kalber, 1959), which strengthened the conservation argument (Casagrande, 1997). The environmental laws put into place in this era, including the National Estuary Protection Act of 1968 and the Clean Water Act of 1972, increased the protection of salt marshes and prevented many major diking projects (Casagrande, 1997). By the late 1980s, the restoration movement was in full swing, further increasing the intrinsic and economic value placed on salt marshes (Casagrande, 1997). Casagrande (1997) asserts that salt marshes were never "disliked," but rather that their eradication was largely due to their association with increased mosquito populations and a lack of understanding about their economic value.

Though there is a generalized sense today that restoration is a process to be encouraged and valued, the general public is generally resistant to change, particularly if it may come at a cost to them (the "Not In My Back Yard," or NIMBY argument; (Hartig et al., 2001), such as dead trees or at-risk wells from salt water inundation (Fraser, 2005) or concern over increased mosquito populations. Interestingly, research on the effects of salt marsh restriction for mosquito prevention has shown that diking and ditching may actually have increased the pest problem in Cape Cod estuaries (Portnoy 1984).

2.3.2 Governance, Legislature, and Assistance

Juda (1999, page 90) defined governance as "a key element in ecosystem management [that] encompasses the formal and informal arrangements, institutions, and mores that determine how resources and the environment are utilized." Governance is utilized in salt marsh restoration projects at the federal, state, and municipal levels. Governance encompasses both formal legislation and the various assistance programs extant at each level. This section seeks to serve as a representative sampling of the various forms of governance potentially at play in salt marsh restoration projects.

On the federal level, major governance includes the 1972 Clean Water Act (CWA), the Estuary Restoration Act (ERA) of 2000, and the Oil Pollution Act (OPA) of 1990. Section 404 of the CWA (33 *U.S.C.* 1344) regulates the discharge of dredge or fill material into wetlands. If damage to the wetland is permissible under the CWA, compensatory mitigation is required. Compensatory mitigation falls under the "no net loss" wetland policy of 1988, a policy goal aimed at protecting existing and creating new wetlands. Parties that damage or destroy existing wetlands, therefore, are required to restore or enhance the existing wetland or create a nearby wetland. Dominguez (2007) suggests that the "no net loss" policy may provide an opportunity for the funding of a wetland restoration project. Funding for a restoration project may also be provided under the 1990 Oil Pollution Act (OPA), but only if a wetland has been affected by an oil spill. Title 1 of the Estuaries and Clean Waters Act (P.L. 106-457) is known as the 2000 Estuary Restoration Act (ERA). The ERA establishes a national framework for restoration projects, and a monitoring plan is required before funding can be issued. The monitoring guidelines emphasize both ecologic and human dimensions of restoration (Thayer et al. 2005).

There are several federal assistance programs, including the Community-Based Restoration Program (CRP) through the NOAA Fisheries Office of Habitat Conservation and Restoration Center. This funding is meant to assist local efforts in various restoration projects, including salt marsh restoration (Dominguez, 2007). There are also various funding opportunities through the US Fish and Wildlife Service, the Army Corps of Engineers, the US Department of Agriculture Natural Resources Conservation Service, and the Environmental Protection Agency.

It is also important to consider the role of the National Park Service (NPS). Three of the salt marshes examined in this project contain at least some land within the Cape Cod National Seashore, an extension of the NPS. In many cases, the NPS purchased land with the specific intent to protect it. The NPS employs scientists to closely monitor the restoration projects within its boundaries, leading to robust datasets of both pre- and post-monitoring characteristics. The NPS also monitors salt marsh dieback, another threat to Cape Cod salt marshes.

Below the federal level, governance for salt marsh restoration includes the Massachusetts Oil and Hazardous Materials Release Prevention and Response Act (MOHMRPRA), the Massachusetts Wetlands Protection Act (WPA), and the Massachusetts Public Waterfront Act (MPWA). The MOHMRPRA exists under an OPA provision that allows states to have their own protection plans in the case of an oil spill or other hazardous material release (33 USC §2718), and protocol for obtaining funding for a restoration project is similar to that of obtaining federal OPA funding.

The Massachusetts WPA (M.G.L. c. 131, §40), combined with its implementing regulations (310 CMR 10.00 *et seq*.), regulate the removal, fill, dredge, or other alterations of wetlands within the state of Massachusetts. M.G.L. c. 131, §40, identifies the following areas of interest in wetland regulation: "protection of public and private water supply; protection of ground water supply; flood control; storm damage prevention; protection of pollution; protection of land containing shellfish; protection of fisheries; protection of wildlife habitat." The compensatory mitigation and "no net loss" policies extant in federal legislature also exist at the state level. The MA WPA, however, provides towns and municipalities with more input and control, as individual towns must review applications for funding and permitting. Both the town and the state are responsible for periodic reviews of progress.

The Massachusetts Public Waterfront Act (M.G.L. c. 91, §1-63) seeks to protect and restore public waterways in the state of Massachusetts. The MPWA details a licensing process for a variety of activities that require authorization, including the placement or construction of any structure (significant for many restoration projects), filling, dredging, any change in use, structural alteration, and removal of unauthorized structures. Individual counties or towns may appropriate funds to restore tidal or non-tidal waterways, and both town and state share the management of a restoration project initiated this way.

The work of non-governmental organizations (NGOs) is also pivotal to many restoration projects. Though many NGOs have assisted in salt marsh restoration projects, of particular importance to this project is the Association to Preserve Cape Cod (APCC). The APCC runs a volunteer salt marsh monitoring program, which ideally monitors a salt marsh for up to three years prior to restoration and up to three years after restoration. The marsh then is monitored at the five- and ten-year marks. The APCC provides valuable datasets to assess the ecological success of a restoration project.

2.4 History of the shellfishing industry on the outer Cape

Shellfishing on the outer Cape has had a varied and fabled history. Sandy Macfarlane, former shellfish biologist for the Town of Orleans, discusses how the outer Cape has experienced “more changes … in the past 50 years than in the first 300-plus years since the Nickersons’ ancestors arrived,” alluding to the fabled founder of Chatham, another Cape Cod town (2002). In a more poetic explanation:

> Gone is a way of life that depended on the land and the sea for its very existence. … The clam hoe and quahog scratcher once were as essential pieces of equipment in nearly every household as hammer and ax. The

> fishing pole once was used here to get fish as food for the table. Every fish that was edible was harvested when it came into the bay. There was sport in fishing, but fishing was not merely for sport. (Macfarlane, 2002)

Macfarlane emphasizes that while life in the first half of the 20th century was difficult on Cape Cod, residents could rely on the fish and shellfish populations for sustenance. With the end of World War II, however, came the end of gasoline rationing, which allowed for more travel. Since Cape Cod is within an easy driving distance of both Boston and New York, particularly with the construction of highways, it became a popular destination spot. With the additional attention from President John F. Kennedy's summer home in Hyannisport, and the implementation of the Cape Cod National Seashore in 1961, the Cape became a tourism destination, and native Cape Codders began to live two lives, described by Macfarlane as, "a 'seasonal' one when they tried to make enough money to make it through the winter, and the rest of the time, when they played 'catch-up,' hoping they could pay their bills until the 'summerfolk' returned to get the economy pumped up again."

By the 1960s, American fisheries everywhere began to feel pressure from foreign offshore factory trawlers. What was once thought to be an "inexhaustible resource" now clearly was beginning to show its true exhaustibility (Nielsen, 1976). In response to this threat, President Ford signed the Fisheries Conservation and Management Act (FCMA) in 1976, creating a 200-nautical-mile fishery conservation zone (FCZ) effective within the next year. The history of the FCMA was tumultuous at best. Trying to balance conservationism and protectionism proved difficult, and it was not until the political climate changed significantly that the act passed. The introduction of the FCMA was generally well received—by limiting foreign fishers, more space opened up for domestic fishers. As domestic fishers realized that the act limits their activities as well as those of foreign fishers, however, fisheries managers were met with contention (Young, 1982).

As the FCMA made it more difficult for fishermen to fish offshore waters, many turned to inshore fisheries and, eventually, shellfishing. Macfarlane describes fishing as an inverse pyramid, with increased fishing pressure increasing as fishermen move closer to shore (Fig. 2.5). More recently, many Cape towns have seen a transition from wild harvest to aquaculture, likely in response to increased pressure on the wild harvest industry. Wellfleet, in particular, has aggressively pursued aquaculture, due largely to the popularity of the Wellfleet Oyster. Almost 200 acres of Wellfleet's estuaries are dedicated to clam and oyster grants (Wellfleet Oysterfest, 2014).

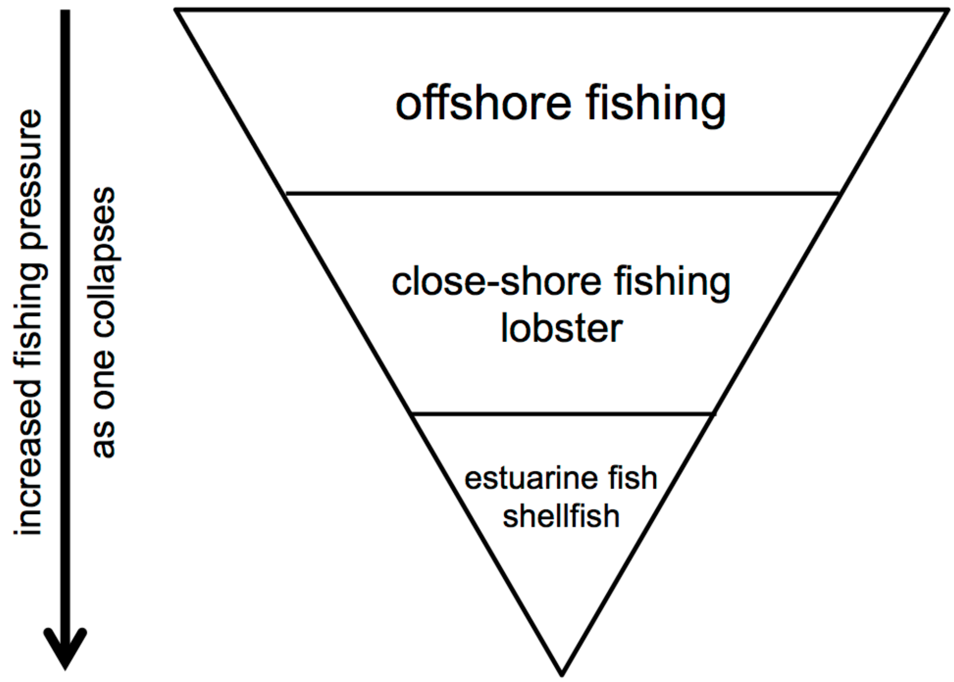

Figure 2.5. Diagram of the effects on fisheries and ecosystems as fishing pressure increases. Modified from Macfarlane (2002).

Oysters and soft-shelled clams have been harvested on the Cape since colonial times, and quahogs have been harvested since the late 1800s (Lind, 2009). Since then, town shellfish constables have been paid by individual towns to enforce state-regulated limits on harvests (Lind 2009). In 1933, Massachusetts Legislature transferred shellfish management to individual towns (Lind, 2009). Though the Massachusetts Division of Marine Fisheries manages many fisheries at the state level, as well as controls size regulations and contamination concerns in shellfish, all enforcement, licensing, propagation, and harvesting issues are controlled at the town level (Macfarlane, 2002).

2.5 Commercially important species

There are many different commercially important species of shellfish harvested annually on the Cape. This project uses three different species to guage the relationship between salt marsh restoration and the shellfishing industry. Two species, the soft-shelled clam (*Mya arenaria*) and the quahog (hard-shelled clam, *Mercenaria mercenaria*) were identified in all five study towns. These two species, along with the both commercially and culturally important oyster (*Crassotrea virginica*) will be detailed below.

2.5.1 Soft-shelled clam

Soft-shelled clams (*Mya arenaria*) are known colloquially as "steamers," "piss clams," or "longnecks" (Fig. 2.6). They are the traditional clam for fried or steamed clams. Soft-shelled clams are found one to two feet below the surface in sandy and muddy substrates (Macfarlane, 2002). Soft-shelled clams, appropriately, have soft shells that break easily, which makes them difficult to harvest using a rake without breaking them. Macfarlane (2002) describes the digging process as "awkward, hard, backbreaking work." A soft-shelled clam must be at least two inches at the longest diameter to be legally harvested (322 CMR 6.20).

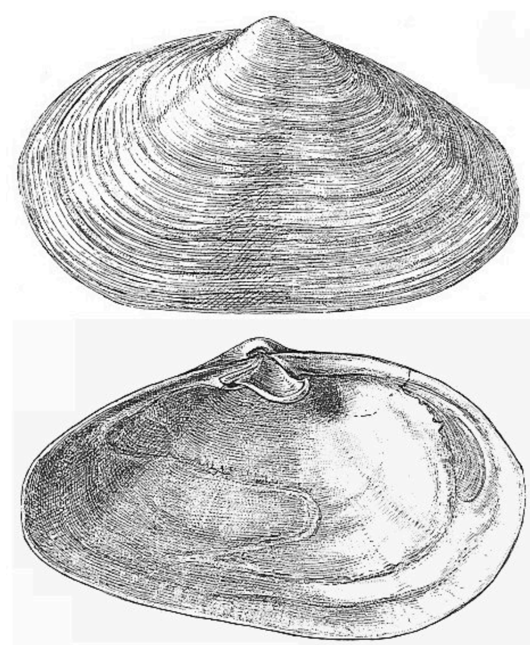

Figure 2.6. *Mya arenaria*. Public domain.

2.5.2 Quahog (hard-shelled clam)

Figure 2.7. ***Mercenaria mercenaria***. From John Norton, North Carolina SeaGrant.

Quahogs (*Mercenaria mercenaria*) are known colloquially as hard clams (Fig. 2.7). They are also identified by size from the smallest, "little necks," to medium-sized "cherrystones," to largest "chowders." They are commonly consumed as stuffed clams or in chowders and clam cakes. Quahogs are often found close to the surface in sandy or sand/mud/shell substrates. They are harvested with a rake, which may or may not be attached to a basket to collect the quahogs (Macfarlane, 2002). A quahog must be at least one inch in shell thickness (at the hinge) to be legally harvested (322 CMR 6.20).

2.5.3 Oyster

Figure 2.8. *Crassotrea virginica*. From Battison (2010).

Oysters (*Crassotrea virginica*) are of particular commercial and cultural importance to the outer Cape (Fig. 2.8). Oysters can be harvested in the wild or farmed in a grant. Juvenile oysters attach to hard, calcareous surfaces. In the wild, this is most often another oyster, but aquaculturists also use a plastic, lime-coated device called a Chinese hat to encourage oyster settlement (Wellfleet Oysterfest, 2014). Piles of broken oyster shells, called "cultch" can also be used to foster settlement. An oyster must be at least three inches at the longest diameter to be legally harvested (322 CMR 6.20).

The Wellfleet oyster, a variety named for where it grows, is touted as "plump and clean with a distinctively good balance of creamy sweetness and brine" (Wellfleet Oysterfest, 2014). Harvesters attribute the flavor to cold waters, high salinity, clean water, and fast-moving tides in the local harbor environment (Wellfleet Oysterfest, 2014). Of particular interest is the Wellfleet Oysterfest, an event "held annually the weekend after Columbus Day on Main Street downtown … to celebrate the town's oyster, clam and shellfishing traditions" (Bragg, 2013). This event draws massive crowds, with 2013's estimated attendance to be greater than 25,000 people (Bragg, 2013).

2.6 Definitions of success

Success is an amorphous term, broadly defined by Lewis (1990) as "achieving established goals." This project seeks first to determine the success of several restoration projects along the outer Cape. Once the success of these projects have been assessed on both ecological and social levels, the linkage between the restoration project and the shellfishing industry will be assessed. These linkages will be explored on both social and ecological levels (Fig 1.1).

Ecological success is defined broadly under the term "functional success," or the restoration of the ecological functions, biological viability, and biological sustainability of the system (Kentula, 2000; Quammen, 1986; West et al., 2000). For the purpose of this project, ecological success of a restoration will be measured through both biological and hydrologic parameters. Hydrologic parameters (primarily salinity; but also water levels, tidal range, and pore water levels) will be assessed through annual salt marsh monitoring reports. Per Buschbaum and Wigand (2012), hydrologic parameters of marshes restored through the elimination of impediments to tidal flow respond quickly to restoration procedures, "providing an early indicator of the likelihood of project success."

Social success is broadly defined by Hopfensperger et al. (2006) as involving multigroup collaboration and public support from stakeholders. The Hopfensperger framework considers a socially-successful restoration project to employ a variety of resolutions to disagreements (meetings and discussions, mediators, compromise) while including several important steps in the policy process (collection of scientific information, collaboration with stakeholders, modeling of scenarios for feasibility, prepare environmental assessment, site meeting needs of mitigation project, addressing concerns of local businesses). A successful salt marsh restoration project, therefore, will employ many of these steps and strategies. Hopfensperger et al. (2006) categorize the group dynamics inherent in restoration projects as cooperative/positive, resistant, involving mutual interests, involving trade-offs, involving public concern/opposition, using a mediator, and/or involving differences in philosophy. These seven criteria will be used to assess the group dynamics present in the five restoration projects considered in this project.

A successful participatory process will include efficient administration, positive participant interaction, active participant involvement, decisions based on complete information, and fair decision making (Dalton 2005). The Hopfensperger framework builds on the successful participatory process by incorporating and expanding on many of these criteria. Since the participatory process of some of the study restoration projects may have occurred more than a decade ago, the Hopfensperger framework allows for a retrospective look at the process by a manager.

This project will follow Hopfensperger et al.'s framework for determining social success accordingly, through interviews with local salt marsh managers. As such, the deemed social success of a given salt marsh restoration is largely an assessment of the implementation process. Once the success of a restoration project is determined, the linkages between salt marsh restoration and the shellfishing industry will be assessed (as discussed in the next section).

3. METHODOLOGY

This project will explore the shellfish industry of five outer Cape Cod towns containing salt marshes that have undergone restoration: Orleans, Eastham, Wellfleet, Truro, and Provincetown. The salt marshes analyzed for this project will include Hatches Harbor (Provincetown), East Harbor (Truro), Herring River (Wellfleet), Sunken Meadow (Eastham), and Namskaket Creek (Orleans) (Fig. 3.1). These marshes were selected for the wealth of available data collected both pre- and post-restoration. The marshes have restoration dates ranging from 1999 to 2011, with the Herring River Restoration Project still pending (Table 3.1). Ecological restoration data for Hatches Harbor and East Harbor were obtained from National Park Service (NPS) Annual Reports, as both of these restoration projects took place on the NPS-managed Cape Cod National Seashore. Ecological restoration data for the remaining three marshes were obtained from annual reports from the Association for the Preservation of Cape Cod (APCC)'s Salt Marsh Monitoring program.

Ecological success of a salt marsh restoration project was determined as a marsh that has experienced increased salinity (porewater, surface water, or combined) post restoration. Increased salinity is a major driver for vegetation change. As salinity increases, salt-intolerant plants, such as the generally considered undesirable *Phragmites australis*, quickly die off (Smith and Warren, 2012). This allows for recolonization of halophytes and traditional salt marsh vegetation, including *Spartina patens* and *Spartina alterniflora* (Smith and Warren, 2012). Without this characteristic change in vegetation, many of the salt marsh ecosystem services cannot occur (Table 2.1). Salinity data from NPS and APCC reports were used as an indicator of this change.

Table 3.1. Description of data source and restoration date for each study marsh.

Salt Marsh	**Data Source**	**Restoration Date**
Namskaket Creek *Orleans, MA*	APCC	2007
Sunken Meadow *Eastham, MA*	APCC	2011
Herring River *Wellfleet, MA*	APCC	Pending
East Harbor *Truro, MA*	NPS	2001
Hatches Harbor *Provincetown, MA*	NPS	1999-2004

Figure 3.1 Map of the study marshes and MassGIS shellfish suitability areas. Data from MassGIS and ESRI basemaps.

The shellfish species analyzed for this project included species that are wild-caught in all five towns: quahog (*Mercenaria mercenaria*) and soft shell clam (*Mya arenaria*). The commercially important oyster (*Crassostrea virginica*) was also assessed. Annual shellfish landings, a measure of the strength of the ecological linkage between salt marsh restoration and the shellfishing industry, have been compiled through data from the Massachusetts Department of Marine Fisheries and the shellfish departments of the individual towns. Unfortunately, uniformity of catch reports varies greatly by town, and gaps do exist in the data. Due to the low quality of the data, conclusions about shellfish harvest must consider this caveat in their interpretations of the data.

Elements of the social success of the implementation of a salt marsh restoration were largely determined through interviews. Restoration experts were interviewed about their experiences with specific marshes, particularly the social success parameters determined through the framework of Hopfensperger et al. (2006). Social success parameters were coded and totaled, ultimately creating a "social success score" in three different categories. Per Hopfensperger et al. (2006) framework, parameters were not weighted. In total, five experts were interviewed about their experiences with restoration. A list of parameters totaled is included in Appendix 1.

Each town has its own shellfish constable, natural resources officer, or municipal shellfish biologist. Individuals from each town were interviewed to determine annual catch/revenue, confounding factors in the data, and their perceptions of salt marsh restoration. These experts were able to identify trends in shellfish landings, as well as identify the local culture of the industry. Interviews were conducted in person from June through August 2013.

To determine the social support for salt marsh restoration among the shellfishing population (thereby establishing a linkage), shellfishermen throughout the outer Cape were contacted and interviewed by phone. In Eastham, Wellfleet, Truro, and Provincetown, lists of individuals holding shellfishing permits or licenses were obtained from town records or shellfish officials. Names were cross-referenced with public information to determine home phone numbers. All identified phone numbers were called between September and November 2013. In total, 42 shellfishermen were interviewed by phone. Shellfishermen were asked about their experiences shellfishing and their opinions on salt marsh restoration, both generally and the restoration project specific to their towns.

A comprehensive table comparing the different sources of data and methodologies used is included in Table 3.2. A list of interview questions is included in Appendix 1.

Table 3.2. Methods of determining components of salt marsh restoration in relation to the shellfish industry.

Success Component/ Linkage	Parameter	Method	Source
Ecological Success: Restoration	Water level and tidal range changes; pore water levels; salinity measurements	Data logger units and monitoring well data	NPS and APCC Annual Reports
Ecological Link: Shellfish	Annual harvests	Assessment pre- and post-restoration project in given town	MA Marine Fisheries; Town Shellfish Depts.
Social Success: Restoration	Number of strategies employed (per Hopfensperger framework)	Interview coding	Interviews with local salt marsh managers and town officials
Social Link: Shellfish	Number of positive responses re: salt marsh restoration	Interview coding	Interviews with local shellfishermen and shellfish managers

Following collection of data, trends in shellfish landings, salinity data, and fishermen responses were analyzed using JMP statistical analysis software. To determine the ecological effects of salt marsh restoration on the shellfish industry, t-tests were used to determine if the mean change in shellfish catch pre- and post-restoration is significant (whether positive, negative, or neutral). In marshes where sufficient salinity data was present and previous research did not exist, regression analysis was used to determine the ecological success of the restoration project (a successful restoration project should see a positive correlation between time and salinity). Interviews with shellfishermen were coded as follows:

- What are your general opinions about salt marsh restoration? (positive, negative, neutral, reserved)
- Are you familiar with the specific salt marsh restoration project in your town? (yes, no)
- What are your opinions about the specific salt marsh restoration project in your town? (positive, negative, neutral, reserved)

This coding was combined with other factors (town, type of shellfishing, years shellfishing, etc.) to determine if a shellfisherman's opinion of salt marsh restoration and its impact on the industry is positive, negative, neutral, or reserved.

Linkages between salt marsh restoration and the shellfishing industry were assessed explicitly through annual shellfish harvest and shellfishermen opinion of salt marsh restoration. Annual shellfish harvest data was used to determine if a linkage exists between salt marsh restoration and the shellfishing industry on an ecologic level. Shellfishermen opinion of salt marsh restoration was used to determine if a linkage exists between salt marsh restoration and the shellfishing industry on a social level. Robustness of the linkage was determined qualitatively—a robust ecologic link would require a significant increase in shellfish harvest after a restoration project, whereas a robust social link would require significantly positive shellfishermen opinions regarding salt marsh restoration.

4. RESULTS

Results will be discussed on a town-by-town basis and then discussed comparatively.

4.1 Orleans

Orleans, MA, is a 22.7-square-mile, 5,890-individual town located at the "elbow" of Cape Cod, with 177 shellfishing licenses issued in 2013. Of the 22.7 square miles, 14.1 square miles are land and 8.5 square miles are water (Farber, 2014; US Census; Fig 4.1).

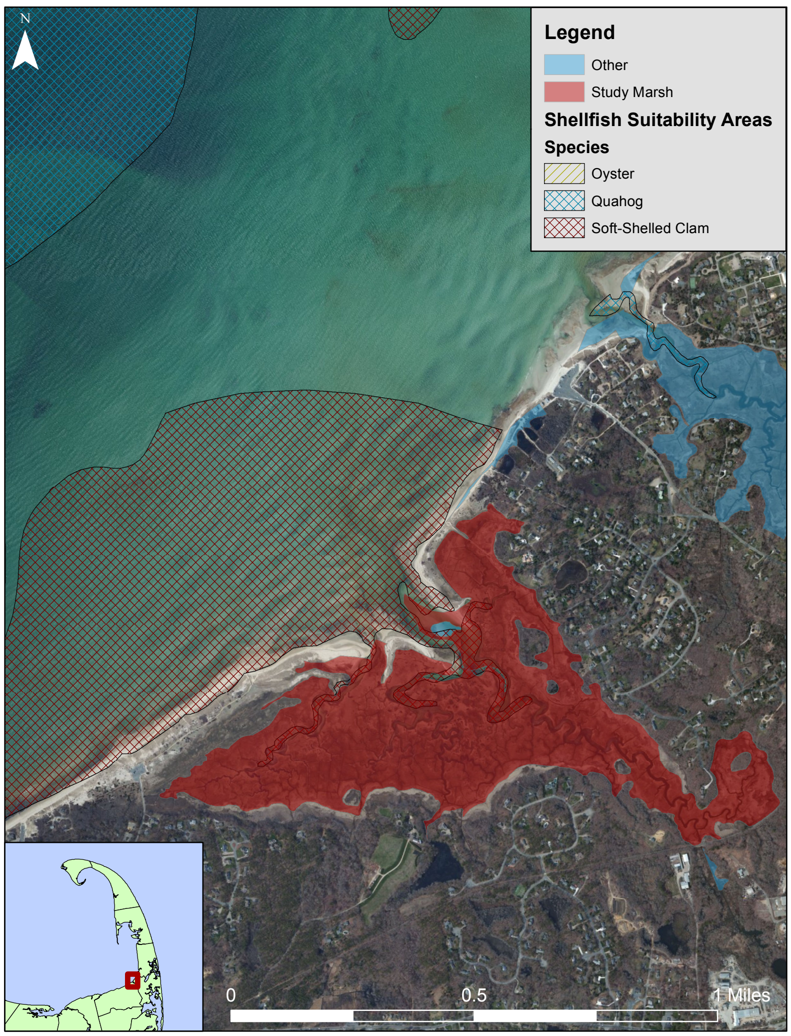

Figure 4.1. Map of Namskaket Creek and MassGIS shellfish suitability areas. Data from MassGIS and ESRI basemaps.

4.1.2 Shellfishing Industry

Shellfishing in Orleans is permitted. Permits available for purchase include commercial (sale of shellfish permissible), family (sale of shellfish prohibited), and apprentice (for individuals under the age of 14). Individuals with commercial shellfishing permits are limited to four bushels of quahogs per day and one ten-quart pail-full of oysters per week. Individuals with family shellfishing permits are limited to one ten-quart pail-full of any kind of shellfish per week. Shellfishing in Orleans takes place in the Nauset Estuary, Pleasant Bay Estuary, or Cape Cod Bay. Residents of the neighboring town of Eastham may also obtain a permit in the town of Orleans. (Shellfish Regulations, Orleans Town Code, Chapter 176) In 2013, Orleans issued 177 shellfishing permits. There are currently 22 aquaculture grants in the town (Farber, 2014).

Five shellfishermen were interviewed from Orleans. Of those shellfishermen, all five had commercial permits, with three considering shellfishing as their primary occupation (60%). Approximately 60% of shellfishermen interviewed harvested soft-shelled clams, 80% harvested quahogs, and 20% harvested oysters. Shellfishermen interviewed have a combined 146 years of shellfishing experience, with an average of 29.2 years of experience (individual responses ranged from 10 to 48 years of experience). When asked about trends they have seen, shellfishermen stressed the cyclic nature of harvests and the potential detrimental effects of septic systems on the local estuaries.

4.1.2 Restoration Project: Namskaket Creek

Namskaket Creek marsh is located on the border of Orleans and Brewster (Fig. 3.1). An outdated one-foot culvert was replaced by two larger, side-by-side, box culverts in January 2007, allowing for increased infiltration of salt water into the marsh. The Association to Preserve Cape Cod (APCC) monitored the marsh for one year before restoration and five years after restoration. Major challenges to the restoration project hinged largely on the creek's location between towns. It is in close proximity to the tri-town septic plant (serving Eastham, Orleans, and Brewster). Given its location near the Cape Cod Rail Trail, the MA Department of Conservation and Recreation (DCR) owns the physical restoration site.

Though restoration took place in 2007, the site has yet to reach full restoration potential because the town of Orleans has yet to remove the flashboards originally placed over the culvert. Flashboards are typically used to gradually introduce saltwater into a more freshwater system, but since the flashboards are still present, the potential for increased tidal flow into Namskaket Creek is greatly reduced. Monitoring data shows a steady increase in salinity since the time of restoration, but marsh experts stress that a far more dramatic and ecologically-effective salinity change would greatly increase the restoration's project ecological success. In 2012, porewater salinity of the study site was 15.4 ppt, whereas the porewater salinity of the unrestricted reference site was 28.9 ppt (Fig. 4.2).

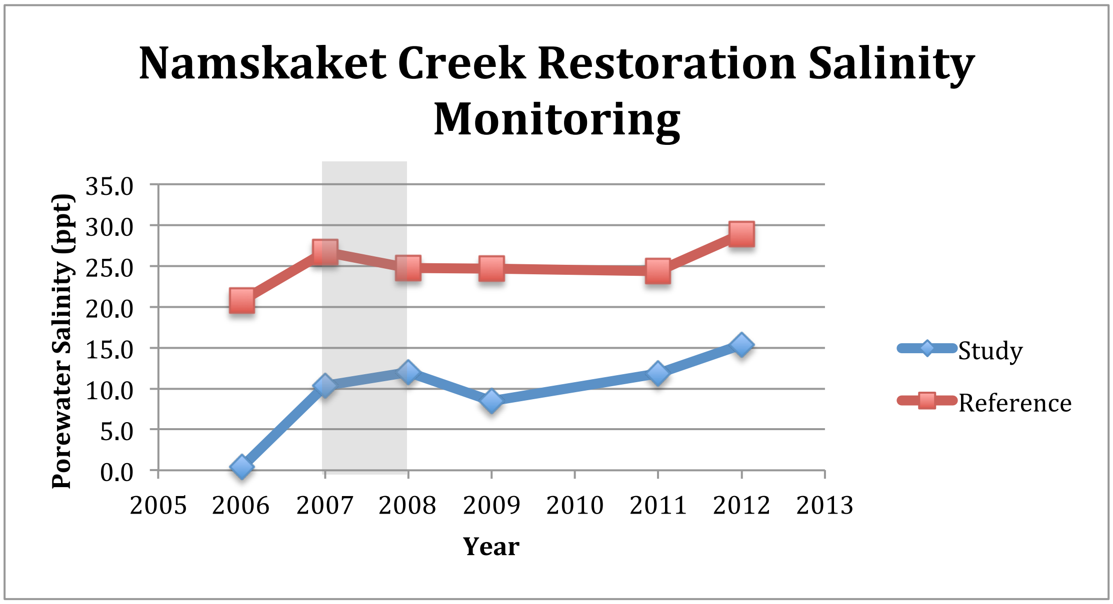

Figure 4.2. Porewater salinity monitoring for Namskaket Creek. Restoration date is highlighted.

There was no statistically significant difference in shellfish yield of soft-shelled clams and quahogs before and after restoration (Fig. 4.3). There was also no statistically significant difference in shellfish yield of soft-shelled clams and quahogs before and after the 2007 restoration date across all five towns (Fig. 4.24). The Namskaket Creek area is currently closed to shellfishing due to high levels of fecal coliform (Farber, 2013).

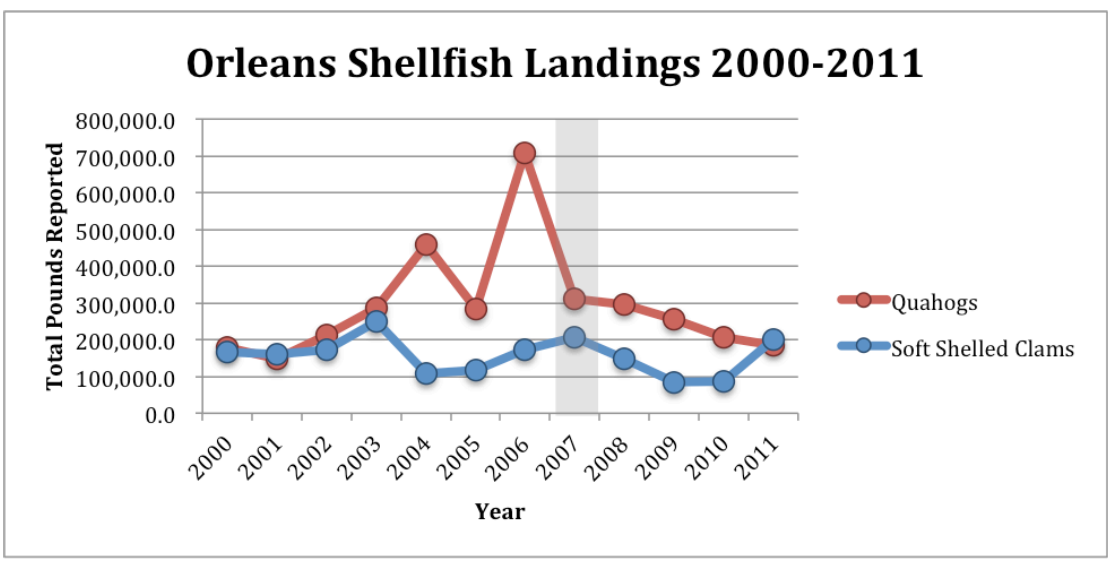

Figure 4.3. Shellfishing landings in Orleans from 2000-2011. Restoration date is highlighted.

Of the social success parameters determined by Hopfensperger et al. (2006), the Namskaket Creek restoration project scored 11/16 (Fig. 4.13). Experts identified the criteria for the decision-making process as including collection of scientific information, collaboration with stakeholders, modeling of scenarios for feasibility, preparing an environmental assessment, and ensuring that the site met the needs of the mitigation project. Criteria for disagreement resolution included meetings, discussions, and compromises. Group dynamics in the process included dynamics that were both cooperative and resistant, involved mutual interests, involved trade-offs, involved public concern, and involved differences in philosophy. Though the marsh has yet to reach its full restoration potential, interviews with experts revealed that the incredibly visible location of the marsh on the Cape Cod Rail Trail lends to a large amount of social support.

Of the shellfishermen from Orleans interviewed (n=5) regarding their experiences, 80% had a positive general opinion about salt marsh restoration, and 20% had a neutral general opinion about salt marsh restoration. There were no negative general opinions about salt marsh restoration. When asked if familiar with the Namskaket Creek restoration project, 20% responded yes, 20% responded no, and 60% were somewhat familiar with the project. Of those who were familiar with the project, 67% had a positive opinion of the restoration, and 33% had a neutral opinion of the restoration. No shellfishermen interviewed noticed an increase in shellfish yield after restoration. This is consistent with the shellfish landing data in the town of Orleans (Fig. 4.3).

4.2 Eastham

Eastham, MA, is a 25.7 square-mile, 4,956-individual town located between Orleans and Wellfleet, with 104 commercial shellfishing permits issued in 2013. Of the 25.7 square miles, 14.0 square miles are land and 11.7 square miles are water (US Census; Fig. 4.4).

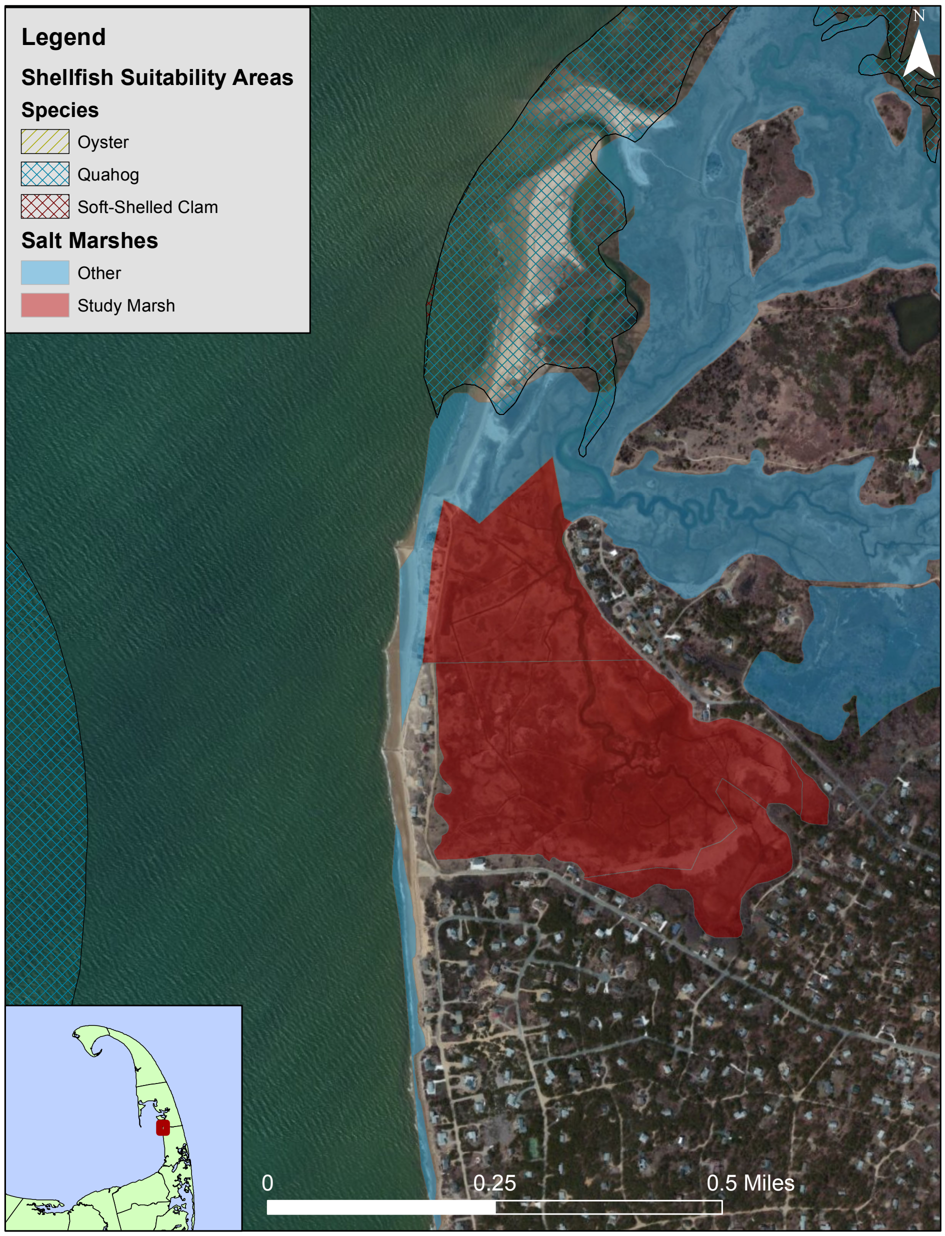

Figure 4.4. Map of Sunken Meadow and MassGIS shellfish suitability areas. Data from MassGIS and ESRI basemaps.

4.2.1 Shellfishing Industry

Shellfishing in Eastham is permitted. Permits available for purchase include commercial (sale of shellfish permissible), family (sale of shellfish prohibited), and apprentice (for individuals under the age of 14). Permits are also classified by taxpayer/renter status, and senior citizen status. Individuals with commercial shellfishing permits are limited to four bushels of quahogs per day. Individuals with family shellfishing permits are limited to one ten-quart pail-full of any kind of shellfish per week. Shellfishing in Eastham takes place in the Nauset Estuary and Cape Cod Bay. Residents of the neighboring town of Orleans may also obtain a permit in the town of Eastham. (Town of Eastham, Shellfish Regulations and Fees and Catch Limits) In 2013, Eastham issued 104 commercial shellfishing permits.

Six shellfishermen were interviewed from Eastham. Of those shellfishermen, five fished for profit (83%) and two fished for recreation (33%), with three considering shellfishing as their primary occupation (50%). Approximately 50% of shellfishermen interviewed harvested soft-shelled clams, 83% harvested quahogs, and 33% harvested oysters. Shellfishermen interviewed had a combined 132 years of shellfishing experience, with an average of 22 years of experience (individual responses ranged from 6 to 37 years of experience). When asked about trends they have seen, shellfishermen stressed the importance of seeding shellfishing areas to maintain quahog populations. Several asserted that harvests were generally “not as good as they used to be.” Unfortunately, lack of consistent shellfish harvest data in Eastham since 2005 prevents quantification of this claim.

4.2.2 Restoration Project: Sunken Meadow Marsh

The Sunken Meadow restoration was a relatively small project (11.5 acres) completed in 2011. The project consisted largely of the removal of 610 feet of an earthen berm and a pipe culvert to restore sheet flow to the area. Monitoring by the APCC took place for one year before and after the restoration. The major challenge to the restoration project was the timeline required to complete the project. Funding from the Estuary Restoration Act (ERA) became available for a short time in 2009-2010, and the project had to be completed before the funding expired. The project was slated to be completed between the last snowfall and the spring high tide due to construction constraints, further tightening the timeframe. Average salinity increased after the restoration was implemented (15.8 ppt pre-restoration to 18.3 ppt post-restoration in combined pore and surface waters; Fig. 4.5), though monitoring data is limited. Experts in the project, however, cited the colonization of *Spartina* as a major indicator of the ecologic success of the project. Given limited shellfish landing data for this timeframe, differences in shellfish yield before and after the restoration project could not be established. The restoration area is currently closed to shellfishing due to consistently high levels of fecal coliform.

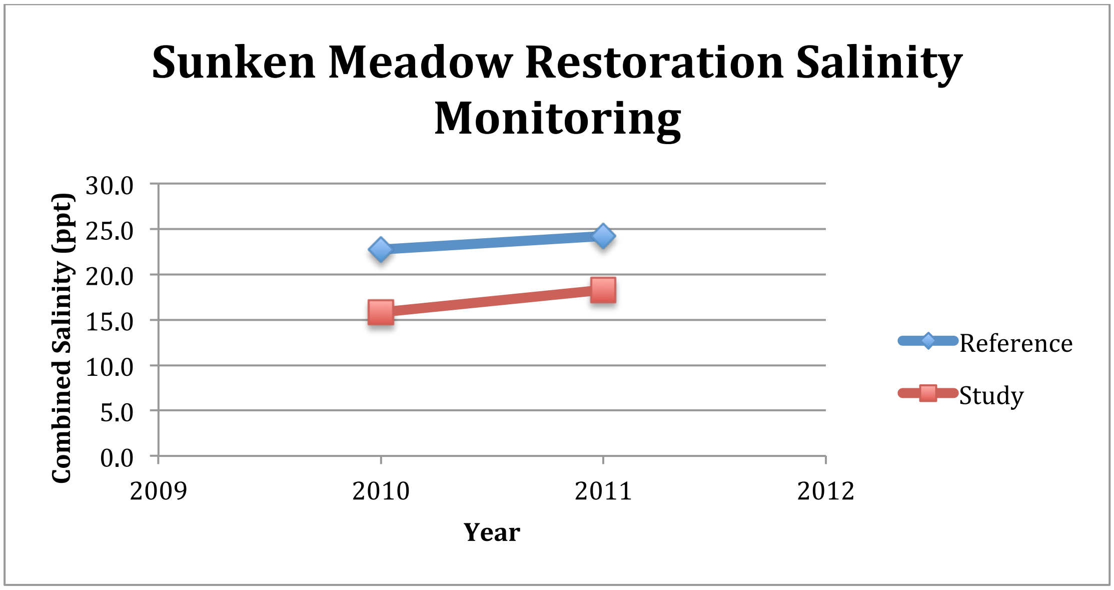

Figure 4.5. Combined salinity monitoring for Sunken Meadow.

Of the social success parameters determined by Hopfensperger et al. (2006), the Sunken Meadow restoration project scored 14/16. Experts identified the criteria for the decision-making process as including collection of scientific information, collaboration with stakeholders, modeling of scenarios for feasibility, preparing an environmental assessment, and ensuring that the site met the needs of the mitigation project. Criteria for disagreement resolution included meetings, discussions, and compromises. Group dynamics in the process included dynamics that were cooperative, involved mutual interests, and involved trade-offs. Since the restoration site was located on private property, and the two local abutters were highly cooperative, the project ran smoothly. The restoration was under budget and finished before the deadline of the spring high tide.

Of the shellfishermen from Eastham interviewed regarding their experiences (N=6), 83% had a positive general opinion about salt marsh restoration, and 17% had a neutral general opinion about salt marsh restoration. There were no negative general opinions about salt marsh restoration. When asked if familiar with the Sunken

Meadow restoration project, 17% responded yes, 66% responded no, and 17% were somewhat familiar with the project. No shellfishermen interviewed noticed an increase in shellfish yield after restoration.

4.3 Wellfleet

Wellfleet, MA, is a 35.4 square-mile, 2,750-individual town located between Eastham and Truro, with 215 commercial shellfishermen in 2013. Of the 35.4 square miles, 19.8 square miles are land and 15.6 square miles are water (US Census; Fig. 4.6).

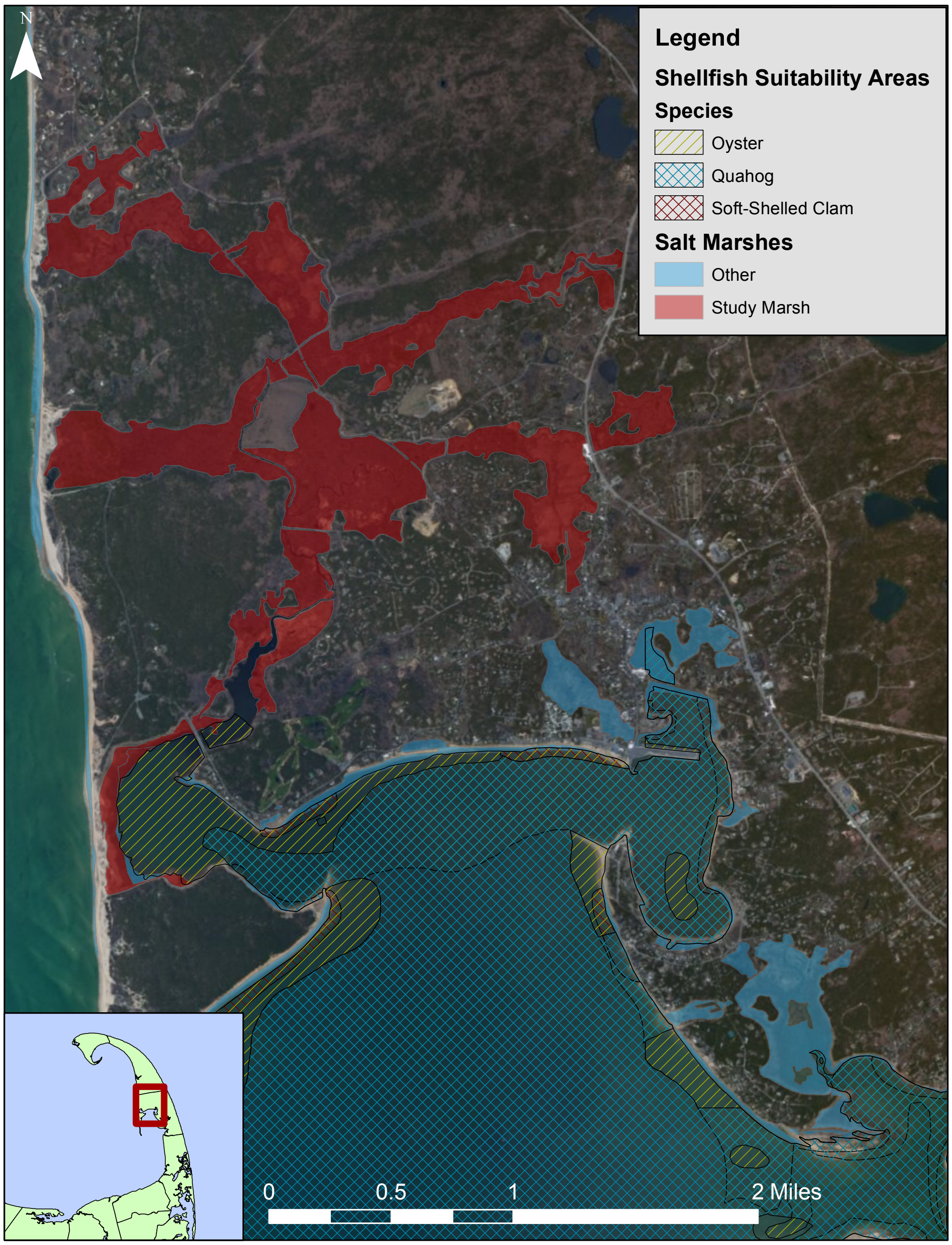

Figure 4.6. Map of Herring River and MassGIS shellfish suitability areas. Data from MassGIS and ESRI basemaps.

4.3.1 Shellfishing Industry

Shellfishing in Wellfleet is permitted. Permits available for purchase include commercial (sale of shellfish permissible) and noncommercial (sale of shellfish prohibited). Permits are differentiated by age (over 65, under 65, aged 14-16) and taxpayer/resident status. Individuals with commercial shellfishing permits are limited to five bushels of oysters, five bushels of quahogs, and three bushels of soft-shell clams per day. If dredging, shellfishermen are limited to five bushels of oysters per permit aboard the vessel with a maximum of ten bushels per day, and fifteen bushels of oysters per permit aboard the vessel with a maximum of twenty-five bushels per day. Individuals with noncommercial shellfishing permits are limited to one ten-quart pail-full of oysters, quahogs, and soft-shelled clams per week. Commercial shellfishing is conditionally and seasonally permitted in Chipman's Cove, Duck Creek, Herring River, West Side, Egg Island, Blackfish Creek, and South Lieutenant Island. Noncommercial shellfishing is conditionally and seasonally permitted in Chipman's Cove, Indian Neck, and the rest of Wellfleet Harbor not explicitly designated for commercial use. (Town of Wellfleet Shellfishing Policy and Regulations)

Wellfleet is unique from the other four towns studied due to its large reliance on aquaculture to produce the fabled "Wellfleet oyster," a variety of oyster lauded in the town's yearly Oysterfest. The Wellfleet Oysterfest takes place annually in the third week of October and has attracted more than 25,000 people in a single weekend (Bragg 2013). In 2013, the town issued approximately 215 commercial shellfishing permits and licensed about 210 acres for shellfish aquaculture (Bragg 2014).

Sixteen shellfishermen were interviewed from Wellfleet. Of those shellfishermen, nine fished for profit (56%) and twelve fished for recreation (75%), with three considering shellfishing as their primary occupation (19%). Approximately 19% of shellfishermen interviewed harvested soft-shelled clams, 63% harvested quahogs, and 75% harvested oysters. Shellfishermen interviewed had a combined 452 years of shellfishing experience, with an average of 28 years of experience (individual responses ranged from 3 to 65 years of experience). When asked about trends they have seen, shellfishermen stressed the important impact of aquaculture grants on wild harvest—aquaculture grants often provide seed and nutrients to the surrounding waters, but they may also transmit various shellfish diseases.

4.3.2 Restoration Project: Herring River

The Herring River Restoration Project in Wellfleet was first proposed in 2007, after extensive assessment of the impacts of diking the river a century ago. The Herring River in its natural state ran from north Wellfleet to south Truro and was bordered by approximately 1,100 acres of coastal wetlands, including extensive salt marsh habitats (HRCRP, 2007). The river was diked in 1909 at Chequessett Neck and subsequently ditched to drain the wetlands for mosquito control. The dike contains three large culverts, two that block seawater inflow while allowing drainage and one that allows minimal seawater inflow (HRCRP, 2007). In the 100 years since the diking of the Herring River, the drained lands on the original coastal floodplain have become developable. These lands include some public and private roads, private residences, and the Chequessett Yacht and Country Club (HRCRP, 2007). There is concern that the restoration of the Herring River will inundate the original coastal floodplain, potentially compromising four roads, the well-water supplies of five houses, and parts of the Chequessett Yacht and Country Club (HRCRP, 2007).

Of the social success parameters determined by Hopfensperger et al. (2006), the Herring River restoration project scores 12/16. Though the restoration has not yet occurred physically, a variety of parameters for social success are already in place. Restoration is a lengthy process, and many of the decision-making processes and disagreement resolutions have already occurred. Criteria for the decision-making process includes collection of scientific information, collaboration with stakeholders, modeling of scenarios for feasibility, preparing an environmental assessment, ensuring that the site meets the needs of the mitigation project, and addressing the concerns of local businesses. Experts identified the criteria for disagreement resolution as including meetings, discussions, compromises, and mediating agencies. Group dynamics in the process includes dynamics that are both cooperative and resistant, involve mutual interests, involve trade-offs, involve public concern and opposition, involve differences in philosophy, and involve the use of a mediator.

The Herring River has been on public radar since several fish and eel kills took place in the 1980s. Though the restoration project was originally met with opposition, there is now generally more board support for the project, with an anticipated start date for restoration construction in 2016. Pre- and post-monitoring, evaluation, and management have been established for the project, including salinity monitoring by the APCC from 2006-2009.

Of the shellfishermen from Wellfleet interviewed regarding their experiences (N=16), 81% had a positive general opinion about salt marsh restoration, and 19% had a neutral general opinion about salt marsh restoration. There were no negative general opinions about salt marsh restoration. When asked if familiar with the Herring River restoration project, 100% responded that they were at least somewhat familiar with the project. When asked their opinions of the specific restoration project, 56% of shellfishermen interviewed had a positive opinion, 13% had a neutral opinion, and 31% expressed a positive opinion with reservations.

4.4 Truro

Truro, MA, is a 26.3 square-mile, 2,003-individual town located between Wellfleet and Provincetown, with 136 shellfishermen in 2013. Of the 26.3 square miles, 21.1 square miles are land and 5.3 square miles are water (US Census; Jackett, 2014; Fig. 4.7).

Figure 4.7. Map of East Harbor and MassGIS shellfish suitability areas. Data from MassGIS and ESRI basemaps.

4.4.1 Shellfishing Industry

Shellfishing in Truro is for recreation only. Permits are available for purchase, classified by taxpayer/resident status and senior citizen status. Residents aged 59 or older can obtain a free lifetime shellfishing permit. Individuals with permits are limited to one ten-quart pail-full of oysters, quahogs, and soft-shelled clams per day, with a limit of five quarts of oysters. Shellfishing in Truro is permitted westward from Pamet Harbor to Cape Cod Bay. (Town of Truro, Regulation for the Taking of Shellfish) In 2013, the town of Truro issued 136 shellfishing permits. The town has six aquaculture grants covering 17 acres (Jackett, 2014).

Four shellfishermen were interviewed from Truro. Of those shellfishermen, all fished for recreation. Approximately 75% of shellfishermen interviewed harvested soft-shelled clams, 100% harvested quahogs, and 100% harvested oysters. Shellfishermen interviewed had a combined 35 years of shellfishing experience, with an average of 9 years of experience (individual responses ranged from 2 to 25 years of experience). When asked about trends they have seen, shellfishermen stressed the importance of seeding the stock, whether intentionally by the shellfish constable or unintentionally from aquaculture grants.

4.4.2 Restoration Project: East Harbor

The East Harbor marsh in Truro is located primarily on land owned by the Cape Cod National Seashore. Originally diked in 1868 to prevent sand from filling Provincetown Harbor, the 720-acre marsh employed a small drainage system by 1894. A culvert and tide-gate system was built in 1956 to lower the water level in an attempt to reduce mosquito population. In 2001, oxygen depletion caused a major fish kill of approximately 40,000 alewives and hundreds of perch. This prompted the National Park Service (NPS) and the town to explore options for restoration (Portnoy et al., 2005). Culvert valves were experimentally opened and closed over the next two years to allow for infiltration of salt water, with monitoring consistently from 2002. Increased salinity caused another fish kill of predominantly freshwater species, and there was increased concern over high levels of fecal coliform at local bathing beaches. In response, the valves were closed again to decrease salinity enough for the spawning of river herring. The closing of the valves often led to algal blooms and midge hatches, prompting the NPS to keep the valves open since November 2002.

Of the social success parameters determined by Hopfensperger et al. (2006), the East Harbor restoration project scored 12/16. Experts identified the criteria for the decision-making process as including collection of scientific information, collaboration with stakeholders, modeling of scenarios for feasibility, preparing an environmental assessment, ensuring that the site met the needs of the mitigation project, and addressing the concerns of local businesses. Criteria for disagreement resolution included meetings, discussions, compromises, and mediating agencies. Group dynamics in the process included dynamics that were both cooperative and resistant, involved mutual interests, involved trade-offs, involved public concern and opposition, involved differences in philosophy, and involved the use of a mediator.

The East Harbor restoration project was not considered wholly successful, since the fish kills, midge hatches, algal blooms, and high bacteria levels generated significant social resistance in a town known for its pristine beaches. Though the culvert is large enough to increase the salinity in East Harbor, tidal flushing is not at an ideal level. Experts assert that a larger culvert would allow for increased tidal range, further increasing the ecological benefits of the restoration (Portnoy, 2013). Interestingly, however, thousands of bivalves, including quahogs and soft-shelled clams, had colonized East Harbor within two years of the culvert remaining open (Portnoy et al., 2005). Overall shellfish harvest in the town of Truro, however, does not reflect this finding (Fig. 4.8). There was no significant difference in harvest of soft-shell clams before or after restoration. Quahog harvest, however, was significantly lower after restoration than before restoration (t_{17}=0.0034, p = 0.0017).

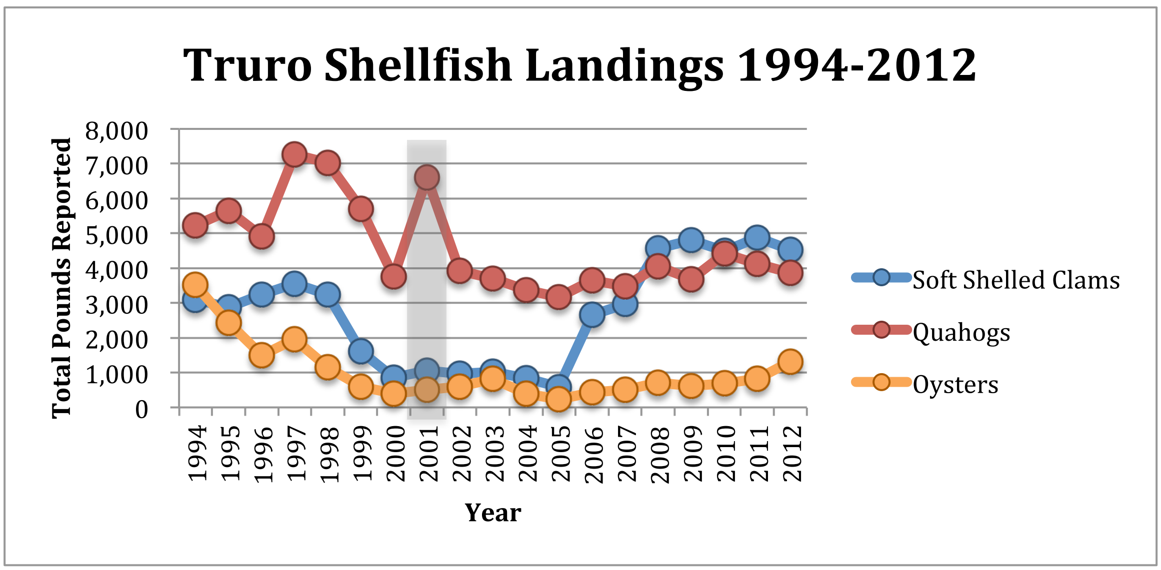

Figure 4.8. Shellfish landings in Truro from 1994-2012. Restoration date is highlighted.

Shellfish yield across the five towns did show a change in both soft shell clam and quahog harvest before and after the restoration in 2001 (Fig. 4.24). There were significantly lower harvests of both species after restoration ($p < 0.001$ in both cases).

Salinity has increased steadily over the course of the restoration (Fig. 4.9), and levels remain high today (~25 ppt average porewater salinity from 2005-2009; Portnoy et al., 2009). Shellfishing is not currently permitted in East Harbor, since the Cape

Cod National Seashore protects a majority of the land. An oyster grant is present off the shore of East Harbor.

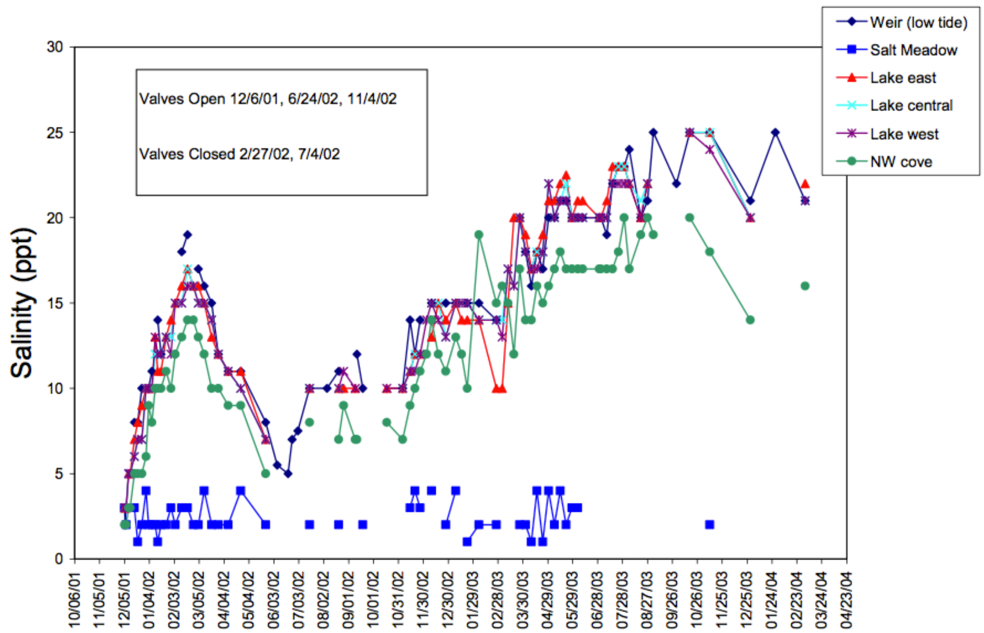

Figure 4.9. Salinity monitoring of East Harbor. From Portnoy et al. (2005).

Of the shellfishermen from Truro interviewed regarding their experiences (N=4), all positive general opinion about salt marsh restoration. When asked if familiar with the East Harbor restoration project, 75% responded yes and 25% responded no. Of those familiar with the restoration, all of shellfishermen had a positive opinion about the project. Two of the shellfishermen interviewed noticed an increase in shellfish yield after restoration, both citing the increase of bivalves in East Harbor post restoration.

4.5 Provincetown

Provincetown, MA, is a 17.5-square-mile, 2,942-individual town located at the northernmost tip of Cape Cod, with 192 shellfishermen in 2013. Of the 17.5 square miles, 9.7 square miles are land and 7.8 square miles are water (US Census; Jackett, 2014; Fig. 4.10).

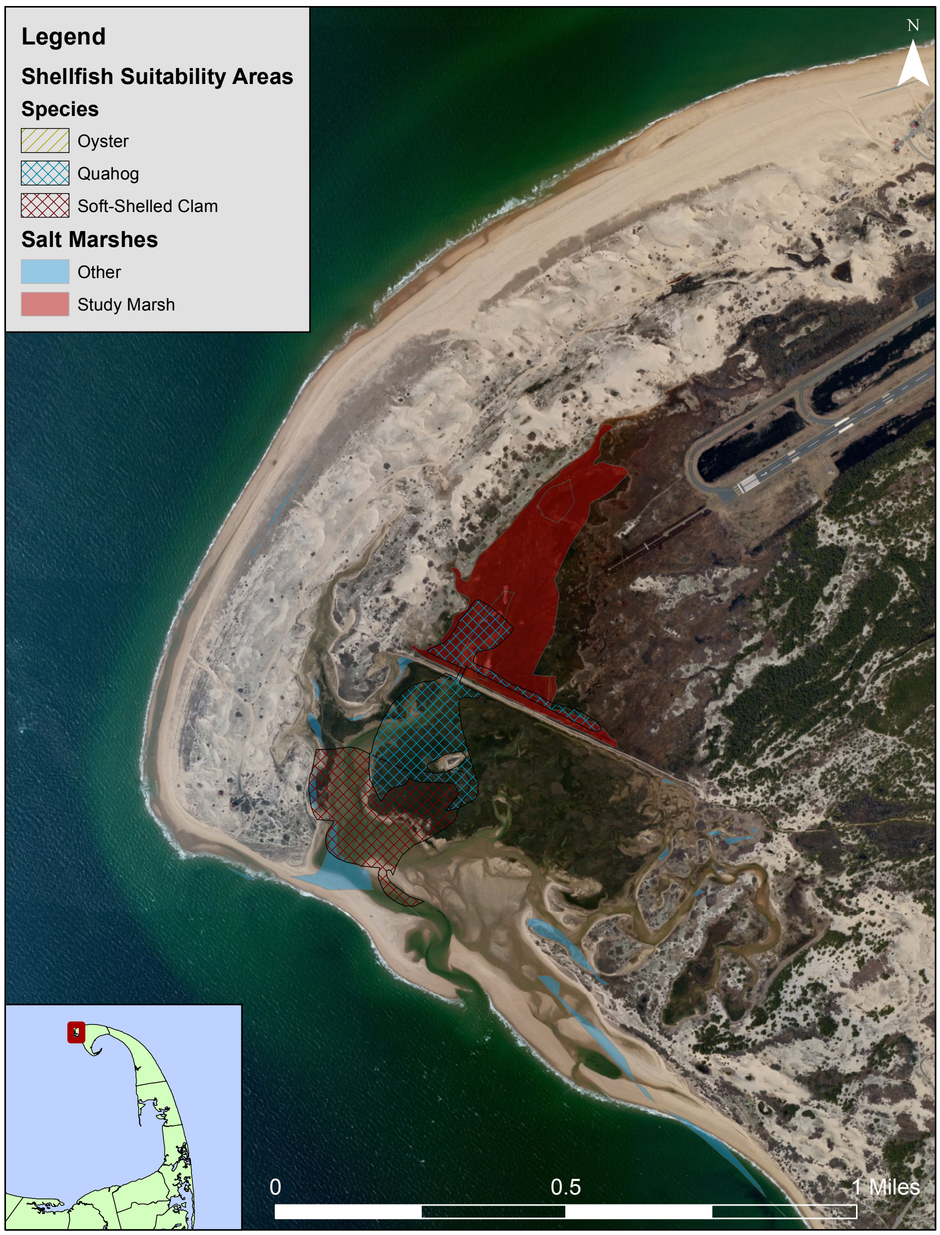

Figure 4.10. Map of Hatches Harbor and MassGIS shellfish suitability areas. Data from MassGIS and ESRI basemaps.

4.5.1 Shellfishing Industry

Shellfishing in Provincetown is for recreation only. Permits are available for purchase, classified by taxpayer/resident status and senior citizen status. Residents aged 59 or older can obtain a free lifetime shellfishing permit. Shellfish may only be harvested once a week, on Friday or Sunday. Individuals with permits are limited to one ten-quart pail-full of oysters, quahogs, and soft-shelled clams per week. Shellfishing in Provincetown is permitted in Hatches Harbor, the West End, the East End, and east and west of the Provincetown Breakwater. (Provincetown Shellfishing Regulations) There were 192 permits issued in 2013, and nine current aquaculture grants, totaling nine acres (Jackett, 2014).

Eleven shellfishermen were interviewed from Provincetown. Of those shellfishermen, all fished for recreation. Approximately 27% of shellfishermen interviewed harvested soft-shelled clams, 55% harvested quahogs, and 18% harvested oysters. Shellfishermen interviewed had a combined 461 years of shellfishing experience, with an average of 42 years of experience (individual responses ranged from 2 to 84 years of experience). As in Truro, when asked about trends they have seen, shellfishermen stressed the importance of seeding the stock, whether intentionally by the shellfish constable or unintentionally from aquaculture grants. Shellfishermen also asserted that more people are shellfishing now than ten years ago.

4.5.2 Restoration Project: Hatches Harbor

The Hatches Harbor marsh is a 420-acre salt marsh located at the northernmost tip of Cape Cod. The marsh was diked in 1930 as a means of mosquito control and later as protection against flooding of an airport constructed in the 1940s. By 1986, a need to rebuild the dike to continue to protect the Provincetown Airport prompted officials to consider implementing a restoration project (Portnoy et al., 2003). Negotiation and research took eleven years, as pre-restoration monitoring began in 1997, and a series of four culverts with a wide, low opening (8.5 meters by 1 meter) were constructed by 1999. The culverts were opened incrementally after their construction as to assuage stakeholder concerns, with all four culverts open by October 2003 (Portnoy et al., 2003). The project has also employed many years of a variety of post-restoration monitoring of salinity, tidal height, sediment elevation, vegetation, and nekton. Scientists found increased salinity and tidal height post-restoration, but no significant change in nekton density (Portnoy et al., 2003). Overall *Phragmites australis* biomass decreased significantly post-restoration, indicating a reduction in unfavorable vegetation (Portnoy et al., 2003). Shellfish populations were not assessed in the annual reports from the NPS.

Of the social success parameters determined by Hopfensperger et al. (2006), the Hatches Harbor restoration project scored 12/16. Experts identified the criteria for the decision-making process as including collection of scientific information, collaboration with stakeholders, modeling of scenarios for feasibility, preparing an environmental assessment, ensuring that the site met the needs of the mitigation project, and addressing the concerns of local businesses. Criteria for disagreement resolution included meetings, discussions, compromises, and mediating agencies. Group dynamics in the process included dynamics that were both cooperative and resistant, involved mutual interests, involved trade-offs, involved public concern and opposition, involved differences in philosophy, and involved the use of a mediator.

The Hatches Harbor restoration project was generally considered successful, even earning the title of “the Hatches Harbor prototype” for estuarine habitat restoration (Portnoy et al., 2003). Marsh managers attribute the success largely to stakeholder education and Hatches Harbor’s remote location (Portnoy, 2013). Monitoring data show a steady increase in salinity since the time of restoration (Fig. 4.11).

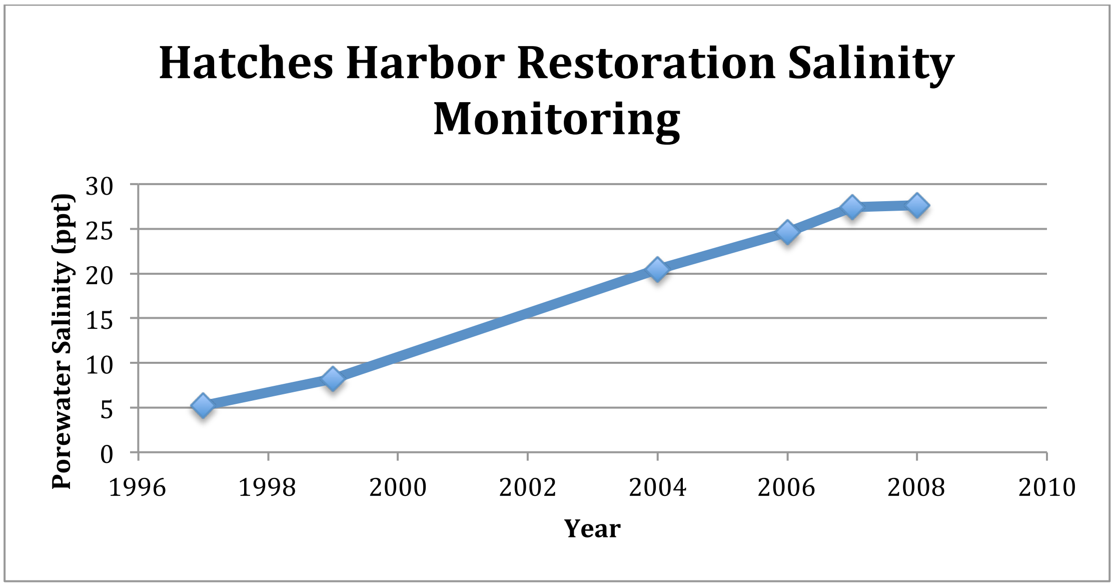

Figure 4.11. Salinity monitoring of Hatches Harbor.

Overall shellfish harvest in the town of Provincetown, however, does not reflect this success (Fig. 4.12). There was no significant difference in harvest of quahogs before, during, or after restoration. Soft-shell clam harvest, however, was significantly lower during and after restoration than before restoration ($F(2, 40)=25.01$, $p < 0.001$). Shellfish yield across the five towns showed no significant difference in soft-shell clam harvest over the course of restoration, but quahog harvest was significantly lower during and after restoration than before restoration ($F(2,40)=6.08$, $p=0.005$) (Fig. 4.24).

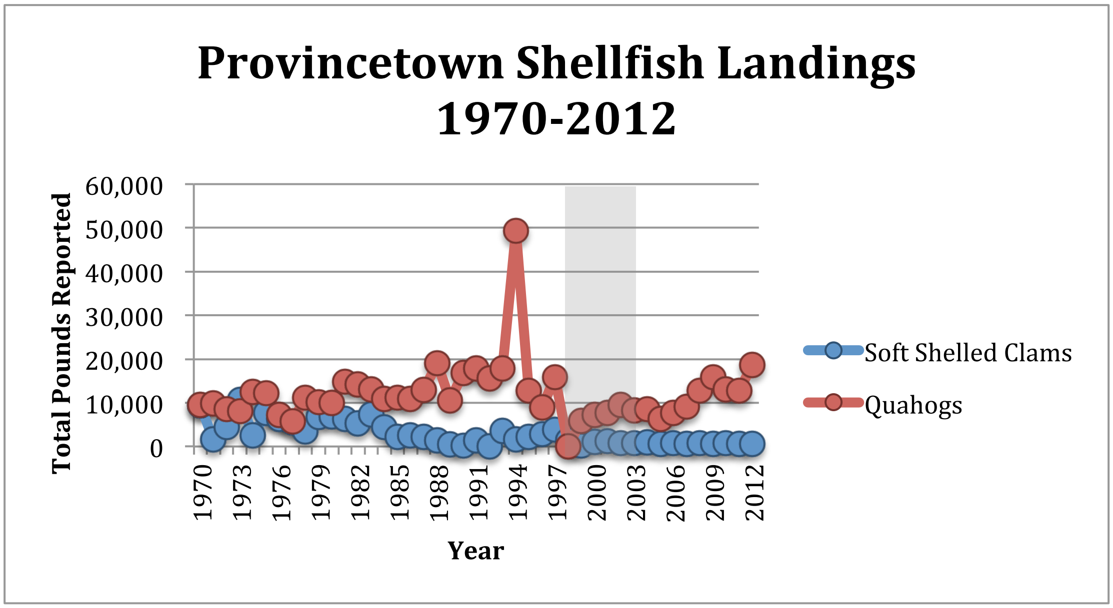

Figure 4.12. Shellfish harvest in Provincetown before and after restoration of Hatches Harbor. Restoration time frame is highlighted.

Of the shellfishermen from Provincetown interviewed regarding their experiences (N=11), 82% had a positive general opinion about salt marsh restoration, and 18% had a neutral general opinion about salt marsh restoration. There were no negative general opinions about salt marsh restoration. When asked if familiar with the Hatches Harbor restoration project, 64% responded yes, 27% responded no, and 9% were somewhat familiar with the project. Of those familiar with the restoration, 67% of shellfishermen had a positive opinion about the project, 22% had a neutral opinion about the project, and 11% had a negative opinion about the project. Four of the shellfishermen interviewed noticed an increase in shellfish yield after restoration.

4.6 Summary

4.6.1 Marsh Social Success Scores

Namskaket Creek in Orleans, MA, scored lowest in social success per Hopfensperger et al. (2006) framework (11/16), whereas Sunken Meadow in Eastham, MA, scored highest in social success (14/16) (Fig. 4.13). Restoration projects ranked generally equally across criteria for the decision making process and in disagreement resolution, but the group dynamics in each restoration process varied greatly (Table 4.1).

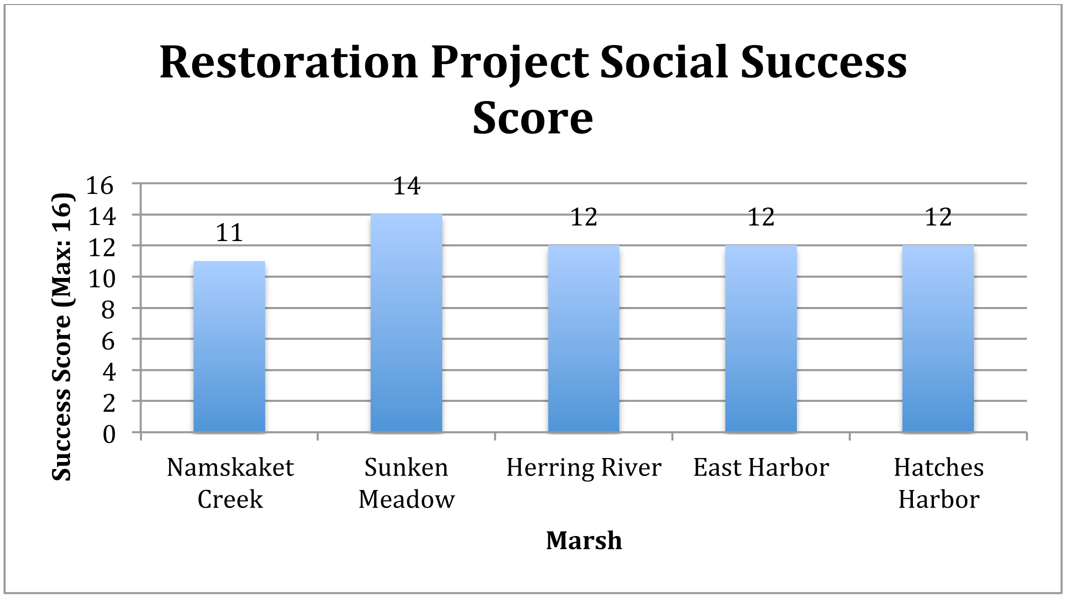

Figure 4.13. Social success scores of the study marshes, per expert interviews. Based on Hopfensperger et al. (2006) framework.

Table 4.1 Breakdown of expert responses regarding social success of restoration projects. Framework based on Hopfensperger et al. (2006).

	Namskaket Creek	**Sunken Meadow**	**Herring River**	**East Harbor**	**Hatches Harbor**
CRITERIA FOR DECISION MAKING PROCESS					
Collection of scientific information	Y	Y	Y	Y	Y
Collaboration with stakeholders	Y	Y	Y	Y	Y
Modeling of scenarios for feasibility	Y	Y	Y	Y	Y
Preparing environmental assessment	Y	Y	Y	Y	Y
Ensuring site met needs of mitigation project	Y	Y	Y	Y	Y
Addressing concerns of local businesses	N	N	Y	Y	Y
Score	5	5	6	6	6
DISAGREEMENT RESOLUTION					
Meetings and discussions	Y	Y	Y	Y	Y
Mediating agencies	N	N	Y	Y	Y
Compromises	Y	Y	Y	Y	Y
Score	2	2	3	3	3
GROUP DYNAMICS IN PROCESS					
Cooperative/positive	Y	Y	Y	Y	Y
Not resistant	N	Y	N	N	N
Involving mutual interests	Y	Y	Y	Y	Y
Involving trade offs	Y	Y	Y	Y	Y
Not involving public opposition/concern	N	Y	N	N	N
No need for a mediator	Y	Y	N	N	N
Not involving differences in philosophy	N	Y	N	N	N
Score	4	7	3	3	3
TOTAL SUCCESS SCORE	11	14	12	12	12

4.6.2 Shellfishermen Trends

Shellfishermen were contacted from lists of license holders obtained from town records and town shellfish constables. Shellfishermen were identified using their home phone number when possible, and there was an attempt to contact all identified shellfishermen. Of the 208 shellfishermen identified, 139 were reached, and 42 were interviewed, resulting in a response rate of 30.2% (Table 4.2).

Total Names	Total Number ID'd	Total Reached	Total Interviewed
582	208	139	42
		RESPONSE RATE	30.2%

Table 4.2 Response rate of shellfishermen interviewed.

Of the 42 shellfishermen interviewed, 29 harvest shellfish for recreation and 19 harvest shellfish for profit (Fig. 4.14). Orleans and Eastham had the largest percentage of shellfishermen-for-profit interviewed, whereas shellfishing is only recreational in Truro and Provincetown (Fig. 4.15). Of the 29 shellfishermen who harvest for profit, nine consider shellfishing to be their primary occupation (Fig. 4.16). The majority of commercial shellfishermen interviewed in Eastham and Wellfleet, however, do not consider shellfishing to be their primary occupation (Fig. 4.17).

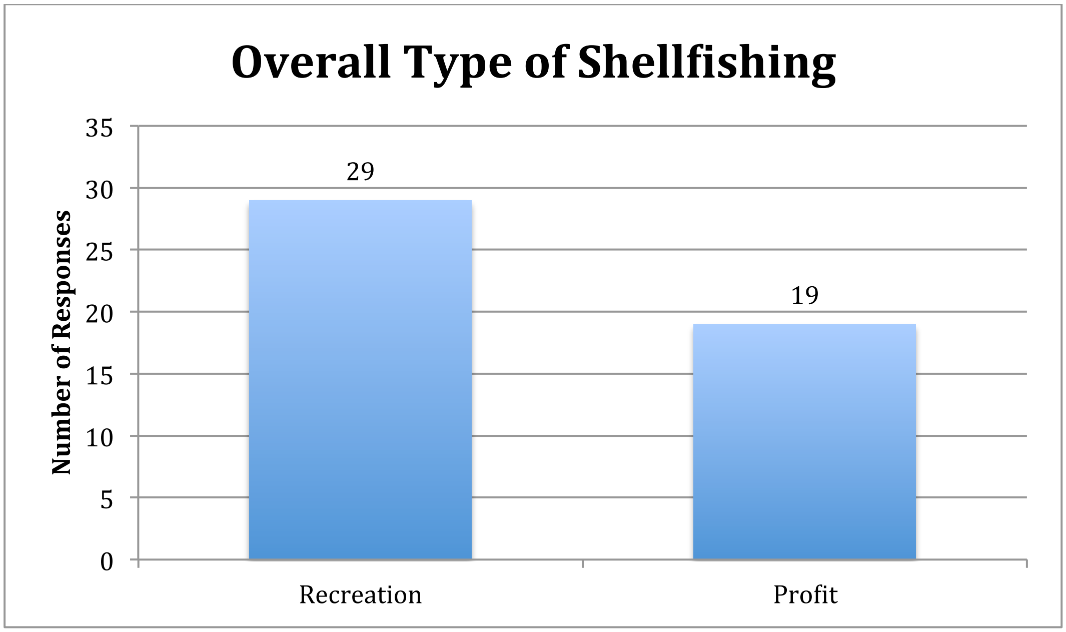

Figure 4.14. Breakdown of shellfishing type for all responses.

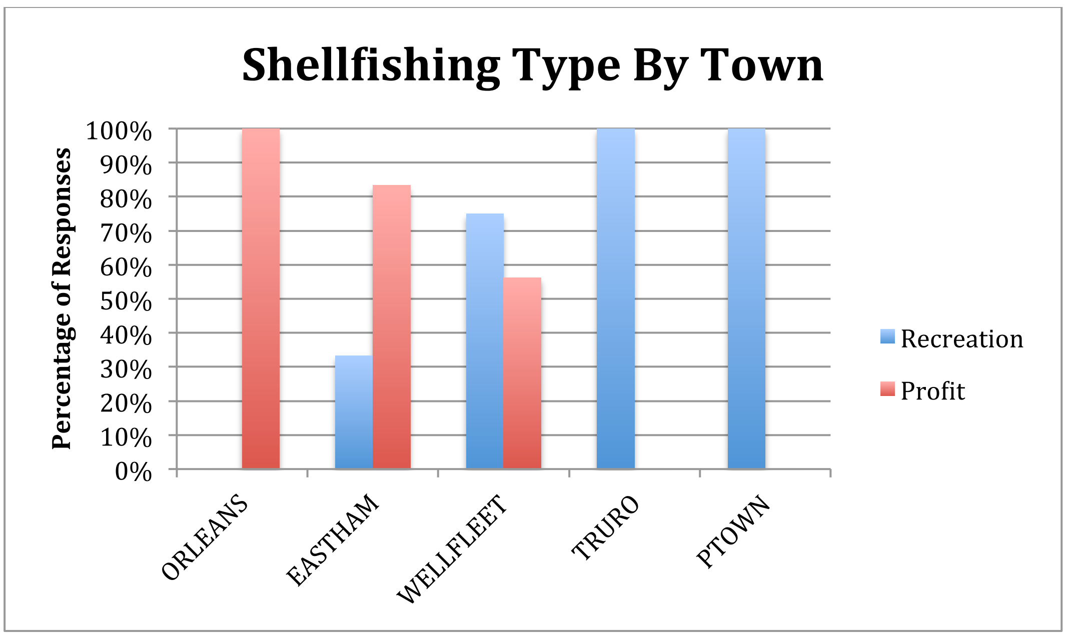

Figure 4.15. Breakdown of shellfishing type by town for all responses.

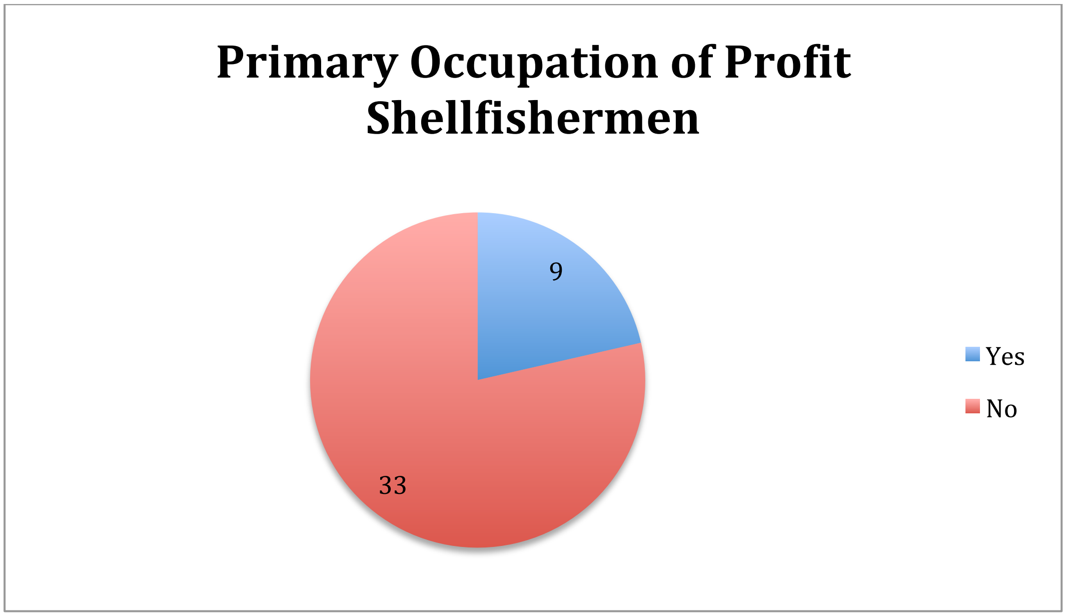

Figure 4.16. Proportion of for-profit shellfishermen who consider it their primary occupation.

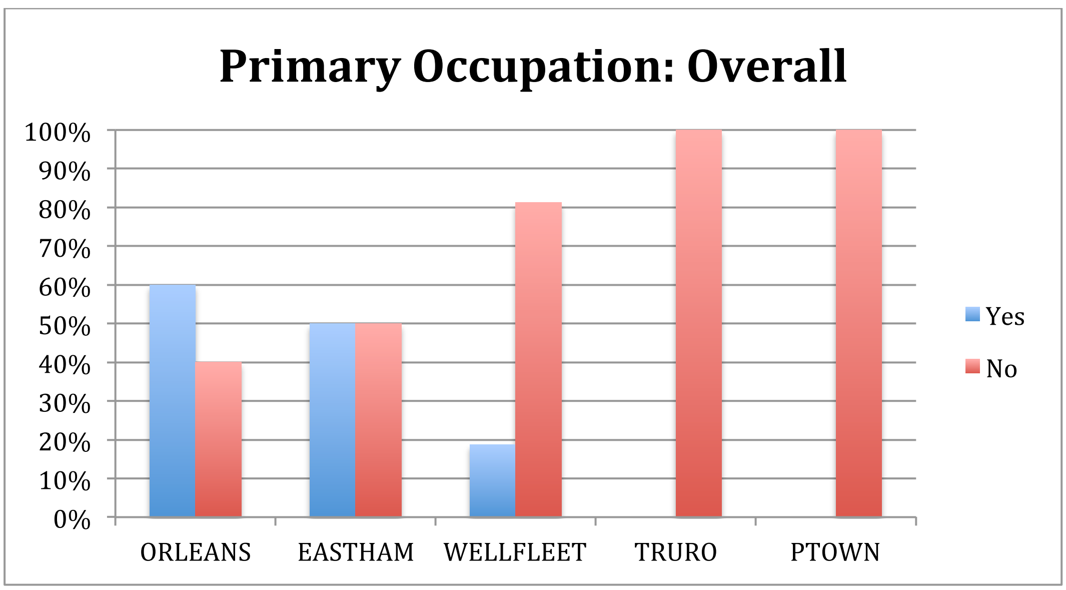

Figure 4.17. Breakdown of primary occupation by town for all responses.

The quahog was the most commonly harvested species in this study (29/42 responses), followed by the oyster (21/42), and the soft-shelled clam (15/42) (Fig. 4.18). The quahog was the most harvested species in all towns but Wellfleet, where the most harvested species was the oyster (75%) (Fig. 4.19).

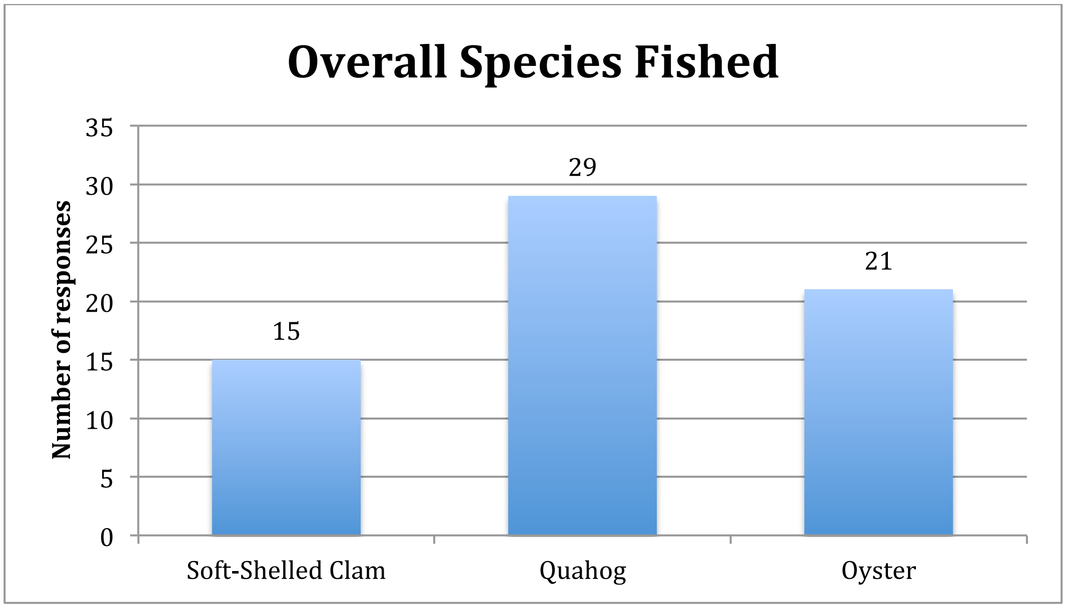

Figure 4.18. Breakdown of species fished for all responses.

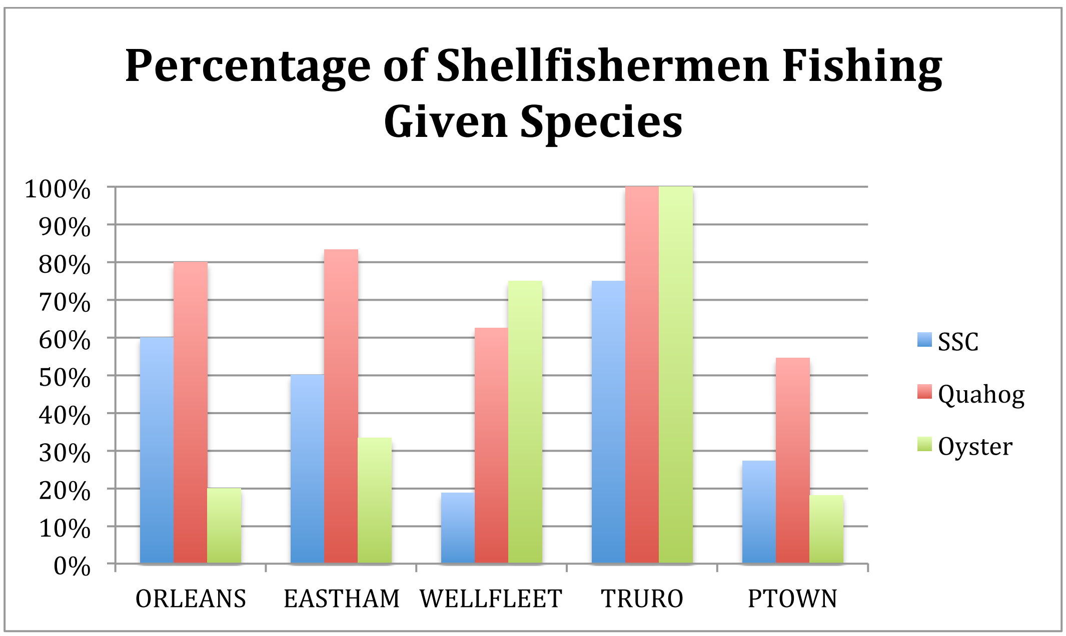

Figure 4.19. Breakdown of species fished by town for all responses.

4.6.3 Shellfishermen Restoration Opinions

Of the 42 shellfishermen interviewed, 35 had a positive opinion about salt marsh restoration and seven had a neutral opinion about salt marsh restoration. No shellfishermen expressed a negative opinion about salt marsh restoration (Fig. 4.20).

In Truro, all shellfishermen interviewed had positive opinions about restoration (Fig. 4.21).

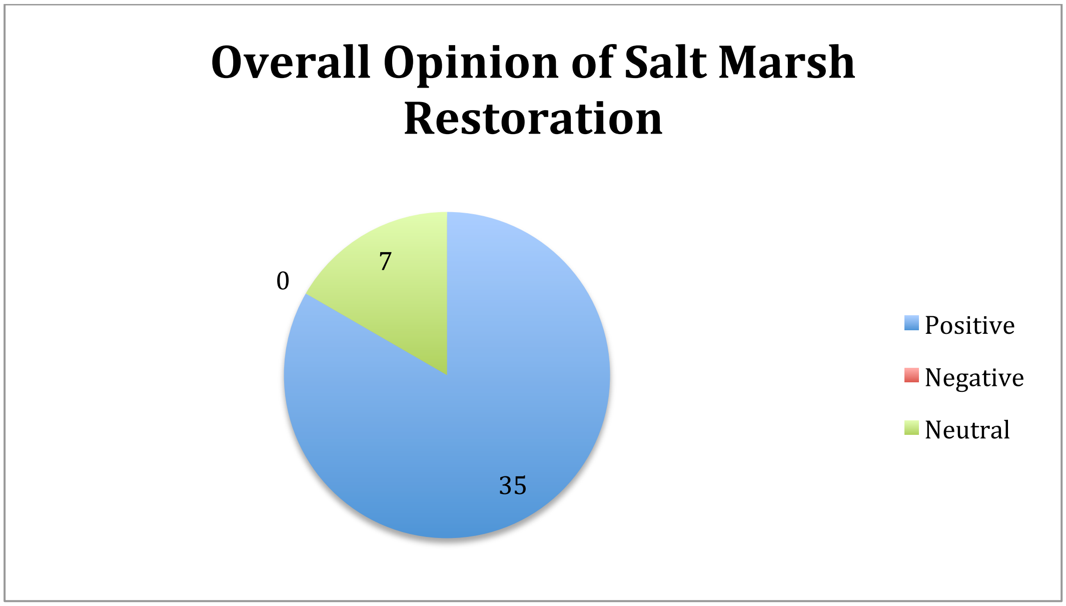

Figure 4.20. Breakdown of shellfisherman opinion of salt marsh restoration.

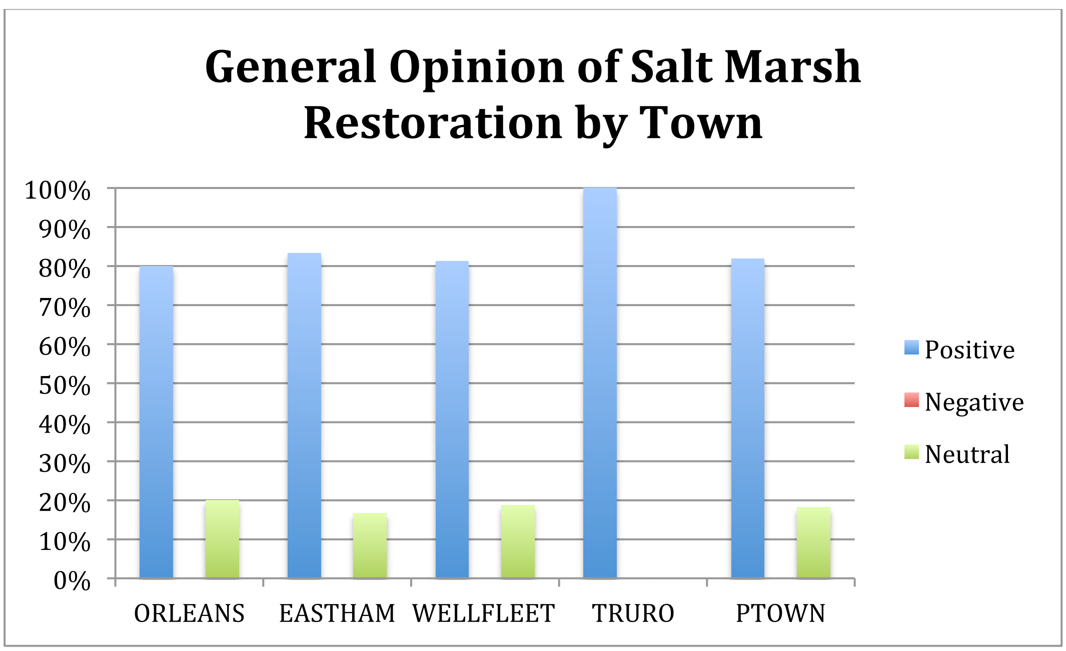

Figure 4.21. Breakdown of shellfisherman opinion of salt marsh restoration by town.

When asked about the study marsh restoration project specific to their town, the response was highly variable by salt marsh. 100% of individuals from Wellfleet were at least somewhat familiar with the large Herring River restoration project, whereas 67% of individuals interviewed in Eastham were not familiar with the smaller Sunken Meadow restoration project (Fig. 4.22; Fig. 4.23).

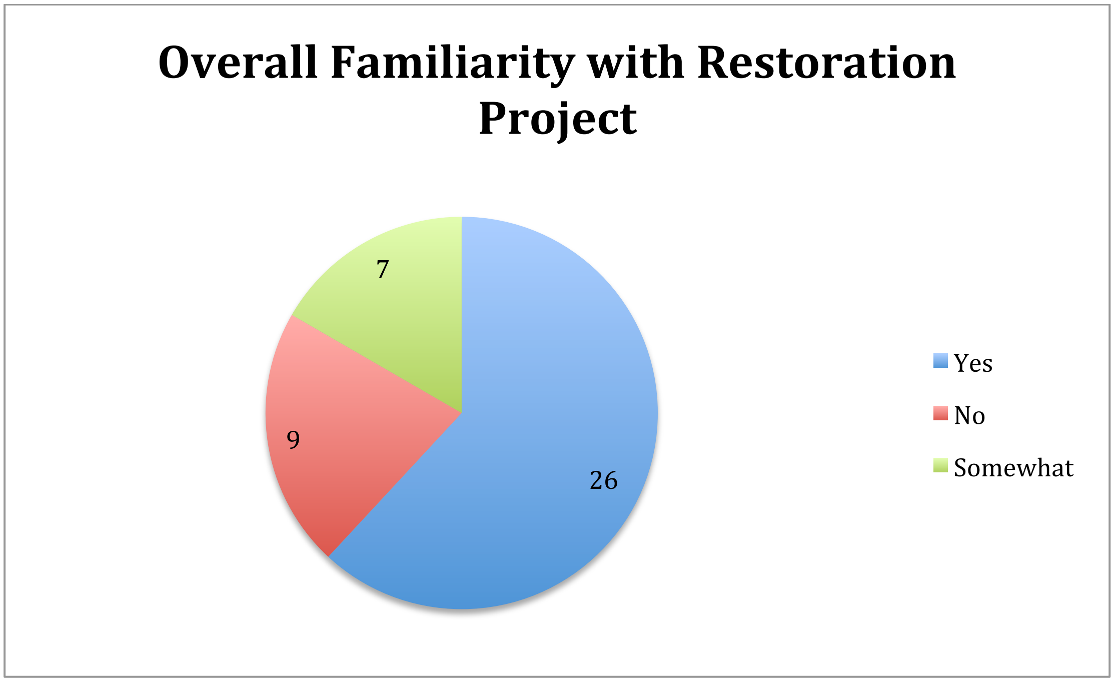

Figure 4.22. Breakdown of shellfisherman familiarity with town restoration project.

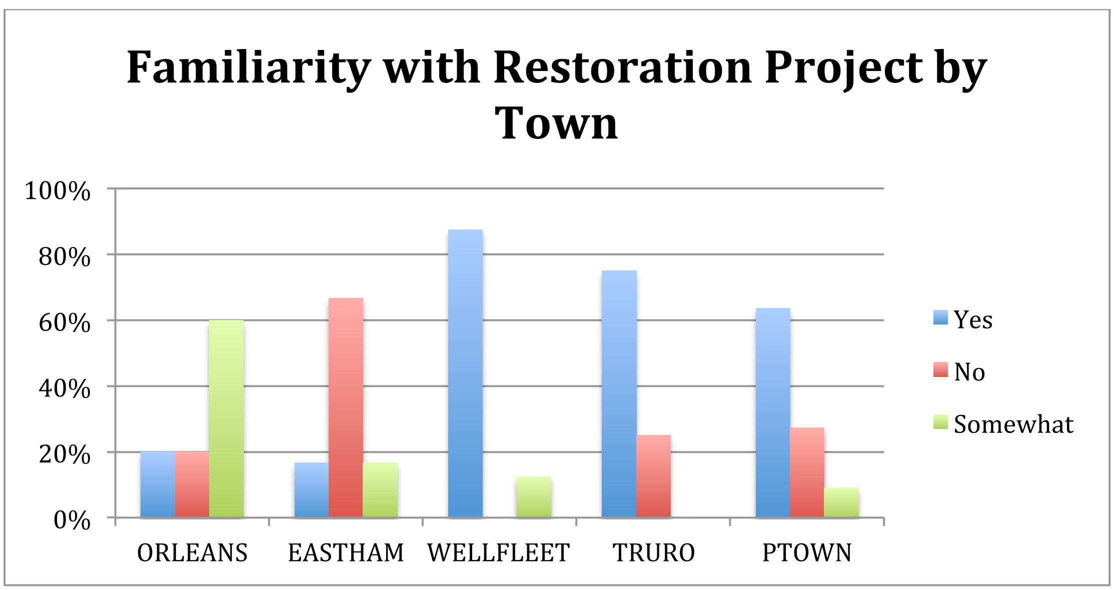

Figure 4.23. Breakdown of shellfisherman familiarity by town with town restoration project.

4.6.4 Shellfish Harvest Trends

Analysis of shellfish yield was performed across all five towns for each year that a study restoration project took place. Town-by-town results have already been detailed, but of particular note is the cyclical nature of landings. In particular, both quahog and oyster populations appear to cycle from 2001-2007. Data was not available for Wellfleet and Eastham post 2007, leading to a lower outer Cape reported harvest for 2007 to present (Fig. 4.24).

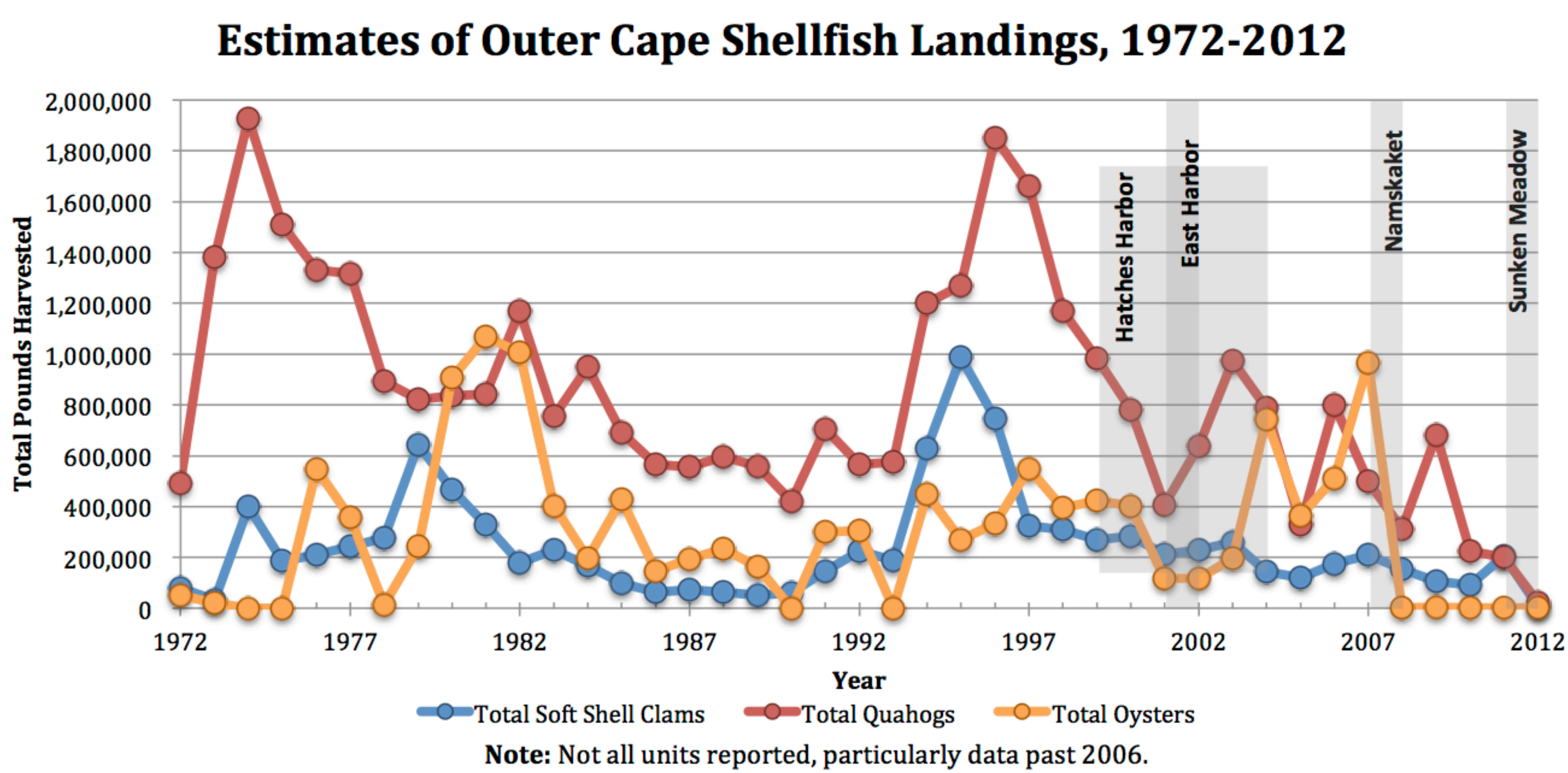

Figure 4.24. Shellfish harvests throughout the outer Cape from 1972-2012. Highlighted areas indicate restoration project timeframes.

4.6.5 Results Summary

A table comparing major results across the various study marshes is included below (Table 4.3).

Marsh	Size	Salinity (ppt)	Town Shellfish Harvest	Restoration Social Score	Fisherman Support
Namskaket Creek	Medium (186 acres)	↑ 0.4→15.4	No difference	11	80% positive 20% neutral
Sunken Meadow	Small (29 acres)	↑ 15.8→18.3	*Insufficient data*	14	83% positive 17% neutral
Herring River	Large (1,100 acres)	*Project Pending*	*Project Pending*	12	81% positive 19% neutral
East Harbor	Medium (282 acres)	↑ 2.0→25.0	Quahog ↓ ($p = 0.0017$)	12	100% positive
Hatches Harbor	Medium (420 acres)	↑ 5.2→27.6	No difference	12	82% positive 18% neutral

Table 4.3. Summary of major results by study marsh.

5. DISCUSSION

First, this section will discuss the success of the study restoration projects, both ecologically and socially. The effects of the restoration projects reflected ecologically in the shellfishing industry will then be assessed. The concept that increased shellfish harvest is a major ecosystem service associated with a restoration project will be analyzed. Finally, the changes noted in the social systems surrounding restoration and the shellfishing industry will be assessed.

5.1 Success of restoration projects

For the purpose of this project, ecological success in a restoration project is defined as a marsh that has experienced increased salinity (porewater, surface water, or combined) post restoration. More successful projects will have salinities closer to that of seawater (~35ppt). Since increased salinity is a major driver for vegetation change characteristic of a transition to salt marsh, marshes with higher salinities will be considered to be closer to fulfilling their full ecologic success potentials.

It is also important to consider the effects of salinity on shellfish populations. Davis (1958) determined optimum salinity levels and ranges for development of both clam and oyster eggs to larvae in Long Island Sound. Clams had an optimum salinity of 27.5ppt, with a range from 20.0ppt to 35.0ppt (Davis 1958). Oysters had an optimum salinity of 22.5ppt, with a range spanning 7.5ppt to 35.0ppt depending on the conditions under which the oysters spawned (Davis, 1958). This understanding informs whether or not a marsh has reached its ecologic success potential, even if it does not reach seawater-level salinities.

Social success in a restoration project is gauged by the project's social success score, a scoring system devised using a framework determined by Hopfensperger et al. (2006). More successful projects will score higher in the framework, indicating the presence of more positive decision-making criteria, steps in disagreement resolution, and overall group dynamics.

5.1.1 Ecologic success and success potential

The Namskaket Creek restoration project, in Orleans, MA, experienced a steady increase in salinity over the course of and post-restoration (from 0.4 ppt to 15.4 ppt over six years). This qualifies the restoration project as ecologically successful, though the salinity of Namskaket Creek is still well below the salinity measured in the unrestricted reference marsh (in 2012, study site salinity was 15.4 ppt, whereas reference site salinity was 28.9 ppt). This is largely due to the continued presence of flashboards on the culvert. Since there is still tidal restriction, though salinity has increased substantially, the project has yet to meet its full ecologic success potential.

Salinity in the Sunken Meadow restoration project in Eastham, MA, was only monitored over two years, one year before and one year after restoration. Combined salinity increased from 15.8 ppt pre-restoration to 18.3 ppt post-restoration, also qualifying the project as ecologically successful. The salinity of Sunken Meadow is also below that of the unrestricted reference marsh (22.7 ppt to 24.2 ppt), suggesting that the project has yet to meet its full ecologic success potential. Since this restoration project has occurred within the last three years, however, continued monitoring is necessary to properly gauge the marsh's current ecologic success.

Salinity in the East Harbor restoration project in Truro, MA, has been monitored continuously since its restoration in 2001. Salinity has increased steadily over the course of the restoration, qualifying the project as ecologically successful. From 2005-2009, average porewater salinity has been approximately 25 ppt, which is far closer to the salinity of seawater than the previous two sites. Though restoration experts stress that a larger culvert would lead to better hydrologic connectivity, for the purpose of this project, the site has reached its ecologic success potential.

Salinity in the Hatches Harbor restoration project in Provincetown, MA, has also been monitored continuously both before and after restoration. Porewater salinity has increased steadily over the course of and post-restoration (reaching 27.5 ppt in 2009), qualifying the project as ecologically successful. Since more than five years have passed since its restoration, and recorded porewater salinity of the Hatches Harbor marsh is closest out of all the marshes studied to that of seawater, for the purpose of this project, the site has reached its ecologic success potential.

The major factor in the ecologic success of a restoration project is an effective restoration construction plan. The only marsh that definitively did not reach its ecologic success potential was Namskaket Creek, where the remaining flashboards continue to prevent ideal tidal exchange. As to be expected, the longer it has been since a marsh has been restored, the more likely it is to reach its ecologic success potential. Both East Harbor and Hatches Harbor restoration projects have been restored for more than five years, and therefore have had substantial time for tidal exchange to gradually increase salinity to a point of ecologic success. Changes in salinity have been well-documented as the first step in biological change, particularly in terms of restoring salt marsh vegetation to more natural conditions (Smith and Warren, 2012; HRCRP, 2007). Within four years of restoration, a permanent vegetation plot at Hatches Harbor displayed a full transition from invasive *Phragmites australis* to bare ground to *Spartina alterniflora* (Smith and Warren, 2012; Fig. 5.1).

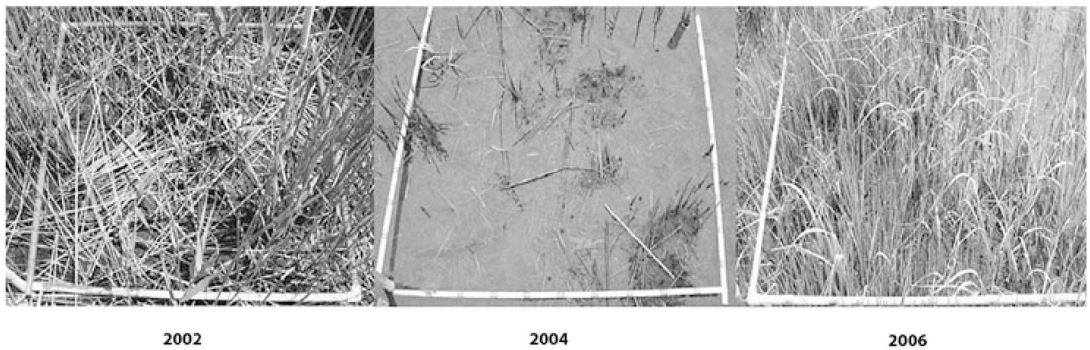

Figure 5.1. Vegetation change over the course of six years at a permanent vegetation plot at Hatches Harbor, Provincetown, MA. From Smith and Warren (2012).

On the outer Cape, hundreds of hectares of original salt marsh habitat have transitioned to freshwater wetlands or upland habitats—habitats that no longer provide the ecosystem services documented in table 2.1. Increased salinity is the first step in returning these habitats to a more original state.

5.1.2 Social success

Namskaket Creek in Orleans, MA, scored lowest in social success (11/16), whereas Sunken Meadow in Eastham, MA, scored highest in social success (14/16) (Fig. 4.13; Table 4.1). The Sunken Meadow restoration project likely scored the highest due to its extremely cooperative group dynamics (7/7). Interviews with marsh experts described the restoration project as largely "being in the right place at the right time," where funding was available for a short time to restore the relatively small marsh. Given the relatively small number of abutters that were also extremely cooperative, the restoration project was able to go ahead quickly and without much contention. Namskaket Creek, with the lowest social success score, had several abutters spanning two towns. The group dynamic was both resistant and cooperative, and there was significant public opposition and concern, leading to a group dynamics score of 4/7. The remaining three marshes shared the same social success score (12/16). Like Namskaket, Herring River, East Harbor, and Hatches Harbor all span a significant amount of space with many abutters.

All marshes studied ranked similarly in decision-making process criteria and disagreement resolution, suggesting that the criteria laid out in the Hopfensperger et al. (2006) framework represent a now uniform understanding of the steps required in these two categories. For example, the process of collecting scientific information before and during a restoration project is considered mandatory for most—if not all—restoration projects to be funded. An environmental assessment is often mandated by law, and collaboration with stakeholders is imperative to any decision making process. Therefore, the two major factors in the social success of a marsh restoration are not necessarily those indicated in the social success score, but rather the factors leading to the group dynamics of the restoration project. These two factors, as discussed above, are the size of the restoration project and the number of abutters. These two factors are often highly intertwined. The smaller the marsh, the more likely there will be fewer abutters to be resistant to the restoration project. The more abutters, the more resistance to the restoration project is inherent. Hopfensperger et al. (2006) established a framework for judging the social success of the implementation of a restoration project. This may have significant implications for future restoration projects—an understanding of the steps required for a socially successful restoration process can be used to qualitatively compare success scores.

A major way to garner social support and, effectively, increase the potential for social success (through decreased resistance), is through emphasis on the potential ecosystem services a restoration will provide. This approach is used in most restoration projects, including the study projects. For example, a 2004 article in the *Cape Cod Times* chronicles not only the appearance of bivalves in East Harbor, but also the impact the increased salinity had on swarms of midges. Since the opening of the dike, the midge population plummeted—as well as public complaint about the swarms descending onto the local highway, causing both visibility and allergy concerns (Fraser, 2004). This article was one of many to also mention the potential of these benefits also occurring with the slated Herring River restoration project. The ecosystem services argument is a major way to garner public support (HRCRP, 2007), which is necessary for a successful restoration project (Hopfensperger et al., 2006; Aikten, 1997; McGurrin and Forsgren, 1997).

5.2 Effects of restoration in the shellfishing industry

Salt marsh restoration so far has not had a significant positive effect on the shellfishing industry on the outer Cape, which is contrary to the initial hypothesis. There are several reasons as to why analysis may have revealed no significant difference in shellfish yield post restoration—or even a significant decrease in shellfish yield post restoration. These reasons include:

- Insufficient harvest data
- Shellfishing not permitted in/near restored marsh
- Natural cycling
- Confounding factors such as shellfish disease, seeding, and weather impacts
- Time lag

5.2.1 Insufficient harvest data

Since shellfish harvest in the state of Massachusetts is managed at the town level, harvest data is largely dependent on individual town records. Massachusetts Division of Marine Fisheries has fairly consistent records of catch reports for various shellfish species from 1950-2007, but harvest data past 2007 was only available for Orleans, Truro, and Provincetown. Post-restoration monitoring data ideally exists for at least two years after the initial project. This limits the ability to properly assess the post-2007 effects of a restoration project on the shellfishing industry. Since the Sunken Meadow restoration project in Eastham was completed in 2011, for example, its effect on the shellfishing industry cannot be determined. Shellfish harvest reports are largely dependent on self-reporting, particularly in recreational settings. Since the catch reports only document wild harvest, the effect of salt marsh restoration on aquaculture grants is unrepresented. The shellfish constables are aware of this difficulty in parsing catch reports, several mentioning the underrepresentation concern, and one shellfish constable considering the catch reports to be so inaccurate as to be misleading.

5.2.2 Shellfishing not permitted in/near restored marsh

In several cases, shellfishing is not permitted in or near the study restoration projects. This may be due to a variety of reasons, including high levels of fecal coliform; unfavorable shellfishing conditions; and federally-protected land at the study site. If shellfishing is not permitted in or near the study sites, the direct effect of restoration on the shellfishing industry cannot be determined. As such, only the indirect effects of hydrologic connectivity and generalized positive impacts on the greater environment can be measured. Since catch reports do not indicate where shellfish have been harvested, it is important to consider the indirect effects of restoration on the greater shellfishing industries, but hydrologic connectivity may not extend to marshes and tidal flats within permitted shellfishing zones.

5.2.3 Natural cycling

Both shellfishermen and shellfish constables alike stressed the importance of natural cycling on the shellfish populations of the outer Cape. When asked about potential causes of the cycling, however, several stressed that it was simply a natural phenomenon of the outer Cape that can't readily be explained by environmental factors. Anecdotal reports of cyclical populations are supported by the total catch reports—both quahog and oyster populations appear to cycle multiple times from 2001-2007. For example, outer Cape wild oyster harvests fluctuated from close to 100,000 pounds in 2003 to approximately 750,000 pounds in 2004, back to 365,000 pounds in 2005, then up to more than 900,000 pounds in 2007 (Fig. 4.24).

5.2.4 Confounding factors

There are a variety of confounding factors that may lead to changes in the shellfish population. With the rise of aquaculture, shellfish diseases have also risen, and infected seed from aquaculture grants can easily infect wild shellfish in close proximity (Ewart and Ford, 1993). Interviews with shellfishermen identified a large die-off due to QPX, a major quahog disease, as well the mention of other, still unknown diseases (W41 Interview, 2013). The Town of Wellfleet's Shellfish Advisory Board released a report in 2007, confirming oyster die-offs from MSX and Dermo and quahog die-offs from QPX.

Several shellfishermen and shellfish constables discussed the importance of shellfish seeding in the maintenance of the shellfish population, particularly for recreational harvest. Shellfish seed being artificially planted in various shellfishing grounds may further mask the effects of salt marsh restoration on shellfish harvest.

Other natural processes—including storms, early freezes, and heat waves—can decimate shellfish beds seemingly overnight. These factors are not necessarily documented in catch reports, and largely are only identified anecdotally. Many shellfishermen mentioned losing shellfish to disease, storms, freezes, or heat waves generally within the last five or ten years, but the actual year such a loss occurred was difficult if not impossible to determine.

5.2.5 Time lag

Salt marsh restoration is a long process that often requires significant adaptive management before achieving desired results. In many cases, it may take years for restored marshes to reach equivalence to unrestricted reference marshes. For example, the two restoration projects with salinities high enough to support shellfish development (Davis, 1958) each have been restored for more than a decade. This is supported in the literature. Levin et al. (1996) found that commercially-important shellfish had yet to be recruited to a restored North Carolina salt marsh after the duration of the 27-month study, though similar species were found in a nearby natural marsh, suggesting that functional equivalence had yet to be reached. In the case of more recent restoration projects (Namskaket Creek, Sunken Meadow, and the pending Herring River), there may be a significant time lag before the results are seen in shellfish populations—and an even longer time lag before the results are seen in shellfish harvest data.

5.2.6 Town analysis

In Orleans, there was no statistically significant difference in shellfish yield of soft-shelled clams and quahogs before and after restoration. There was also no statistically significant difference in shellfish yield of soft-shelled clams and quahogs across all five towns before and after the 2007 restoration of Namskaket Creek. Since the restoration project has not reached its ecologic success potential, however, we would not expect a significant impact on the shellfishing industry of Orleans. Additionally, Namskaket Creek is currently closed to shellfishing due to high levels of fecal coliform, likely due to overextended septic systems throughout the area. Since the town is not sewered, wastewater from septic systems has been a contentious issue in the town—proposals to put the town on public water and sewers are costly and often met with strong opposition (Zezima, 2010). Regardless, increased sewage inputs touted by the APCC as the "biggest environmental issue the Cape has ever faced"

(Zezima, 2010), have caused many shellfish closures. This may be another contributing factor to the results.

Current wastewater plans for the town of Orleans estimate a potential cost from $145 million to $204 million (Wastewater, 2014). Estimates from Louis Berger and Associates (1997) indicate that the cost of a salt marsh restoration may cost between $1,200 and $120,000 per acre (prices adjusted for 2014 dollars). Since the average restoration project may be several acres, the cost of a major restoration project could be almost equivalent to the cost to implement a new wastewater management plan in Orleans. Regardless of the potential water purification services of a salt marsh, however, the effects would not be seen in the shellfishing industry—without a new wastewater treatment plan, shellfishing areas will continue to close due to high levels of fecal coliform. Though opening the restoration area to shellfishing may have the potential to impact shellfish harvest numbers, it also would come at the cost of a new wastewater treatment plan.

In Eastham, shellfish harvest data was not available past 2006. The most recent harvest data for Orleans, Truro, and Provincetown is 2012. The Sunken Meadow marsh restoration project, completed in 2011, was the most recent of completed study projects. Therefore, the effects of this restoration project on the shellfishing industry cannot be determined. In addition to the lack of data, the marsh is relatively small, it is located predominantly on privately-owned land, and it is not in close proximity to shellfishing grounds.

In Truro, there was no significant difference in harvest of soft-shell clams post-restoration. Quahog harvest was significantly lower after restoration than before restoration (t_{17}=0.0034, p = 0.0017). Shellfish yield across the five towns did show a change in both soft shell clam and quahog harvest before and after the restoration of East Harbor in 2001, with significantly lower harvests of both species after restoration ($p < 0.001$ in both cases). Interestingly, East Harbor is often used a key exemplar of the shellfish/salt marsh connection, with thousands of bivalves having colonized the site within two years of the restoration. Because shellfishing is not currently permitted in East Harbor, this suggests that the positive effects of increased shellfish populations may not be as far-reaching as anticipated. Additionally, though East Harbor has reached its ecologic success potential, experts still assert that the project would benefit from a bigger culvert. It is suggested that a bigger culvert would increase hydrologic connectivity and, as a result, further the positive impacts on the shellfishing industry.

In Provincetown, there was no significant difference in harvest of quahogs after restoration, and soft-shell clam harvest was significantly lower after restoration ($F(2, 40)=25.01$, $p < 0.001$). Since the Hatches Harbor restoration project spanned from 1999-2003, shellfish yield across the outer Cape was analyzed over this time frame. There was no significant difference in soft-shell clam harvest over the course of restoration, but quahog harvest was significantly lower during and after restoration than before restoration ($F(2,40)=6.08$, $p=0.005$). Shellfishing is cyclically permitted in Hatches Harbor, indicating that there are enough shellfish to harvest at least once every four years. Since the shellfish population is able to maintain its presence year after year (even in the face of harvesting) it is suggested that the ecosystem service of increased shellfish population may hold true on a small scale in this case—even if it not reflected in the larger scale of town-wide harvest data.

Each of these cases, combined with the understanding of the influence of several different confounding factors, suggest a major conclusion: the anticipated ecosystem service of increased shellfish population, and thus increased shellfish yield, may not be present on the outer Cape. If this is the case, marsh restoration experts may need to reframe the ecosystem services argument in terms of shellfish population. Previous research proves the validity of several other ecosystem services of salt marsh restoration, particularly that of pelagic fish (Minton, 1997), however, which suggests that policy and management decisions made with the support of shellfishermen likely do not indicate any act of misleading on the part of the policy makers.

5.3 Validity of the ecosystem services argument

As previously explored in Chapter 2, salt marshes provide an important habitat for shellfish (Weinstein, 1979; Heck et al, 1995; Roman et al., 2000). It is understood, therefore, that shellfish production may be a valuable ecosystem service of salt marshes. It follows that as salt marshes are restored, shellfish production will increase. The ecosystem services of shellfish beds—nutrient and water filtering, in particular—will then follow. As water quality improves, it is suggested that the overall estuarine water quality will improve, creating a more favorable environment for shellfish colonization.

Though the majority of the literature only cites an implicit link between salt marsh habitat and shellfish populations (Weinstein, 1979; Heck et al., 1995; Roman et al., 2000; Levin et al., 1996), evidence from the East Harbor restoration project in Truro, MA, suggests that restoration may indeed result in increased shellfish populations. The fact remains, however, that the ecosystem services of increased shellfish populations and, as an extension, increased shellfish harvest have not been documented on the outer Cape. This may be a result of the many confounding factors discussed above, including insufficient shellfish harvest data and study marshes located relatively far from shellfishing areas, or it may be indicative of the true nature of the ecosystem service. Many studies cite increased shellfish populations as a potential benefit of salt marsh restoration, but an extensive literature review has not revealed any case study in which that link has been demonstrated. Currently, the ecologic link between salt marsh restoration success and increased shellfish harvest cannot be made on the outer Cape.

5.4 Social system changes

Though this study has not revealed a significant ecologic link between salt marsh restoration and the shellfishing industry, the connection does exist on a social level. Shellfishermen interviewed were generally positive and enthusiastic about salt marsh restoration, particularly in regard to the future of their stocks:

- "The salt marsh is so much more productive to the food in the water than any kind of freshwater marsh. As a shellfishermen, I'd much rather see that." (W66 Interview, 2013)
- "I think it's good for the whole aquaculture system. We do quite a bit of shellfishing in salt marsh areas, and I think the salt marsh is good for the whole coast. Without the vegetation, you can't get the food for the fish population, so I think that it's a good thing that we take care of the marshes." (W13 Interview, 2013)

- “I think it goes together. If the quality of the water is better, the quality of the shellfish is better.” (W41 Interview, 2013)
- “I think you’re never going to be able to limit the number of boats [out fishing], but if you can enhance things any way you can, by god do it!” (O06 Interview, 2013).

The socially-understood link between salt marshes and shellfishing exists even where the ecologic link is lacking.

No shellfishermen had a negative opinion about salt marsh restoration, with the vast majority expressing their enthusiasm for past, present, and future projects. Shellfishermen expressed their opinions in unequivocal terms, including:

- “I’m absolutely supportive of it.” (O06 Interview, 2013)
- “I’m more or less 100% on the conservation side of salt marshes.” (P20, 2013)
- “It’s a great idea. Turn everything back to salt water like it was one hundred years ago! No pipes and clappers and all that!” (P57 Interview, 2013)

The only shellfishermen who indicated reservations about restoration projects were from Wellfleet, where the large-scale Herring River restoration project is still in the works. The shellfishermen were tentatively supportive of the restoration project, with their main reservation the potential threat to their shellfishing grounds:

- “It’s a matter of considering the unintended consequences of what you may think is a good thing to do. … They made a mistake in 1910 [putting in the dike at Herring River]; I hope they’re not compounding it now!” (W71 Interview, 2013)

- “Shellfish grants are close to the action, particularly in Wellfleet. If the Herring River project gets away from us, a bunch of us will be out of shellfishing for a while.” (W41 Interview, 2013)
- “I’m not sure what pollutants are going to come out of it and put my shellfish grant in trouble.” (W54 Interview, 2013)

This concern has been an issue in the Herring River restoration process for at least a decade. Notes from the General Membership Meeting of the Wellfleet Non-Resident Taxpayers Association in July 2005 indicated that several speakers expressed concern over the impact of restoration on the shellfishing industry, particularly the impacts on oyster farms in the area (Croen, 2005). Since the Herring River Restoration Project is the largest restoration project from Maine to New York (Bragg, 2013) and has yet to be implemented, it is no surprise that shellfishermen are wary of the potentially unknown impacts to their livelihoods. That being said, even when an interviewee expressed a reservation with salt marsh restoration, it was always qualified with a tentative support for the ecologic benefits of the process.

Shellfishing, if not a major contributor to the outer Cape economy, is of undeniable cultural value. Consider the importance of the Wellfleet Oyster, the “charismatic epifauna” of the outer Cape. One species grown in one particular area has tremendous cultural and economic value—the town of Wellfleet even holds an annual celebration of shellfishing and the Wellfleet Oyster, with more than 25,000 in attendance in 2013 (Bragg, 2013). Events include tours of the shellfishing flats, informative lectures, a road race, family activities, and even a fabled “shuck-off,” where contestants compete to see who can shuck the most oysters the most accurately in a given time period (Wellfleet OysterFest, 2014; Fig. 5.2). This alone shows how important shellfishing is to the local community.

Figure 5.2. A shellfisherman at the 2013 Wellfleet OysterFest "Shuck-Off." Of particular interest is the sheer size of the crowd watching. Source: Cape Cod Times / Steve Heaslip

Though increased shellfish and pelagic fish populations is often cited as a major provisioning ecosystem service of salt marsh restorations—providing sustenance and income to commercial fisherman—it is important to consider the impact of salt marsh restoration on recreational shellfishing, a major cultural ecosystem service. Since 69% of shellfishermen interviewed said they harvested for recreation, cultural ecosystem services may potentially be more important than provisioning services in this setting.

Of the 42 shellfishermen interviewed, 33 had more than ten years of shellfishing experience. Many shellfishermen discussed the importance of shellfishing to the culture of the outer Cape:

- "It's a super recreational way to provide some nourishment and food and fun!" (P26 Interview, 2013)
- "I shellfish for recreation and the sheer pleasure of eating a whole bucket of quahogs between my family. It's beautiful going out there at sunrise, getting clams is just a bonus!" (P40 Interview, 2013).

- “I feel fortunate to live in Provincetown. It’s a wonderful social and economic resource to us. Most of us shellfish, and it adds a wonderful thing to an incredible town already.” (P62 Interview, 2013)
- “We get six dozen oysters every other week and it’s a tremendous adjunct to our diet.” (T05 Interview, 2013)
- “I let my grandkids dig.” (E15 Interview, 2013)

Fishermen’s overwhelming support for salt marsh restoration combined with the strong social understanding of the value of shellfishing on the outer Cape indicates the significant social link between salt marsh restoration and the shellfishing industry. Though valuation may vary between shellfishermen (a commercial shellfisherman values shellfish for economic as well as cultural reasons), the strong sense of pride and stewardship on the outer Cape suggests that the social link between salt marsh restoration and the shellfishing industry is robust. Though there has not been a documented increase in shellfish harvest, the qualitative support for social success of marsh restoration still exists—an apparent incongruity. This, again, suggests the strong cultural value of shellfishing on the outer Cape. Shellfishermen do not necessarily need to see a significant increase in their harvests to place importance on habitats that may maintain the ecological health of Cape Cod.

6. CONCLUSIONS AND FUTURE IMPLICATIONS

This project has determined the robust social link between salt marsh restoration and the shellfishing industry, but the hypothesis that it largely hinges on the ecosystem services argument is lacking. The sense of community and culture that rallies around both salt marsh restoration and shellfishing, however, proves that the link between ecologic and social understanding is important. Both play a valuable role in the community.

In terms of success of a restoration project, all marshes showed an increase in salinity post-restoration, indicating ecological success. All marshes ranked similarly in decision-making process and disagreement resolution criteria per Hopfensperger framework. This indicates a uniform understanding of the steps required to complete a restoration project. The social success of the salt marsh restoration project, therefore, is largely due to factors that affect the group dynamics of the restoration project—number of abutters and size of the project.

The restoration of the Herring River in Wellfleet is a massive project. With construction slated to begin as early as 2016, this project has serious implications for the project's fate. The Herring River restoration project scored similarly to the East Harbor (Truro) and Hatches Harbor (Provincetown) restoration projects in terms of social success. This suggests that the implementation of the project will have similar success in going forward with social support. Indeed, interviews with shellfishermen have confirmed this.

The Herring River restoration project is unique in that it is close to shellfishing grounds—increasing the chance that hydrologic connectivity will yield increased shellfish populations. Shellfishing is currently permitted in the Herring River, and these shellfishing grounds may change with more inundation of salt water from the removal of the dike at Chequessett Neck. Even if the increased shellfish population ecosystem service of salt marsh restoration is not wholly present on the outer Cape, situational evidence of thousands of bivalves populating East Harbor suggest that positive ecologic results may be seen. Even with reservations, shellfishermen are wholly supporting this project, which may have potentially enormous positive impacts on the shellfishing industry, the town of Wellfleet, and the social and ecologic culture of the outer Cape as a whole.

Many studies cite increased shellfish populations as a potential benefit of salt marsh restoration, though no case studies have explicitly shown that link. The salt marsh restoration projects on the outer Cape are no exception. Though an ecologic link between salt marsh restoration and the shellfishing industry could not be determined, this study instead revealed the robust social link between the two. The fact that this social link is present even in the face of potentially conflicting ecologic evidence speaks to its strength.

APPENDIX: Interview questions

Fishermen:

- What do you shellfish for?
- How long have you been shellfishing?
- Do you shellfish for recreation, profit, or a combination of the two? What proportion is recreational or for profit?
- Is shellfishing your primary occupation?
- In what general area do you shellfish?
- Do you have any insights on trends in shellfish landings? How have shellfish landings changed over the past 5-10 years?
- What are your opinions about salt marsh restoration in general? What are your opinions about the restoration project specific to your town?
- Have you noticed any differences in shellfish yield post-restoration? What are they? What are the primary reasons for these changes in yield?

Shellfish managers:

- How did you come into your current position?
- What are the responsibilities of your current position?
- Do you have any insights on trends in shellfish landings? How have shellfish landings changed over the past 5-10 years?
- What are your opinions about salt marsh restoration in general? What are your opinions about the restoration project specific to your town?
- Have you noticed any differences in shellfish yield post-restoration? What are they? What are the primary reasons for these changes in yield?
- Have any grounds been opened to shellfishing due to restoration?

APPENDIX (cont.): Interview questions

Salt marsh restoration officials (adapted from J. Dominguez):

- How did you come into your current position?
- How are you involved with salt marsh restoration projects?
- What experience have you had with the given salt marsh restoration project?
- What was the goal of this project?
- What was the process leading to the decision to restore the site (per Hopfensperger et al.)?
    - Collection of scientific information
    - Collaboration with stakeholders
    - Modeling of scenarios for feasibility
    - Preparing of an environmental assessment
    - Ensuring the site met the needs of the mitigation project
    - Addressing concerns of local businesses
- What were the main challenges to this project?
- How were disagreements resolved (per Hopfensperger et al.)?
    - Meetings and discussions
    - Mediating agencies
    - Compromises
- How would you categorize the group dynamics inherent in the process (per Hopfensperger et al.)?
    - cooperative/positive
    - resistant
    - involving mutual interests
    - involving trade-offs
    - involving public concern/opposition
    - using a mediator
    - involving differences in philosophy
- Would you consider the project to be successful on ecological, social, or economic levels? Why or why not?
- Is a monitoring program in place? Has it been considered successful? Why?
- What are the biggest obstacles to future restoration projects?
- What impact does salt marsh restoration have on shellfish populations in restored areas?
- What impact, if any, do you feel that salt marsh restoration has on the shellfish industry?

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