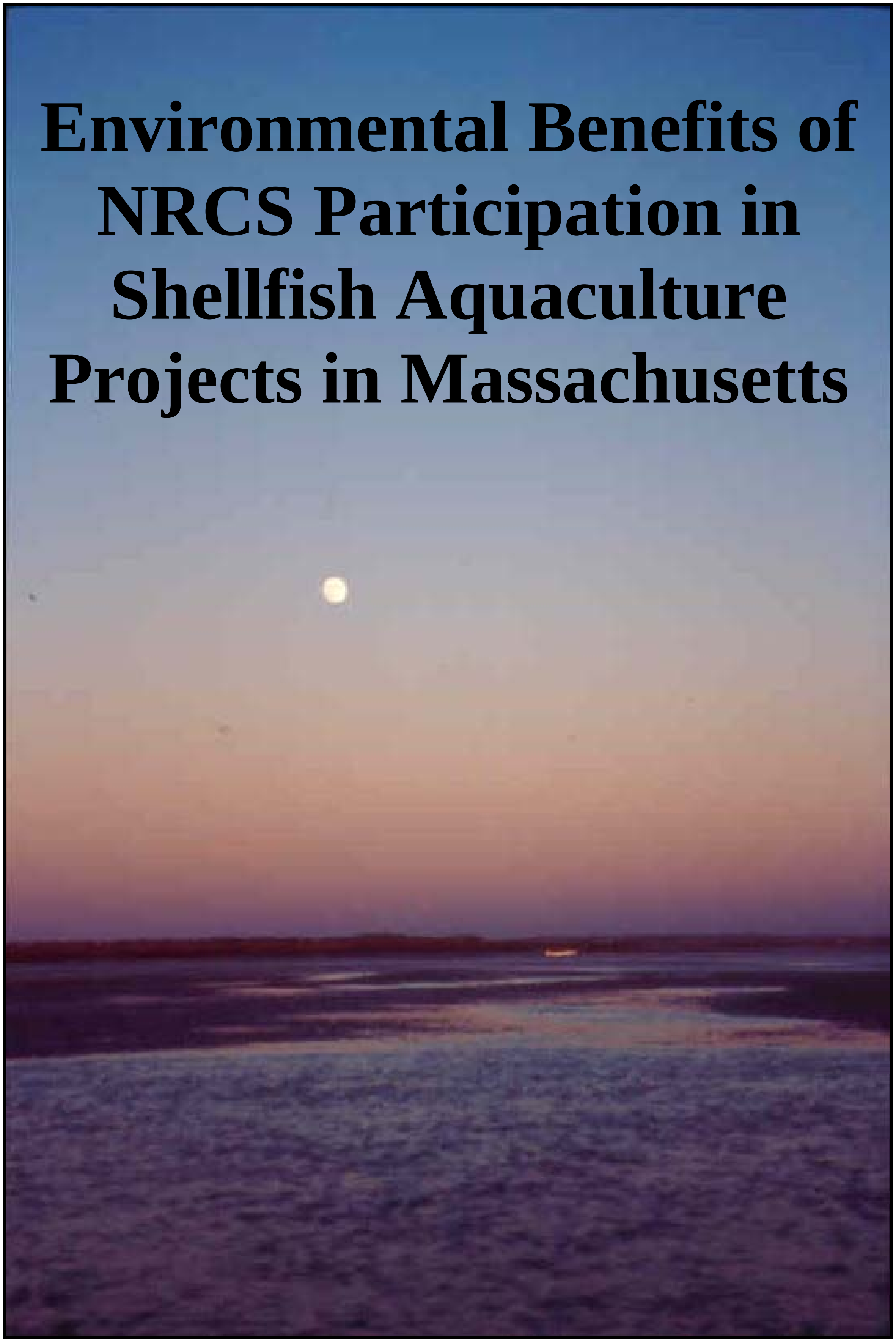
Environmental Benefits of NRCS Participation in Shellfish Aquaculture Projects in Massachusetts



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Cover photo: Moonrise over Barnstable Harbor Tidal Flats
Photos courtesy of the Barnstable NRCS Office and Kristin Smith

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I. Executive Summary

Introduction and Purpose

The USDA Natural Resources Conservation Service (NRCS) State Office in Massachusetts requested assistance from the East National Technology Support Center (ENTSC) in determining the potential environmental benefits that will likely result from implementation of the Massachusetts interim *Shellfish Aquaculture Management* conservation practice standard and Environmental Quality Incentives Program (EQIP) aquaculture pilot project. The interim practice standard is designed to address the primary environmental concerns arising from shellfish farming and incorporates Best Management Practices (BMPs) set forth in the "Best Management Practices for the Shellfish Culture Industry in Southeastern Massachusetts" (Leavitt, 2004). Beginning in 2005, NRCS in Massachusetts also provides financial and technical assistance to encourage accelerated local adoption of BMPs. To date, contracts have been developed with 34 shellfish producers for approximately $550,000 in EQIP funds.

The ENTSC team examined the details of the Shellfish Aquaculture Management practice to confirm and specify benefits to natural (soil, water, air, plant, animal), human and energy resources. Only public benefits and costs were considered. As used here, public costs include financial assistance provided through the EQIP pilot project and any adverse environmental impacts resulting from the practice of shellfish aquaculture. Public benefits include the improvements to environmental quality and mitigation of adverse environmental impacts that NRCS conservation practice standards are designed to produce.

Shellfish aquaculture is a growing industry in southeastern Massachusetts, with Eastern, or American, oysters and quahogs, or common hardshell clams, the two most commonly grown species. BMPs were developed for the shellfish industry in Massachusetts in 2004 "to improve production while preserving the environment" upon which the industry depends (Leavitt, 2004). Typical shellfish operations in Massachusetts involve subdividing a previously unmodified tidal mud flat into smaller units of space by adding a variety of materials to mark boundaries and support cultivation and harvest processes. Two methods of shellfish culture are commonly used: Bottom Culture and Water Column, or Off-Bottom, Culture. Both involve the placement of juvenile shellfish, obtained from hatcheries, in racks, bags or cages, or under nets, located on or suspended over individual leases on the tidal flats granted to shellfish producers by local shellfish boards. Shellfish are grown to merchantable size over several growing seasons, with removal and refrigeration of some species occurring in the winter months.

Resource Concerns Associated with Shellfish Aquaculture

Properly managed commercial shellfish production is generally considered to have minimal impacts on other coastal marine resources. Impacts vary with the production system used and the scale of the individual operation. A mix of potential beneficial and adverse impacts resulting from the practice of shellfish aquaculture in Massachusetts has been identified for the following resource concerns: soils; water quantity and quality; plants (seagrasses and biofouling organisms); wildlife including benthic organisms, fish, sea turtles, and terrestrial and marine birds and mammals; energy use; and human considerations including land use, access, aesthetics, navigation, local culture, and sustainability.

Benefits of NRCS Assistance

A summary of the expected environmental impacts resulting from NRCS participation in Shellfish Aquaculture Management in Massachusetts is provided in Appendix C. The Farm Management Plan, developed through the nine-step NRCS Conservation Planning Process, is the foundation of NRCS assistance. A properly prepared Farm Management Plan, equivalent to the Conservation Plan provided to other NRCS agricultural producers, provides a record of the producer's decisions and the information necessary to implement the BMPs that the shellfish producer has selected. The BMPs available to producers through the EQIP pilot project are described in Appendix B.

Soil. Adverse aquaculture impacts to subaqueous soils present on the tidal flats are generally minimal. Increased soil disturbance and adverse impacts to benthic organisms may occur if hydraulic raking is used for harvest. Placement of structures on the tidal flats for shellfish production may initially result in slightly increased soil disturbance, but ultimately produces an increase in on-site sedimentation and substrate stability. In turn, periodic removal of gear for maintenance (*Net Cycling*) and *Winter Management* may reduce substrate stability. Greater adverse impacts resulting from ice movement and damage are likely to result, however, if gear is not removed through *Winter Management*. *Buffers,* strips or corridors of unfarmed sediment, within shellfish plots also provide undisturbed areas and may mitigate some of the adverse impacts.

Water Quantity. Shellfish aquaculture does not impact water quantity in the environment per se. Other factors, such as biofouling, may adversely affect the quantity of water available for shellfish and other benthic health and productivity. Incentives provided for *Net Cycling* allow producers to regularly remove biofouled gear to an upland site for cleaning which improves water flow to shellfish and other benthic organisms while protecting or maintaining water quality. The presence of structures used for aquaculture may facilitate ice formation on the tidal flats in winter. These impacts are mitigated through proper *Winter Management*. Incentive payments for proper *Disposal of Gear Waste* encourage producers to remove and dispose of nets and other gear prior to ice formation. Unfarmed *buffer* strips within plots may also provide a benefit by increasing the distance between structures.

Water Quality. Increasing shellfish populations in an area can improve water quality, while the boat motors used to access shellfish leases are a significant contributor to petroleum products in the marine environment. The biofiltration benefits of shellfish can be enhanced by *Net Cycling* at proper intervals to reduce biofouling organisms and restore water flow to shellfish. *Engine Exchange*, providing incentives for producers to replace carbureted two-stroke engines with cleaner, more efficient four-stroke or direct inject two-stroke engines, benefits the marine environment by greatly reducing the discharge of petroleum products from boat motors. In addition, incentive payments to encourage the purchase and use of *Spill Prevention Kits* further benefits water quality by making it relatively easy for producers to contain both smaller and larger spills resulting from fueling operations, engine maintenance, damaged engines, collisions, or other accidental spills.

Air. Emission of smog-forming exhaust from marine engines can be significantly reduced through the replacement of less efficient carbureted two-stroke engines with four-stroke or direct inject engines. Incentive payments for *Engine Exchange* may reduce emissions by 70 to 90% or more.

Plant. Seagrasses may benefit from water quality improvements related to *Engine Exchange*. Biofouling organisms and the grazers who feed upon them benefit from the placement of structures on shellfish leases. However, in a well-managed operation, *Net Cycling* reduces the interval in which biofouling organisms are allowed to grow, making these benefits short-lived.

Animal. *Winter Management* of gear has perhaps the most significant potential to mitigate adverse impacts of shellfish aquaculture to wildlife. *Net Cycling* and *Disposal of Gear Waste* similarly benefit wildlife populations by increasing the amount of gear removed from the marine environment, decreasing the amount of free-floating gear in which entanglement may occur, and, therefore, reducing injury and mortality associated with entanglement. Unfarmed b*uffer* strips preserve natural areas of tidal zone for native fauna and likely limit adverse impacts of aquaculture associated with migration, resting, foraging, and rearing of young. Shellfish producers who *Monitor and Record Wildlife Sightings* are more likely to be familiar with rare, threatened and endangered wildlife species. As a result, interactions with humans and the ensuing changes in behavior that can impact migration, foraging and reproductive success should be minimized.

Monitoring and recording the presence of predators and exotic, invasive and other nuisance species assists producers in anticipating and planning for future problems and may benefit native aquatic species over time. *Monitoring and Recording Disease,* with associated timely control of disease outbreaks, reduces the risk of diseases spreading from commercial shellfish to adjacent wild populations. Establishment of open, unplanted b*uffers* between adjacent shellfish growing areas also helps limit disease transmission between commercial shellfish operations and protects adjacent wild shellfish from exposure to parasites, viruses, and bacteria in the event that commercial populations become infected.

Human. *Winter Management* reduces the amount of gear "lost" to winter conditions, subsequently reducing navigational hazards for boaters and improving aesthetics, with less free-floating gear and other trash present in marine waters and along the shoreline in the spring. The introduction of *Standard Navigational Aids* helps shellfish producers to comply with local and state regulations and should reduce navigational mishaps. Unfortunately, placement of these large yellow buoys may have negative visual impacts, but these can be mitigated by reducing the number of buoys so that only corners of groups of leases are marked. *Buffers* between shellfish growing areas not only provide space for site access and gear manipulation, but may also provide improved aesthetics and public access for fishing and fowling. *Environmental Monitoring and Recordkeeping* can help producers improve management of shellfish and equipment, particularly in preparation for winter conditions.

Energy. *Engine Exchange* improves fuel efficiency by as much as 15 to 30%. Over the course of a year, this can result in significant fuel savings, as well as a reduction in petrochemicals discharged into the marine environment. *Winter Management*, *Net Cycling* and *Disposal of Gear Waste* result in additional trips to and from aquaculture lease sites; however the additional energy consumed is much less than that saved with efficiencies gained through *Engine Exchange.*

Quantifying Benefits

Many of the benefits described above are qualitative in nature and difficult to quantify. Net beneficial fuel savings and reductions in hydrocarbon emissions resulting from *Engine Exchange* can be estimated using information provided by the shellfish producers in conjunction with known efficiency and emission factors.

Conclusions and Considerations

NRCS involvement in shellfish aquaculture in Massachusetts appears to be generating beneficial environmental impacts. Most of these benefits are qualitative in nature, and the magnitude is unknown. Extensive efforts would be required to establish baselines and obtain comparison data for quantification of the majority of benefits.

The ENSTC team has proposed the following actions for consideration, and staff is available to provide further assistance if requested:

1. Expand the content of the Farm Management Plans to include additional details about the individual shellfish operations and the requirements of the various components of the EQIP pilot project. This information can be useful in ascertaining needs, establishing baselines and determining benefits.
2. Strengthen the focus on continued operation and maintenance (O&M).
3. Use the Annual Observation Checklist as a “monitoring tool” to establish average and extreme dates for removal of shellfish and equipment in preparation for winter conditions.
4. Provide additional specific actions for producers to take (or not take) when sensitive species are in the local area.
5. Modify the interim *Shellfish Aquaculture Management* practice standard to require removal of collected biofouled material from the marine environment within a reasonable specified time period after removal from shellfish plots.
6. Furnish informational signs at boat landings.
7. Encourage program participants to initiate dialog with tribal nations, recreational fishers and other locals regarding potential reduced access to tidal flats that have traditionally been considered a public resource.
8. Establish realistic quantitative goals for the Shellfish Aquaculture Project.
9. Collect more rigorous baseline information at each aquaculture plot at the outset of assistance to enable monitoring and evaluation of aquaculture effects.
10. Continue to target assistance to the entire ecological system, upland and marine.

II. Introduction and Purpose

In late 2005, USDA Natural Resources Conservation Service (NRCS) State Office in Massachusetts requested assistance from the East National Technology Support Center (ENTSC) in determining the potential environmental benefits that will likely result from implementation of the Massachusetts interim *Shellfish Aquaculture Management* conservation practice standard and accelerated adoption of Best Management Practices (BMPs) by shellfish growers under the Massachusetts aquaculture EQIP pilot project. A team of ENTSC staff visited Cape Cod to learn first-hand about the shellfish aquaculture industry, NRCS interim practice standard, and EQIP pilot program and investigated potential associated environmental benefits. Literature searches were also conducted to investigate the environmental impacts of shellfish aquaculture and the potential beneficial effects of implementing the *Shellfish Aquaculture Management* practice standard.

USDA-NRCS Role in Marine Aquaculture in Massachusetts

USDA has traditionally focused on inland aquaculture, such as catfish farming. Most of the federal involvement in marine aquaculture has been through the Department of Commerce and Sea Grant research programs. However, the National Aquaculture Act of 1980 (Public Law 96-362) established marine aquaculture as a form of farming, bringing USDA into the marine aquaculture arena.

In March of 2005, in response to requests from shellfish producers, the NRCS State Office for Massachusetts approved the first interim conservation practice standard for shellfish aquaculture for a 3-year trial period. The *Shellfish Aquaculture Management* interim practice standard (Appendix A) is designed to address the primary environmental concerns arising from shellfish farming—water quality and quantity and habitat modification, including the protection of important, threatened, rare and endangered wildlife and plant species. The standard also incorporates the BMPs set forth by the state in the "Best Management Practices for the Shellfish Culture Industry in Southeastern Massachusetts" (Leavitt, 2004).

Beginning in 2005, NRCS in Massachusetts also provides financial and technical assistance through EQIP to encourage accelerated local adoption of BMPs. NRCS initially allocated $248,000 in EQIP funds for marine aquaculture, as a pilot effort to gauge producer interest and to begin collecting data to determine the environmental benefits afforded by such an initiative. Requests for over $400,000 in financial assistance were received from over 40 shellfish farmers on approximately 100 acres. This represents about 10% of the total area where shellfish are cultivated in southeastern Massachusetts. Twenty-one EQIP contracts were developed with shellfish producers. In 2006, nearly

$302,000 in EQIP financial assistance has been provided to growers under 13 contracts covering 44 acres of shellfish leases, primarily in Barnstable Harbor. Efforts were targeted to specific growing areas in 2006 in an attempt to maximize and facilitate measurement of environmental benefits.

Measuring "Environmental Benefits"

> "Agricultural activities may impact the environment directly, indirectly and cumulatively through the effects of farming practices on land use, natural landscapes, soil quality, water management, air quality, and the diversity of animal and plant species, habitats and ecosystems" (Portugal, 1999).

A recent report from the Blue Ribbon Panel conducting an external review of the USDA Conservation Effects Assessment Project (CEAP) stressed the difference between quantification of effects and evaluating effectiveness of USDA conservation programs. To fully understand the effectiveness of agency activities, impacts must be considered in the appropriate ecological and environmental context and linked to the:

- locations where the benefits occur,
- sensitivity to the affected resource, and
- threshold levels that must be achieved to produce measurable environmental improvement (SWCS, 2006).

When considering environmental benefits, it is also important to clearly define what is meant by "benefit". NRCS policy and technical documents offer some general guidance. The objectives of EQIP, as stated in the 2002 Farm Bill, are (1) to promote agricultural production and environmental quality as compatible national goals, and (2) to optimize environmental benefits. Specific ways in which these objectives may be accomplished include:

- Assisting producers in complying with local, State, Tribal and National regulatory requirements;
- Avoiding, to the maximum extent practicable, the need for regulatory programs by assisting producers in protecting soil, water, air, and related natural resources and meeting environmental quality criteria established by Federal, State, Tribal, and local agencies; and
- Providing flexible assistance to producers to install and maintain conservation practices that enhance soil, water and related natural resources while sustaining production of food and fiber (NRCS, 2004).

NRCS groups natural resources into several categories: Soil, Water, Air, Plant, and Animal (SWAPA).   Human and Energy concerns are also considered. The impacts of activities on these resources can be either “beneficial” or “adverse”.   Resources act in an interdependent manner, and a “benefit” to one might be “adverse” to another. As a result, judgment of which effects are “beneficial” and which are “adverse” may be perceived as subjective. NRCS bases its policies and strategies on the following concept: an action that provides environmental “benefits” moves us closer to some goal or objective, while a harmful or adverse impact moves us away from that goal or objective (Bromley, 1999).

NRCS conservation practices are developed to minimize or mitigate adverse environmental impacts and/or to produce beneficial effects upon some resource. NRCS in Massachusetts reinforced this objective in the Massachusetts *Shellfish Aquaculture Management* interim practice standard by stating the following purposes:

- Enhance the sustainability of aquaculture;
- Minimize adverse impacts of shellfish farming on water, plant, animal and human resources;
- Ensure dependable quantity and quality of water to support shellfish production; and
- Ensure adequate quantity and quality of food to support shellfish production.

Environmental benefits of implementing this practice should move shellfish growers and the agency toward these purposes and ultimately, a goal of a “landscape in which a productive agricultural sector and a high quality environment are both achieved” (NRCS, 2006). The ENTSC team examined the details of the Shellfish Aquaculture projects to confirm and specify benefits to natural, human and energy resources with this goal in mind.

Scope of Analysis

In reviewing the Massachusetts Shellfish Aquaculture projects, the ENTSC staff considered only public costs and benefits. As used here, public costs include financial assistance provided through the EQIP pilot project and any adverse environmental impacts resulting from the practice of shellfish aquaculture. Public benefits include improvements to environmental quality as well as mitigation of adverse environmental impacts.

Conservation practices having a primary purpose of enhancing agricultural production are not eligible for EQIP (NRCS, 2004). Direct and indirect benefits of improved production to individual producers participating in the project, the shellfish industry, and potential multiplier effects in the local economy were considered only with respect to their likelihood of yielding additional environmental benefits.

Shellfish Aquaculture in Massachusetts

Shellfish aquaculture, the husbandry of all or part of the life cycle of various bivalve mollusc species for the purpose of generating a harvestable and marketable product, is a growing industry in southeastern Massachusetts. The principal species grown in the region are Eastern, or American, oysters (*Crassostrea virginica*) and quahogs, or common hard shell clams (*Mercenaria mercenaria*). Soft shell clams (*Mya arenaria*), bay scallops (*Argopecten irradians*), surf clams (Spisula solidissima), European oysters (*Ostrea edulis*), and blue mussels (*Mytilus edulis*) are also grown on a smaller scale (Leavitt, 2004; MA OCZM, 1995a).

Commercial shellfish growers are licensed by the state and regulated by the Division of Marine Fisheries. Shellfish leases for particular growing locations are granted by the 55 local shellfish boards. Roughly 300 companies and individuals grow shellfish commercially on approximately 1,000 acres of intertidal and shallow subtidal flats (Figure 1), generating an estimated $6 million annually (Hemilla, et al, 2005). It is estimated that roughly 50 percent, or 150 permit holders, are full time shellfish producers (Soares, 2006). Individual shellfish farms range from one to four acres in size, and the majority are held under leases of one to fifteen years, depending on the leasing authority and the tenure of the lessee on the permit.

Shellfish aquaculture is dependent upon clean water and a healthy environment. BMPs were developed for the shellfish culture industry in Massachusetts in 2004 and published as the "Best Management Practices for the Shellfish Culture Industry in Southeastern Massachusetts" (Leavitt, 2004). Although development was a collaborative effort involving growers, regulators, and other groups, the resulting BMPs were developed primarily by the shellfish industry for voluntary use within the industry to "address areas where attention should be focused to improve production while preserving the environment" (Leavitt, 2004). The BMPs are grouped in five categories of activities: (1) site selection and access; (2) materials, operation and maintenance; (3) improvement of shellfish survival and productivity; (4) disease prevention and management; and (5) maintenance of environmental quality.

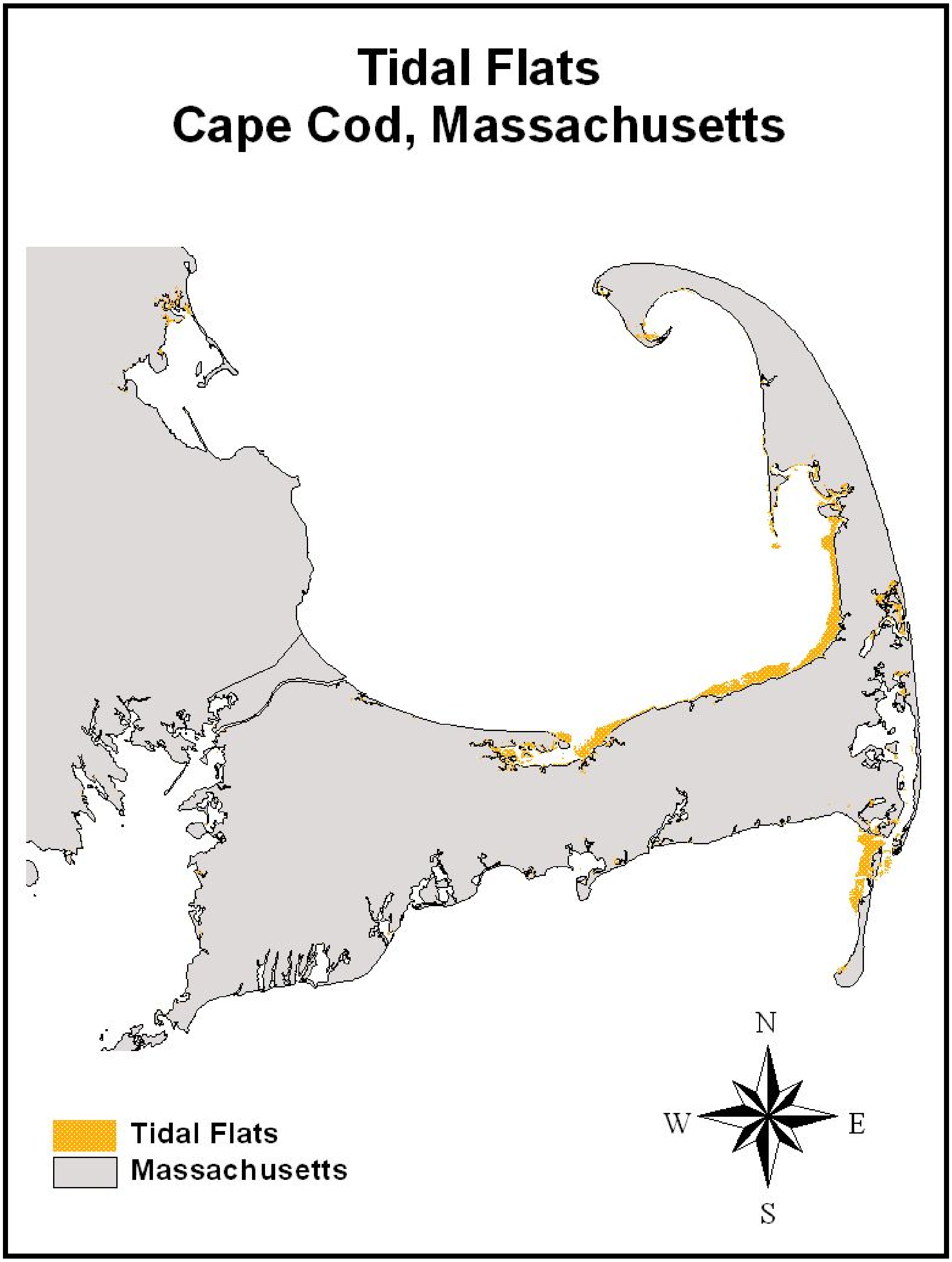

Figure 1: General location of tidal flats along the shores of Cape Cod, in southeastern Massachusetts

Aquacultural Methods

The Pleistocene glaciations of New England, including Massachusetts, left a landscape uniquely suited to a diverse, productive assemblage of upland, coastal, freshwater, estuarine, and marine habitats. Geomorphically, coastal areas of Massachusetts suitable for shellfish aquaculture practices consist of coves, embayments, and tidal flats, surrounded by salt marshes, beaches, and rocky shores. Coastal areas grade upland into woodlands, barrens, and sandplain grasslands. Aquaculture sites are commonly tidal flats, or gently sloping unvegetated areas extending seaward of coastal landforms out to mean low water. Tidal flats are generally depositional areas composed of sand and silts, and usually associated with spits and barrier beaches that provide a source of sediment for development (Howes and Goehringer 1996), as well as protection from storm-driven winds and waves.

Typical shellfish operations in Massachusetts involve subdividing a previously unmodified tidal mud flat into smaller units of space by adding a variety of artificial materials to mark boundaries and support cultivation and harvest processes. Nets, boxes, crates, pens, pipes, lengths of rebar, various types of plastics, trays, and other artificial materials are used by shellfish growers in their individual operations. In addition to the placement of boundary markers and equipment on an otherwise structureless mudflat, aquaculture enclosures are tended by producers who come and go, at least once a day during low tide periods in the growing season, in motor driven boats of various kinds.

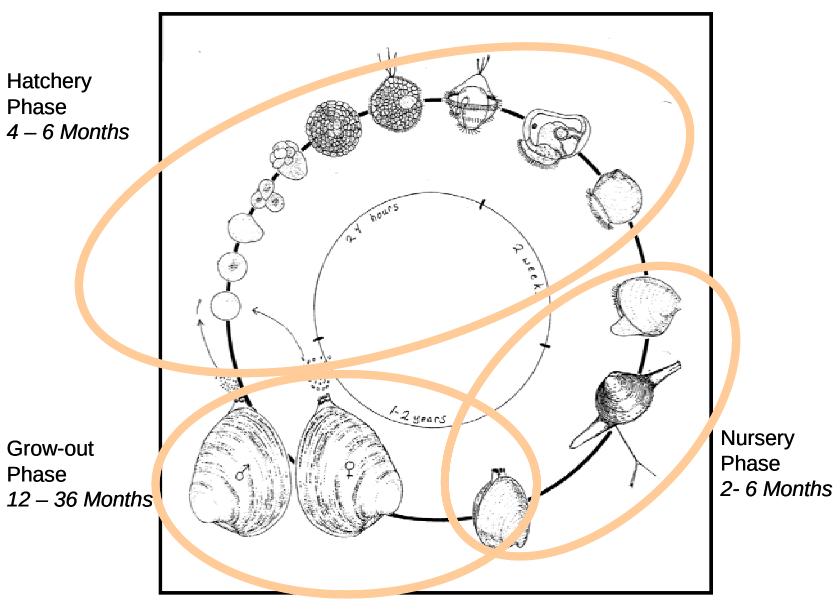

Figure 2: General bivalve mollusk life cycle (from Hemmila et al, 2005). The commercial shellfish aquaculture discussed here involves the “nursery” and “grow out” phases.

Two methods of shellfish culture are commonly used: Bottom Culture and Water Column (or Off-Bottom) Culture. Generally, the young shellfish, or “seed” (Figure 2), are obtained from commercial hatcheries and placed in racks, bags or cages located on or suspended over individual leases on the tidal flats. Shellfish are grown to merchantable sizes over several growing seasons using a wide variety of materials and methods. Some of the shellfish are removed and refrigerated through the winter while others remain in tidal areas. Any equipment or gear that is left on the tidal flats over the winter is subject to damage and loss resulting from the effects of weather and ice.

Bottom Culture, the predominant method, is the practice of cultivating bottom-dwelling shellfish in nursery trays, bags or pens placed directly on intertidal flats and covered by protective netting. Oysters and quahogs are both grown using this technique, which involves the three stages described below.

(1) Field Planting – Juvenile shellfish (> 2mm in size) are “planted” in nursery trays, net-covered boxes that are filled with sand that does not contain predator species and slightly elevated above the intertidal flats on legs (Figure 3). The shellfish remain in the nursery trays until they reach a sufficient size to be less vulnerable to predators.

Figure 3: Nursery trays for juvenile shellfish, which are typically filled with sand and covered with anti-predator nets.

(2) Grow Out – The shellfish are then transferred to narrow, net-covered plots for grow out, which may take several seasons (Figure 4). As quahogs get older and larger, they are infaunal, meaning that they live buried in the sediment of the tidal flats. Oysters primarily live on top of the sediment. Both types of shellfish are covered with nets to keep the crop in one place and to protect them from predators.

(3) Harvest –Shellfish are harvested when they reach marketable size, which varies by species and market. Harvesting oysters and quahogs involves mechanical or manual removal from the sediment, which has traditionally been accomplished with some type of rake to physically excavate the site and separate the shellfish. Oyster harvest typically involves less excavation, as these shellfish are found on or near the surface. Oysters may also be "picked" by hand, the method of harvest least disruptive to sediments. On the other end of the spectrum, hydraulic rakes, which pump pressurized water into the sediment to liquefy it and expose the buried quahogs, are used in some locations.

Figure 4: Bottom culture plots where shellfish are grown to marketable size. Nets over the plots provide protection from predators and keep the shellfish within the plot.

Water Column (Off-Bottom) Culture involves the use of water column suspension techniques, including lines and enclosures such as nets, bags, baskets, cages, racks, and trays. This method can be used to grow bottom-dwelling and sedentary as well as motile species of shellfish (i.e., scallops), and has uniformly produced more oysters, accelerated growth rates, improvements in meat quality, and significant reductions in predation (MA OCZM, 1995a). Juveniles of some species may also readily "set" on lines, eliminating the need to obtain “seed” from a hatchery. Variations of Water Column Culture include: Lantern Culture; Raft Culture; and Rack Culture.

Figure 5: Two types of lantern culture, with bags containing shellfish suspended above the tidal flats

In Lantern Culture (Figure 5), a cylindrical container fashioned from nylon netting, divided into sections and hung from floats is used to culture bay scallops and oysters. Raft Culture uses long lines or fine mesh nets suspended from surface rafts, which are anchored to the bottom. Rack Culture (Figure 6), involving cages, bags, and racks that are either raised above the sediment or suspended several feet off of the bottom by lines, is a popular kind of Water Column Culture. The types of racks used in Massachusetts are somewhat constrained by a restriction that structures cannot be higher than 18 inches above the tidal flats.

Figure 6: Typical rack culture in Massachusetts, with bags of shellfish elevated above the tidal flat.

Regardless of the methods used, these “farms in the water column” present unusual challenges to growers. The shellfish producer has little influence over inputs and exports in this dynamic tidal system. However, selection of “seed”, gear layout and management, and management of pests and disease are among the few factors that the operator can control.

III. Resource Concerns Associated with Shellfish Aquaculture

Environmental impacts of aquaculture vary with the type of organism raised and the production system used (Goldberg, et al., 2001). Properly managed commercial shellfish production is generally considered to have minimal impact on other coastal marine resources. Some potential impacts are mitigated by the fact that shellfish aquaculture requires clean water, does not use introduced food or chemicals, and produces little waste (Deal, 2005). However, a number of impacts have been identified in the literature, and, as with any agricultural operation, the magnitude of environmental changes that occur from shellfish aquaculture is linked to the scale of the cultivation processes (Kaiser, et al., 1998). Site-specific environmental factors such as the extent and frequency of tidal flushing can also ameliorate or intensify impacts.

Barnstable Harbor, Wellfleet Harbor, Pleasant Bay, Inner Cape Cod Bay, and Waquoit Bay contain aquaculture leases and have been designated by the Commonwealth as Areas of Critical Environmental Concern (ACEC) due to the presence of extraordinary natural resources. The purpose of the ACEC Program is to preserve, restore, and enhance critical environmental resources and resource areas through increased levels of protection, facilitation, and support of the stewardship within the areas. While shellfish aquaculture is dependent upon the extraordinary natural resources that exist in these waters, commercial shellfish operations may impact these same resources in various ways.

Soil

The sediments upon which shellfish are grown in Massachusetts are considered to be “subaqueous soils”. As defined by NRCS, subaqueous soils occur under shallow water and undergo pedogenesis, or the process of soil formation. These soils provide the same functions and undergo processes similar to those occurring in terrestrial soils. They support submerged aquatic vegetation, provide nutrients, structure and habitats for diverse benthic faunal communities, and have a discernable topography (Bradley and Stolt, 2003).

In the practice of commercial aquaculture, equipment is placed on the bare, intermittently exposed soils of previously unmodified tidal flats. These subaqueous soils exist naturally in a very dynamic environment, subject to diurnal tidal flows and harsh winter conditions, while providing substrate, food and cover for various vegetative, benthic, aquatic, and even terrestrial communities.

Geomorphology. Placement of equipment upon tidal flats may affect substrate stability and local geomorphic interactions within each of the bays, inlets, and harbors where shellfish aquaculture is practiced. Netting and other protection devices intended to protect young clams and oysters from predators can result in areas becoming more stable over time as they are sheltered from currents and normal tidal sediment transport dynamics (Kaiser et al., 1998). Racks and other equipment that pose obstructions to tidal flow can produce higher sedimentation rates in some areas and local scour that increases erosion in others. However, the magnitude of scour, aggradation, or stabilization is related to the number and types of equipment used, where the equipment is placed in intertidal areas, and the nature of tidal flow rates and embayment substrates. Shellfish farmers in Massachusetts generally avoid areas where tidal action creates maintenance issues, and long-term soil stabilization is relatively rare because many growers remove the majority of their equipment during the winter months when coastal conditions are the most rigorous.

Sediment Disturbance. Establishment and maintenance of shellfish plots often results in disturbance of marine sediments. In the establishment of bottom culture shellfish plots for the grow out phase, the edges of anti-predator netting are buried in the sediments of the tidal flats (Figure 7), creating areas of localized disturbance subject to increased erosion. Periodic replacement of nets throughout the growing season produces similar results. Sediments may also be disturbed when racks, posts or other objects are driven into the sediments for use in off-bottom culture or marking lease boundaries. Similarly, dismantlement of equipment to remove it during the winter may also disturb sediments.

Figure 7: Localized soil disturbance occurs when predator exclusion nets are placed over and buried in sediments.

Other aquaculture activities that may disturb sediments include harvest in bottom culture and the use of motorboats to access shellfish plots. Short-term adverse impacts to benthic organisms and communities can be severe when shellfish are harvested with hydraulic rakes. Hand-raking, which leaves most of the sediment in place, does not affect all of the benthic organisms and allows rapid recovery of communities (Kaiser, et al., 1998). The amount of sediment disturbance that occurs from commercial shellfish harvesting is, however, less than what would occur from harvest of wild stocks, due to increased stocking density (Shumway, et al., 2003). A considerable amount of bottom sediments may also be moved by the operation of outboard motors in water less than 30 inches deep (Jackivicz and Kuzminski, 1973), a common occurrence during low tide along the tidal flats.

Sediment disturbance increases the potential for erosion, transport, sedimentation and release of organic matter and other nutrients associated with sediments. Organic matter could pose water quality problems if transported from shellfish plots where tidal hydraulics were weak or nonexistent. Disturbed sediments could deplete dissolved oxygen, increase nutrients, and introduce suspended sediments and sedimentation that are out of phase and concentration with the life history of native intertidal animals. While the tidal flux along the coastal areas of Massachusetts increases the potential for sediment movement following disturbance, it is generally strong enough to provide a thorough exchange of materials and oxygen, mitigating any adverse impacts that may result from disturbance.

Benthic Communities. Shellfish aquaculture can adversely impact the benthic communities in the immediate vicinity of the aquaculture plots. These benthic organisms are important food sources for many fish and bird species. Shellfish deposit feces and pseudofeces into the environment, increasing levels of nutrients and organic matter in benthic communities. The filtration activities of the shellfish can also result in an increased sedimentation rate and, in combination with pseudofeces, form “mussel mud” that persists in excess of 18 months. Sedimentation can result in high levels of mortality in benthic communities from burial and/or low dissolved oxygen levels in buried substrates. Environmental effects are most severe where water exchange is restricted (Kaiser, et al., 1998). As noted above, this is not the situation in Massachusetts waters where diurnal tides appear to provide sufficient flushing action to minimize accumulation of organic matter and fine sediments.

Water Quantity

The tidal and subtidal flats where shellfish are grown are dynamic hydrologic systems. Tides along the eastern U.S. coastline are diurnal, with two high tides and two low tides each day. As a result, conditions on the tidal flats are constantly changing.

Sufficient water quantity and quality is critical for shellfish production. Shellfish rely on water flow for oxygen and food. Tidal flows also carry any wastes produced by the shellfish away from the production area. The installation of structures for shellfish production may influence these flows, changing velocities and potentially reducing flushing, particularly where leases and structures are packed closely-together (Deal, 2005).

Ice. Ice formation involves the basic processes of heat exchange, nucleation, and ice growth. Conditions most suitable for ice formation occur where flows are laminar and velocities are low, permitting supercooling of the surface. Tidal flats, characterized by large surface area to volume ratio, can quickly exchange heat with the atmosphere. Hence, given the same meteorological conditions, wide shallow intertidal zones cool more rapidly than deeper areas and freeze more easily and often.

Once nucleated, a supercooled layer of water will promote the rapid development of appreciable ice cover across large surfaces in a very short amount of time. As in rivers and streams, fluid in shellfish aquaculture areas is in motion. Therefore, evolving ice crystals must oppose the forces of moving water if they are to grow and ultimately form a solid ice cover. However, aquaculture gear not removed in the winter provides slackwater areas where ice could form and propagate. Once ice cover gains a foothold adjacent to obstructions in the water column, it creates and maintains conditions that encourage even greater ice accumulation.

Floating ice can significantly affect the geomorphology and ecology of coastal areas. Ice floes can obstruct harbors and inlets, promoting scour and fill along areas where shipping and navigation are important to transportation and commerce. Ice scour can significantly alter coastal ecosystems, removing submerged vegetation and killing or injuring hibernating or aestivating animals. Items locked in ice are readily transported, and can come to rest in transportation corridors, becoming navigational hazards. Further, ice floes can pile up along coastal areas, redirecting waves and currents into areas where no natural protection exists. Consequently, aquaculture gear left on tidal flats along the coasts of Massachusetts poses a significant risk to the coastal ecology, navigational safety, and the negative effects of winter storm-driven waves.

Water Quality

Coastal embayments throughout Massachusetts and the Cape Cod area are becoming nutrient enriched. Nutrient enrichment has been related to changes in watershed land-use associated with increasing population within the coastal zone. The ecological health of many Cape Code area embayments is declining due to nutrient levels that exceed the embayments' assimilative capacity as a result of this "eutrophication" or nutrient enrichment from anthropogenic sources. The decline in ecological health results in the loss of fisheries habitat, eelgrass beds, and a general disruption of benthic communities. This decline also leads to aesthetic degradation and impaired recreational use of coastal waters.

Many estuaries are at risk of, or are already experiencing, degraded water quality and habitat due to increases in nitrogen discharges within their watersheds. With local communities dependent on a high quality of water for fishing, shellfishing, and tourism, degradation of these resources has serious economic results: reductions in property values, local commerce, and tax revenues. Given the synergy among these interests, embayment protection and restoration is of paramount importance to the Commonwealth and its coastal communities (MDEP, 2003).

In addition to nutrient-related ecological declines, an increasing number of embayments are being closed to swimming, shellfishing, and other activities as a result of bacterial contamination. While bacterial contamination does not generally degrade the habitat, it restricts human uses. However, like nutrients, bacterial contamination is related to changes in land-use as the watershed becomes more developed. The regional effects of both nutrient loading and bacterial contamination span the spectrum from environmental to socio-economic impacts and have direct consequences to the culture, economy, and tax base of Massachusetts's coastal communities (Howes et al., 2001).

Biofiltration. As filter-feeders, shellfish utilize a natural food supply, drawing in food and oxygen from surrounding waters. A single oyster can filter over 15 gallons a day, retaining particles as small as 2 microns (ECSGA, unknown). Unlike many other aquaculture enterprises, the production of shellfish does not contribute to nutrient loading. Instead, shellfish improve water quality as they feed by filtering microscopic particles from the water. Oysters, for example, reduce estuarine turbidities when they actively filter suspended phytoplankton and inorganic particles from the water column. Nitrogen and phosphorous associated with the sediments and phytoplankton are incorporated into body of the shellfish or are deposited to the sediment surface. There, nitrogen will go through a microbial nitrification-denitrification process that will lead to the loss of nitrogen from the ecosystem and phosphorus burial in the sediments. (Newell et al., 2002)

Biofiltration can be extremely important in regulating water column processes where bivalves are abundant in coastal waters and in seasons when water temperatures are warm enough to promote active feeding. Removal of phytoplankton can increase the amount of light which reaches the sediment surface, extending the depth to which ecologically important benthic plants, such as seagrasses and benthic microalgae, can grow.

Oysters and clams are thought to be an important part of a water quality restoration effort. Estimates made by Newell (1988) suggest that before 1870, the Chesapeake Bay native oyster population could filter the entire Bay in less than 4 days. By 1988, the sharply reduced size of Bay-wide oyster populations increased that time to 325 days.   For this reason, reintroduction of oysters into Chesapeake Bay is an important part of the Bay restoration effort. Oysters and clams have also been used in other areas such as Prince Edward Island, Canada and Israel, to mitigate impacts of landuse on estuaries.

Boat Motors. According to the Environmental Protection Agency (EPA), there are currently over 12 million marine engines operated in the United States. The traditional carbureted two-stroke outboard motor is a significant source of pollution in often fragile areas. Between 20 and 30 percent of the fuel and oil used by these engines gets discharged into the water through the exhaust port unburned – producing the all-too-familiar rainbow sheen. That means if you operate a two-stroke outboard motor, for every 10 gallons of gas you use, more than 2 gallons go directly into the stream, lake, or estuary where you are boating. The used oil from leaky motors can contain toxic chemicals and heavy metals and will stick to everything from beach sand to bird feathers. One gallon of motor oil can create an oil slick on surface water up to eight acres in size and contaminate up to one million gallons of water.

In addition, incomplete combustion of fuel and oil can form polycyclic aromatic hydrocarbons (PAH). A number of PAHs, such as benzo(a)pyrene, are carcinogenic and mutagenic. These PAHs and unburned petrochemicals released from two-stroke engines eventually settle within the estuarine and shallow ecosystems of bays, lakes, rivers, and oceans, where marine life is youngest and most vulnerable. These areas are inhabited by fish eggs, larvae, algae, shellfish, crab, lobster, shrimp, and zoo-plankton which are the base of the food chain. Though little data are available, information from the U.S. Environmental Protection Agency indicates that PAHs are believed to bioconcentrate in aquatic organisms (EPA, 2006a).

Toxicological studies have shown that long term exposure to exhaust from outboard engines is toxic to aquatic organisms in laboratory environments (Jackivicz, and Kuzminski, 1973), with exhaust from two-stroke engines proving to be much more toxic than that from four-stroke engines (Juttner, et al., 1995). Fortunately, the vast amounts of water and dynamic coastal hydraulic system along the Massachusetts coast should prevent toxic chemicals in engine exhaust from ever reaching toxic levels.

Traditional carbureted two-stroke engines, mounted on broad-beamed working skiffs (Figure 8), continue to be popular with shellfish producers because they are simpler and lighter, producing about twice as much power per pound of engine weight as newer, more fuel efficient four-stroke engines. Four-stroke engines are 30 percent more expensive, heavier and more complex, making maintenance more difficult.

Figure 8: Broad-beamed working skiffs, like this one, with 25 to 40 horsepower outboard motors are commonly used to access shellfish leases.

Air

Along with much of the rest of the Commonwealth, the Cape Cod area of southeastern Massachusetts has been designated as nonattainment for 8-hour ground level ozone. EPA designates an area as nonattainment if it has violated, or has contributed to violations of the national 8-hour ozone standard over a three-year period. Ozone is the prime ingredient of smog. When inhaled, even at very low levels, ozone can cause acute respiratory problems; aggravate asthma; cause significant temporary decreases in lung capacity of 15 to over 20 percent in some healthy adults; cause inflammation of lung tissue; lead to hospital admissions and emergency room visits; and impair the body's immune system defenses, making people more susceptible to respiratory illnesses, including bronchitis and pneumonia (EPA, 2006b). If not for the boats and outboard motors necessary to access shellfish leases on tidal flats, it is not likely that the commercial production of shellfish would impact air quality.

Boat Motors. Currently, 12.5 million marine engines are operated in the United States. These marine engines are among the highest contributors of air pollution in many areas of the country. Pollution from marine engines produces ground-level ozone (smog), and the two-stroke engine, found on 75 percent of all boats and personal watercraft, causes 1.1 billion pounds of hydrocarbon emissions per year (Martin, 1999).

Of nonroad sources, EPA has determined that gasoline marine engines are one of the largest average contributors of hydrocarbon (HC) emissions. Of all categories of nonroad engines, recreational marine engines contribute the second highest average level of HC exhaust emissions. Only small gasoline engines used in lawn and garden equipment emit higher levels on average. The California Air Resources Board found that a seven-hour ride on a personal watercraft powered by a conventional two-stroke engine produces the same amount of smog-forming emissions as over 100,000 miles driven in a modern passenger car. Controlling emissions from these engines will help reduce adverse health and welfare impacts associated with ground-level ozone (smog).

Conventional carbureted marine engines also emit 75% to 95% more ozone-forming exhaust (NO_x) than do two-stroke direct fuel injection engines for the same horsepower. A conventional four-stroke engine produces roughly 14 times less ozone-forming pollution as a carbureted two-stroke stroke engine. The nitrogen dioxide (NO_2) emitted by carbureted engines lowers resistance to respiratory infections, aggravates symptoms associated with asthma and bronchitis, and contributes to acid deposition (acid rain).

Plants

The coastal waters of southeastern Massachusetts provide habitats for numerous plant species, ranging from microscopic algae to undersea grasses. These plants are the base for aquatic food webs and provide other important ecological services. Decreasing water quality, sediment contamination, and seafloor disturbance can alter environmental features necessary for plant growth and survival. Placement of aquaculture equipment in the marine environment can also create new habitat on which plants flourish.

Seagrasses. The shallow, protected intertidal and subtidal flats of Cape Cod provide habitat for seagrasses, predominantly eelgrass (*Zostera marina*). Widgeon grass (*Ruppia maritime*) is also found in areas of reduced salinity in Cape Cod Bay and Buzzards Bay. These plants, often referred to as submerged aquatic vegetation (SAV) or submersed rooted vascular beds (SRV), are rooted in the bottom sediments and almost all of their structure is submerged. Seagrass beds provide important habitat, serving as nurseries, refuges, and feeding grounds for fish, waterfowl and invertebrates. The leaf canopy calms the water, filters suspended matter and, with the roots and rhizomes, stabilizes sediment, perhaps slowing coastal erosion (Costa, 1988; MA DEP, 2006; MA DMF, 2002).

Eelgrass is found in a variety of habitats, but predominantly in soft sediments. The upper limit of growth is set by physical factors, such as wave action, ice scour and desiccation, while the lower limit is set by light penetration through the water column. Although eelgrass reproduces both vegetatively and by seed production, beds are generally maintained and expanded by vegetative lateral shoots and by recruitment of new seedlings. Bare areas can be colonized by new seedlings, but established plants that are uprooted tend to float, be cast ashore or washed out to sea (Costa, 1988).

Several surveys of eelgrass area and cover have been conducted (Figure 9), and declines in eelgrass over time have been observed in Massachusetts (Costa, 1988; MA DEP, 2006; MA DMF, 2002). Eelgrass loss is currently more widespread in southern Cape Cod and Buzzards Bay (Wilbur, 2004). Threats to eelgrass resources may include (Costa, 2004; Costa 2005; Lipskey, et. al., 2005; MA DMF, 2002):

- storms and icing
- shading by coastal construction (docks, bulkheads and other man-made objects)
- physical disturbance by boats, anchors and mooring chains
- shallow water operation of boat motors and jet skis
    - shearing and scarring of plants
    - re-suspension of soft sediments
- dredging
- harvest of fish and shellfish
- decreased water quality
    - sedimentation
    - coastal eutrophication

The current large-scale decline in eelgrass is principally attributed to decreases in water quality, particularly increased nitrogen loading. Increased levels of nitrogen, the limiting nutrient in coastal marine environments, typically result in increased growth and abundance of algae, which in turn reduces the amount of sunlight reaching eelgrass beds (Costa, 2005). On the local scale, human disturbances such as shading by placement of structures in or over the water, shearing by boat motors, or hydraulic dredging may be important. Both the percent of habitat disturbed at a site each year and the size of the disturbance affects natural recovery of the eelgrass beds (Costa, 1988).

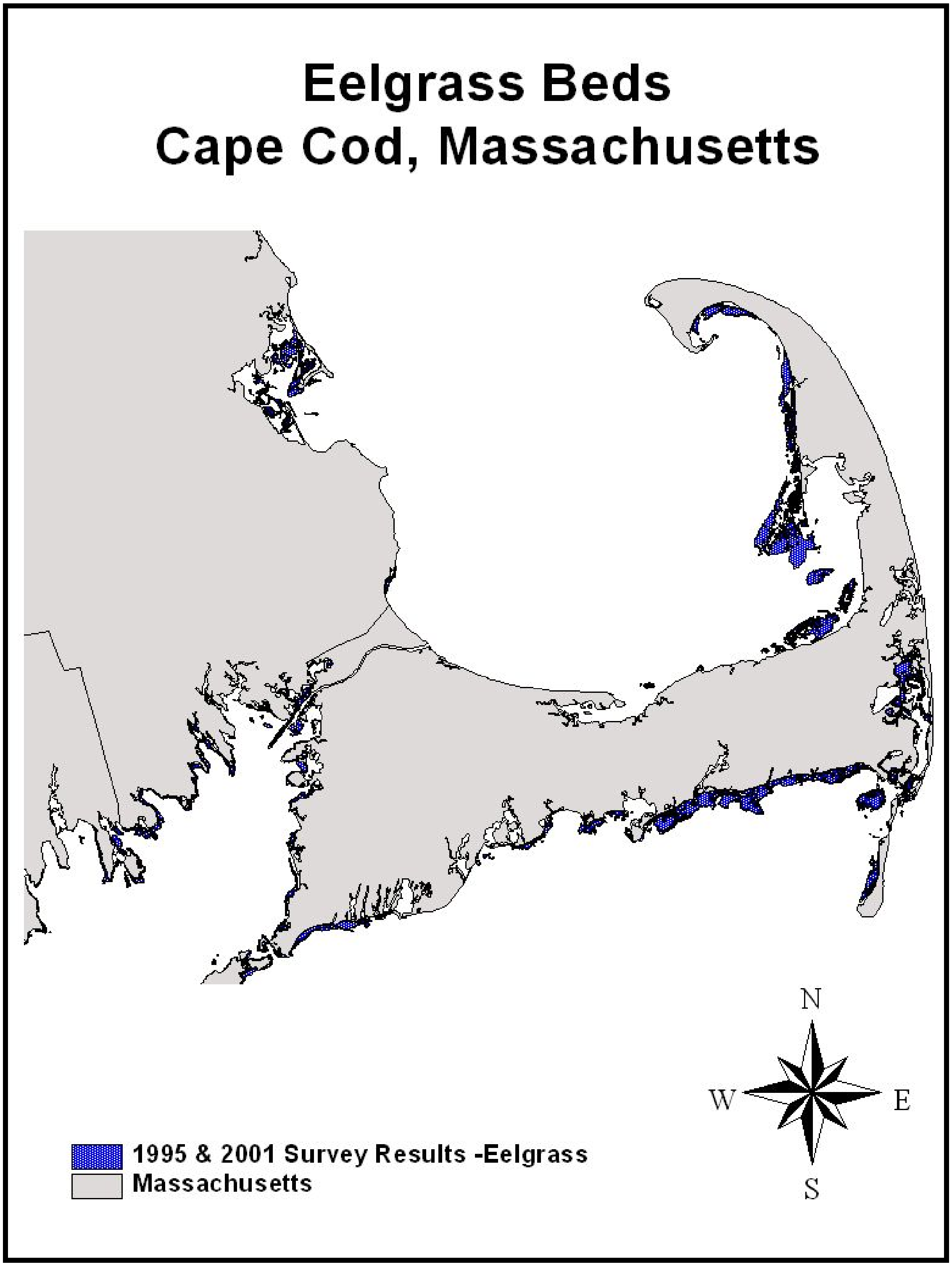

Figure 9: Eelgrass beds in the Cape Cod area, from 1995 and 2001 surveys.

Commercial shellfish production in Massachusetts is limited to "nonproductive tideland" (MA OCZM, 1995a), which is commonly interpreted to mean the absence of naturally productive shellfish beds, seagrass beds, and critical habitat for an aquatic or upland species identified as important, threatened or endangered. The determination of presence or absence of eelgrass is made during a mandated site review when the Massachusetts Marine Division of Marine Fisheries must "certify that issuance of a shellfish aquaculture license and operation thereunder will cause no substantial adverse effect on the shellfish or other natural resources of the city or town" (MA General Law, Part I, Title XIX, Chaper 130, Section 57). The Aquaculture Guidelines included in the Programmatic General Permit issued by the U.S. Army Corps of Engineers prohibit activities "within a distance of 25 feet from beds of eelgrass, widgeon grass, or salt marsh" as well as damage or removal of vegetation (USACE, 2005).

Although eelgrass should not be present on lease sites when commercial shellfish operations are established, aquaculture activities may influence the potential for eelgrass establishment on the site over time. Establishment is unlikely on sites where bottom culture is practiced due to disturbance of the site during grow out and harvest. However, the structures associated with off-bottom culture may provide new sites for eelgrass establishment by stabilizing and aggrading sediments. This is most likely to occur in areas where eelgrass beds are located nearby off-bottom culture operations. Higher populations of shellfish on aquaculture leases may also benefit eelgrass beds by improving water quality through biofiltration.

Biofouling. Marine biofouling is the accumulation of microorganisms, plants, and animals on artificial surfaces submerged in seawater. Microfoulers such as sticky biofilms of bacteria colonize new surfaces first (Figure 10), facilitating the growth of macrofoulers such as barnacles, limpets and seaweeds (Clare, 1998). Biofoulers will grow on almost any manmade surface. The structures used in aquaculture provide increased surface area for the growth of fouling organisms, which may temporarily benefit

Figure 10: Biofouling organisms on a recently installed anti-predator net.

microorganisms, grazers and other organisms by providing an increased food supply (Shumway, et. al., 2003).

Figure 11: Biofouling can reduce water flow critical to shellfish.

The growth of biofouling organisms may actually benefit the natural environment by providing additional primary and secondary production. However, with coastal eutrophication enhancing the growth of these organisms, biofouling is a ubiquitous "human" concern for shellfish producers (Leavitt, 2004). Biofouling organisms block the mesh openings in nets or bags used in aquaculture, restricting water flow across the growing shellfish (Figure 11). Shellfish rely on water flow to provide oxygen and food; without adequate water flow, shellfish growth will slow or stop, and ultimately the shellfish will die. Marine macroalgae may also settle on top of shellfish and cause local hypoxia/anoxic conditions. Shellfish producers report that biofouling results in over-crowding, reduced survival, reduced growth rates, and increased size distribution of harvested shellfish (Univ. of Florida, 2006). In addition, biofouling shades and reduces water flow to naturally occurring benthic communities that may coexist with the shellfish operation.

In a survey of Northeastern shellfish producers, 40 percent indicated that biofouling is a major and constant problem, increasing operational costs of labor, repair/maintenance and fuel, and consuming 20 percent of annual operating costs (Univ. of Florida, 2006). Biofouling organisms attach firmly to netting and are hard to remove. In Massachusetts, shellfish producers are prohibited from using chemicals, including pesticides, to manage these organisms. Typical techniques for removal include physically brushing the organisms from structures or applying high-pressure streams of water. Removal and air drying of nets is also used (Leavitt, 2004). In some cases, removal of biofouling can result in localized degradation of water quality. Cleaning large amounts of gear on-site at one time, could result in increased turbidity and undesirable oxygen consumption/depletion as the biofouling organisms undergo decay. Removal and cleaning of gear off-site, on an upland area, is preferable since it eliminates the potential for increased oxygen demand and removes excess nutrients that have been incorporated into the biofouling organisms from eutrophic marine systems. However, it has significant economic implications for the shellfish producer who must purchase additional replacement gear.

Animals

The sandy coves and embayments used as aquaculture plots for growing clams and oysters also provide foraging and nursery habitat for a variety of marine species (Figure 12), while freshwater rivers and streams serve as inland conduits for migratory fishes. Migratory, anadromous, and catadromous fish common to Massachusetts ecosystems include shad, alewives, striped bass, herring, perch, sturgeon (Atlantic and shortnose), Atlantic salmon, brook lamprey, and American eel. Although life history timing and habitat usage differs among these species, all require suitable coastal and estuarine habitat and unimpeded passage into and out of freshwater to survive.

Many commercially and recreationally important marine species, including winter flounder, black sea bass, tautog, bluefish, scup, and menhaden, use tidal and near-shore environments on a seasonal basis as nursery, feeding, and foraging areas. Coastal and estuarine environments also provide essential habitat roles to marine mammals, sea turtles, and a host of birds and terrestrial animals. For example, sea turtles and seals are known to frequent coves, embayments, beaches, and marshes during feeding and migration. Whales, porpoises, and dolphins generally remain further offshore in deeper waters with topographic and oceanic features that provide better habitat. However, beachings and near-shore sightings occur infrequently, and some inlets and bay entrances provide depth transitions that help concentrate prey species for feeding.

Numerous species of state or federal concern (i.e., listed or protected under the Endangered Species Act [ESA] or Marine Mammal Protection Act [MMPA]), including northern right whales, hooded seals, sea turtles (e.g., Kemp's ridley, loggerhead, and green), Atlantic salmon, shortnosed sturgeon, piping plover, roseate tern, and northern diamondback terrapin, frequent the coastal and offshore areas of Massachusetts. Animals listed as threatened or endangered, or as a state species of concern, are usually afforded special regulations and habitat restrictions that protect critical life history requirements. For example, a significant portion of the coast of Massachusetts, including Cape Cod Bay and Massachusetts Bay, is listed as critical habitat for the Northern Right Whale. Right whales use these areas as summer feeding and nursery grounds.

Shellfish aquaculture introduces a number of modifications to the natural environment that have the potential to affect aquatic and terrestrial resources. Many of the factors that make these areas desirable for shellfish production are also those that may attract and benefit wildlife. The following sections detail some potential effects to animal resources from equipment and activities related to growing clams and oysters on tidal flats.

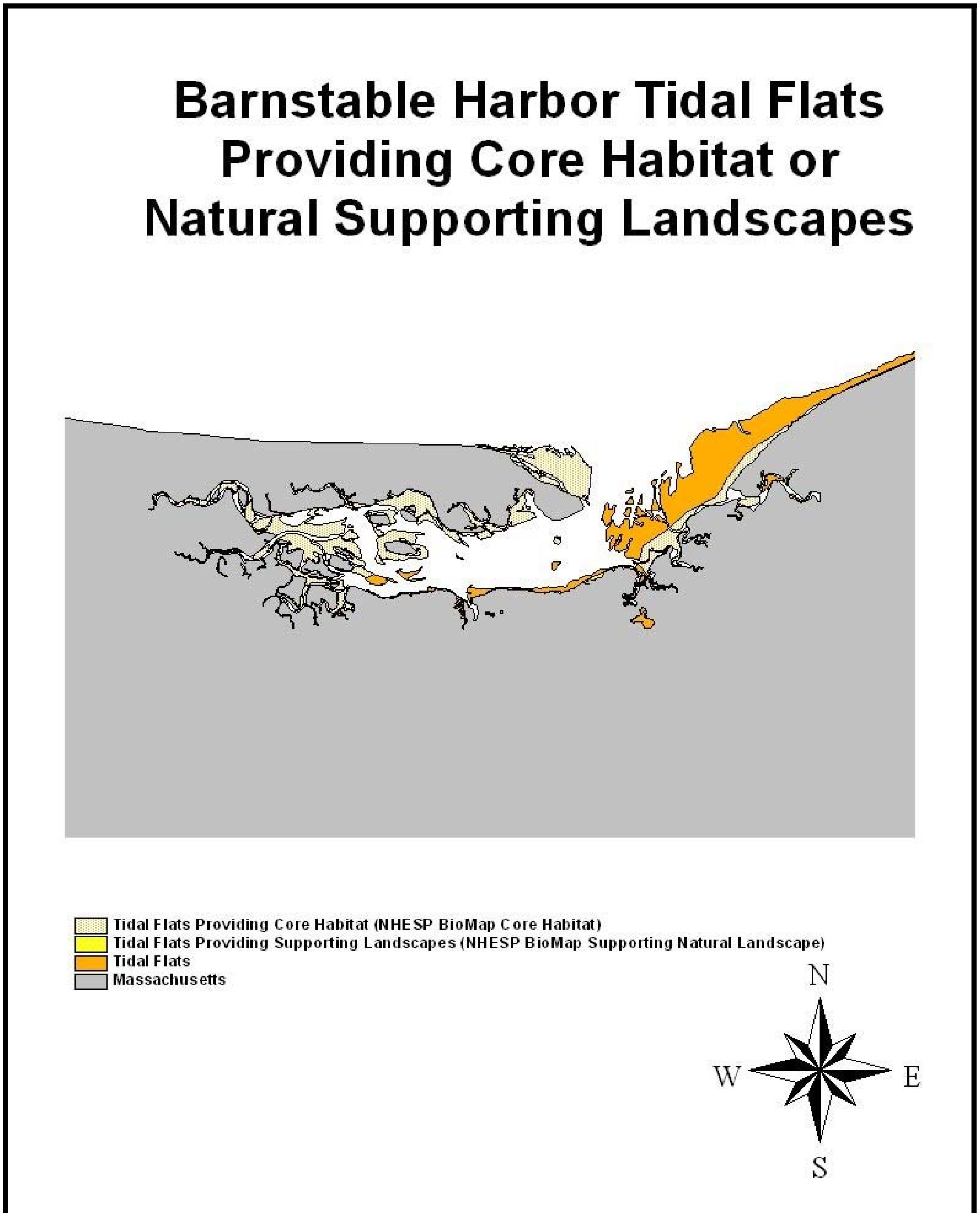

Figure 12: Tidal flats used for aquaculture also serve as important habitat for wildlife; for example, those in Barnstable Harbor identified as providing core habitat or "supporting natural landscapes" for wildlife species.

Entanglement. Mismanaged, damaged, or abandoned aquaculture gear poses a threat to marine mammals, sea turtles, terrapins, and bird species that frequent tidal flats or adjacent coastal areas. Gear that becomes dislodged, is left out over the winter, or damaged from boat propellers will float freely in coastal and estuarine areas where aquatic and avian species may become entangled.

Entanglement poses a host of serious consequences to animals, ranging from nuisances that hinder feeding or growth to death. Until recent federal restrictions and rules regarding fishing areas and gear, a major source of mortality for northern right whales, sei whales, and fin whales was entanglement in nets, floats, and tether lines (Knowlton and Kraus, 2001). Sea turtles, whales, seals, and dolphins have been found with various injuries attributable to gear entanglement for varying periods of time. For example, turtles that are bromating, i.e., in a very low metabolic state, are relatively sluggish, and entanglement in nets or other debris that prohibits them from surfacing for air will result in their drowning. Resident fish species that overwinter by burrowing into tidal pools (e.g., sticklebacks, killifish, mummichog, and sheepshead minnow) could be adversely affected by loose gear that prevents access to substrates (Howes and Goehringer 1996). Consequently, these fish will be less likely to survive the winter, and may be at increased risk of predation because they are unable to reach adequate cover.

Behavioral Changes. Behavioral changes in tidal and estuarine animal species will likely result from shellfish aquaculture practices, including avoidance, movement to and exploitation of new or similar habitat adjacent to aquaculture plots, or increased foraging and feeding around structure created by the practice. Generally, these behavioral changes are attributable to the physical presence of aquaculture gear, increased boat and human traffic, and ecosystem productivity changes from growing high densities of shellfish.

Aquaculture equipment adds new structure to a tidal flat area (Figure 13). Consequently, animals inhabiting or transiting the area may exhibit some form of behavioral change in reaction to new structure. Tidal flats and embayments used for aquaculture purposes are subject to wide depth variations according to daily tides, and most shellfish farms are associated with topographic "highs" that can be worked when the tide is low or out. Where these "highs" exist, behavioral changes in marine species are likely to be minimal because racks and cages generally don't extend more than 18 inches off the substrate and are placed in areas subjected to exposure to air during low tide. Thus, most aquaculture gear is only fully inundated for half a day (or less). Coastal and estuarine fish species are accustomed to daily changes in habitat location and quality, and exploit different portions of an embayment or cove according to tidal direction and stage.

Figure 13: Some types of birds may continue to land and feed among the structures present on aquaculture plots, while other species may avoid them.

Shellfish gear may provide additional summer cover and foraging opportunities for small-bodied or juvenile fish while the tide is high. Although the footprints of aquaculture plots cover natural substrates, shellfish production and management may increase system productivity and enhance the overall abundance of food organisms in the adjacent area for marine animals, birds, and terrestrial species. Small invertebrates that are often attracted to the gear and the biofouling organisms growing there can provide an important food source for juvenile fish and birds. Similarly, food availability to birds and marine fishes is likely increased at certain times when aquaculturists disturb a few inches of sediment while performing maintenance activities on or harvesting a given shellfish plot. Organisms within this layer of sediment are disturbed, brought nearer the surface, and thus accessed more easily by birds and other predators.

At the same time, the anti-predator netting installed over shellfish plots may reduce avian foraging success by excluding birds from traditional foraging grounds and providing refuges for prey (Deal, 2005; Lloyd, 2003). Tidal flats are a significant foraging area for resident and migratory shorebirds, wading birds, diving ducks, and dabbling ducks. Different guilds of species use these areas at different times in the tidal cycle. Exposed flats are important for foraging shorebirds at low tide, while wading birds will use the same areas when they are partially flooded, and ducks will feed there during higher tides. Potential impacts of exclusion of birds from these important foraging areas vary depending upon the extent of exclusion, the habitat needs of the species and the time of year. During spring and fall migrations, sustaining energy reserves and protein levels is critical for survival and reproductive success of migrants; summer and permanent residents depend upon benthic invertebrates and juvenile shellfish during the breeding season; and over-wintering sea and diving ducks need resources to maintain body fat under challenging circumstances.

Other localized changes in food webs may also occur, especially where shellfish densities are high. Filtering of phytoplankton by shellfish diverts primary production and energy flow from planktonic to benthic food webs. Depletion of plankton, the primary building block for all marine food webs, may alter availability of food for zooplankton, larval fish (Cranford, et al., 2003), and, in turn, all organisms in the marine ecosystem. High densities of shellfish may also reduce the larval settlement of other benthic species as their larvae are filtered and digested or become trapped within pseudofaeces (Kaiser, et al., 1998).

Unimpeded movement and migration corridors are vital to all animals. Benthic organisms and fish can be adversely affected by continuous barriers that preclude them from accessing habitats critical to their life histories. Long rows of racks or anti-predator netting on a shellfish lease may block access to feeding or nesting areas. For example, horseshoe crabs crawl up onto beaches to reproduce between April and June in Massachusetts coastal areas. Shellfish plots that do not include corridors between nets, cages, and/or racks may pose significant passage barriers to these animals, potentially adversely affecting their chances of successful reproduction.

Shellfish farming practices will likely increase boat traffic in a given area above baseline conditions and thus affect animal behavior. Marine animals and birds all react differently to boat traffic, and the greatest magnitude of adverse effects are generally associated with boat movements in sensitive areas used for staging, spawning, breeding, incubation, or nurseries. Shellfish operations largely avoid or are precluded from using sensitive habitats by prevailing Massachusetts laws and ordinances, so adverse effects from increased boat traffic should be minimized. Small amounts of petroleum distillates in boat exhaust are not expected to result in significant behavioral changes.

Increased Beach Access. The sandy beaches and salt marshes of Massachusetts provide habitat for both resident and migratory bird species and numerous terrestrial mammals. For the most part, these mammals restrict their activities to the marsh and beaches and are not normally found on the mud flats exposed at low tide. Although the effects of marine aquaculture on birds and mammals have not been extensively studied, Kelly et al. (1996) reported that tidal flats with aquacultural operations were generally used less by migratory birds in California, although one species preferred these areas.

Although many avian species utilize the beaches and surrounding habitat, there are three species of notable concern. Two federally listed bird species, the piping plover

(*Charadrius melodus*) and roseate tern (*Sterna dougalli*), and one bird species determined to be of "special concern" by the Massachusetts Natural Heritage Program and Endangered Species Program, the least tern (*Sterna antillarum*), are known to nest on the sandy beaches and offshore islands of Massachusetts. These beach-nesting birds are very sensitive to disturbance in the nesting through post-fledging periods, which run from early April to late August (USFWS, 1996). During this time, known nesting sites, as well as potential sites, are blocked off to vehicle, and sometimes foot traffic, to protect the nests. In addition, individual nests are often covered by wire cages to protect the nest from predation.

Development, increases in human activity on and near nesting sites, and nest predation are major concerns and are considered to be factors in the reduced populations of these species. Even without the actual predation of nests, human activity can disturb nesting birds, causing them to abandon the nests. Even kite flying near ground-nesting birds can affect their behavior because the kites are perceived as large avian predators. (Howes and Goehringer, 1996). Some shellfish aquaculture leases are accessed directly via beaches. The increased presence of shellfish producers crossing the beaches to access leases and transport gear may endanger nests, particularly where the nesting season and efforts to re-establish shellfish on leases in the spring coincide in time and space.

Diseases and Parasites. Shellfish aquaculture increases the density of clams and oysters in a given area and thus increases chances for disease development and transmission within the shellfish population. A number of shellfish diseases are harmful to wild shellfish populations and potentially disastrous to Massachusetts shellfish producers. These diseases are usually caused by parasites (e.g., Multinucleated Spheroid Unknown [MSX] and Quahog Parasite Unknown [QPX]), bacteria (e.g., Juvenile Oyster Disease [JOD]), and viruses (e.g., *Hematopoietic neoplasia* [clam leukemia]). Movement and transmission of these diseases varies. Some infect by direct transmission, e.g., a sick shellfish dies and the pathogen is released to a neighboring shellfish of the same species. Other pathogens infect by indirect transmission where an alternate host or carrier moves the disease from one individual to another. Several methodologies can be used by commercial shellfish producers to ensure that aquaculture-introduced pathogens are not transferred to wild shellfish populations.

Disease transfer can be managed through careful monitoring of disease status in shellfish considered for transport to ensure that a disease-free area is not exposed to harmful pathogens. Managing planting densities at a level that maximizes growth helps discourage disease transmission by minimizing density-dependent mortality. Shellfish farmers are well educated on signs and symptoms that may indicate the presence of a given disease on their plots. When potential diseased organisms are identified, shellfish growers usually contact Massachusetts Division of Marine Fisheries shellfish biologists, aquaculture extension agents, the shellfish constable, and neighboring farmers. Producers are critical links in diagnosing and containing any potentially disastrous disease outbreaks that can affect aquaculture beds and adjacent wild shellfish populations.

Another method to control the transmission of pathogens between shellfish plots as well as between "captive" and wild populations involves plot architecture. Corridors of varying widths placed between plots, racks, and growth areas provide: (1) isolation by distance from pathogen transfer; (2) movement and migration corridors for birds, terrestrial, and benthic organisms; and (3) areas from which farmers can access and work their crops. Shellfish disease transmission can be managed by ensuring that individual plots are isolated from adjacent plots and from wild shellfish populations to the maximum extent practicable. If a given plot is infected by a pathogen, direct transmission to nearby plots or wild populations will be greatly limited by relatively narrow strips of unfarmed natural substrate. Although less effective at limiting indirect transmission, corridors between plots also help provide some protection against pathogen transfer by other organisms (e.g., birds, crabs, other molluscs).

Human - Social and Cultural Considerations

In addition to natural resource concerns, there are numerous human concerns associated with marine shellfish aquaculture management. Some of these are:

- Land Use, Access, and Property Rights
- Aesthetics and Navigation
- Regulatory Environment
- Cultural Concerns
- Treaty Rights and Tribal Nations Interests
- Sustainability of Environmental Resources and the Shellfish Industry

Shellfishing in many forms has been part of the lifestyle in the Massachusetts and New England area from early prehistory through the present. A great deal of data is available on the historic, current, and potential practice and effects associated with shellfish aquaculture in the New England area (Mckay, 1998; Shumway et. al., 2003; Underwood, 1995; MA OCZM, 1995a; SEMAC, 2004). However, shellfish aquaculture, in its current intensive, commercial form, has been practiced along the Cape Cod area of Massachusetts for less than 40 years. Prior to that, local fishermen and harvesters used different methods of "seeding" areas with juvenile clams and oysters (Figure 14) and returning to harvest the resulting stock. This practice, which is still used by some local fishermen, differs from the modern form of aquaculture in that it typically does not use artificial cages, boxes, trays or netting to contain and demarcate units of controlled space and shellfish stocks.

Figure 14: Citizens seeding a shellfish area near Barnstable Harbor for recreational use

Land Use, Access, and Property Rights. Massachusetts is unusual in that private individuals can own lands between the low and high tide marks. In most coastal states, these intertidal lands are owned by towns, municipalities, or the state itself, and are normally regulated for the benefit of all residents. In Massachusetts, shellfish aquaculture is practiced on intertidal flats that have historically been used by recreational finfishers, shellfishers, and hunters, as well as recreational boaters and beachcombers in accordance with public trust rights. Permitting and leasing acreages for commercial shellfish production restricts access to tidal flats for other uses and may limit navigation routes, reduce areas available for small scale recreational shellfishing and finfishing, and affect the access rights of adjacent private tidal flat owners. These access issues may have long term implications for shorefront landowners and the public.

The Commonwealth of Massachusetts "recognizes the need to support aquaculture in a manner that is compatible with the other existing uses of Massachusetts' waters and uplands" and to balance aquaculture "with other compatible activities" (Massachusetts Aquaculture Strategic Plan, 1995). Explicit efforts have been made to coordinate aquaculture regulation and permitting in order to facilitate the expansion of the industry in the state. The following statement summarizes the position Massachusetts takes on encouraging the development of aquaculture:

> *Massachusetts is particularly well situated to take advantage of the opportunities in aquaculture, including seafood production as well as technology development. The state has a wealth of diverse marine and freshwater resources well suited to offshore, inshore, and land based aquaculture……Massachusetts is also strategically located to service one of the largest seafood markets in the world – the eastern seaboard of the United States. The state also has an immensely talented and diverse workforce and an established seafood processing and distribution network ready to deliver aquaculture products to domestic and world markets (Massachusetts Aquaculture Strategic Plan, 1995b, Chapter IV, pp. 2).*

Given this strong backing for the development of aquaculture, there are ongoing efforts to clarify and remedy potential conflicts involving permitting and licensing authorities and property rights (MA OCZM, 1995b). Any potential confusion of ownership of the tidal flats is resolved by a review of Massachusetts laws and regulations, which state repeatedly that the granting of a license or permit to practice shellfish aquaculture does not grant any real property rights to the grantee (MA OCZM, 1995a; Leavitt, 2004).

The Massachusetts Supreme Judicial Court has ruled (Pazolt v. Director of the Division of Marine Fisheries, et al., 1994) that aquaculture is not deemed to be part of the public trust right of fishing, and, therefore, aquaculturists must obtain permission from private upland property owners to practice aquaculture in the intertidal zone (MA OCZM, 1995a). Growers are granted exclusive use of the lease site for aquacultural purposes and have exclusive right to harvest within their lease area. The public retains the right to cross aquaculture leases while fishing, fowling, or navigating. However, there are penalties for damaging, disturbing or removing any markings, equipment or shellfish.

Aesthetics and Navigation Issues. The establishment of relatively large, contiguous, shellfish aquaculture areas is becoming more common in southeastern Massachusetts (MA OCZM 1995a; SEMAC 2004; Woods Hole 2000). Within these "areas", individual lessees practice aquaculture on smaller parcels, usually one to four acres in extent. Each lessee may place nets, bags, frames, pens, "hats", lines, cables, and a wide variety of other equipment within their leased area to facilitate the production of shellfish.

At low tide, these structures are exposed to varying degrees, and are visible at substantial distances (Figure 15). Under the Programmatic General Permit issued to the Commonwealth of Massachusetts, structures may protrude no more than eighteen inches above the substrate, (SEMAC, 2004; USACE, 2005). During higher tide conditions, buoys mark the perimeter of groups of these aquaculture enclosures. Upon receipt of a shellfish license, the licensee is required by law to mark the boundaries with "monuments, marks or ranges, and by stakes or buoys, with the number of his license painted in figures at least two inches in height…" (MGL Chapter 130 Section 61). The data are insufficient to ascertain to what degree these structures affect the aesthetics of the shoreline and intertidal zones. The introduction of structures for shellfish aquaculture onto intertidal mudflats certainly has a visual and aesthetic impact, but further assessment is needed to determine the degree and character of the effect.

Figure 15: Structures placed on the tidal flats for shellfish production may impact aesthetics and navigation.

A common problem encountered by both shellfish farmers and other users of shallow water shoreline areas is collision between boats and shellfish gear. Such collisions result in costs for both the shellfish producer and the boat owner. Uprooted and free-floating shellfish gear resulting from collisions may pose an environmental hazard as well. Collisions may best be prevented by placement of consistent, clear, buoys marking the edges of shellfish areas, with concurrent education of watercraft users about the buoy system (Leavitt, 2004).

Regulatory Environment. The regulatory environment for shellfish aquaculture in Massachusetts is complex. The current three tiered system of local, state, and federal regulation incorporates multiple levels and scales of concerns and issues relative to shellfish aquaculture (MA OCZM, 1995a). Massachusetts is a commonwealth of towns and municipalities, with many regulatory functions and powers retained by towns.

Coastal towns and municipalities establish shellfish boards and designate shellfish constables to monitor and enforce local regulations on season and limits. The Massachusetts Division of Marine Fisheries (DMF) oversees the issuance of licenses in order to protect native shellfish stocks and rights of access to waterways and other public trust rights, such as fishing and fowling. Federal permits under the River and Harbors Act of 1899 and compliance with other Federal regulations may be necessary, depending on the location, scope, and land status of any given aquaculture lease.

Massachusetts has recognized the problems that arise from such a mass of regulation, and has responded with the following position:

> *With our wealth of diverse marine and freshwater resources, world class research institutions, concentration of marine technology firms, and strategic location to serve one of the world's largest seafood markets, Massachusetts is a natural place for extensive aquaculture. Up to this time, however, the full opportunities provided by aquaculture have not been seized upon, largely due to a number of regulatory barriers. Now is the time to develop a plan to remove these regulatory barriers so that the future of aquaculture in the Commonwealth can be secured (Massachusetts Aquaculture Strategic Plan, 1995, Executive Summary, pp. 1).*

There is great potential for conflicting and confusing regulation of controversial areas such as shorelines and the intertidal zone. Currently, efforts are being made to coordinate and streamline the permitting and regulatory process for shellfish aquaculture. The regulatory and permitting process is being refined and clarified to reduce conflicts and duplication (Soares, 2006).

Treaty Rights and Tribal Nation Interests. The Wampanoag Tribe has demonstrated traditional fishing and gathering interests throughout the Cape Cod region. Fishing rights in particular have been upheld by case law (Commonwealth of Massachusetts v. Maxim and Greene, discussion found at www.nativeweb.org/pages/legal/wampanoag/), with the result that tribal members can gather shellfish as a part of traditional hunting and gathering rights. These rights, and the rights of other tribes in the region, should be fully assessed to insure treaties are upheld and interests respected..

Cultural Concerns. In addition to the use of the coastal and shoreline areas by indigenous peoples, there is a long and well documented history of use by Euroamericans (McKay, 1998). Early settlement of the pre-Revolutionary War northeast centered around seaports and use of the sea for subsistence and economic purposes. There is a long tradition of "watermen" making a living from the sea and the coast in Massachusetts

(SEMAC, 2004; PBRMA, 1998). Shellfish aquaculture continues this tradition. The expansion of shellfish aquaculture may allow more residents of the area to develop or maintain a lifestyle centered on marine resources utilization. The benefits derived from shellfish aquaculture may allow more individuals and families to remain along the Massachusetts coast as full time residents, without having to search for higher paying work in other areas. Shellfish "farms" may also allow local dealers and restaurants to continue to provide "local" shellfish, such as quahogs and oysters, to consumers. The presence and quality of such "local" products often becomes a "draw" when marketing areas as tourist destinations (Conway, 1997).

Sustainability. The Cape Cod Conservation District emphasizes that sustainability of the marine resource is a concern. Sustainability is mentioned several times in the shellfish aquaculture BMPs (Leavitt, 2004), usually in relation to the environment, e.g., "To be considered a best management practice, an action must maintain or increase crop production while minimizing impact on the environment, i.e. promote sustainability" (p. vi). In defining sustainability, the Massachusetts State Sustainability Program references the 1987 World Commission on Environment and Development Brundtland Report, which defines sustainability as "Meeting the needs of the present generation without compromising the ability of future generations to meet their needs" (MA EOEA, 2004).

In order to have useful discussions of sustainability, desired future conditions must be defined and agreed upon by all parties. Discussions should include the length of time to sustain the resource(s) and/or the industry, what levels of production are desired, with what levels of specifically defined inputs, and threshold levels at which the resource(s) might no longer be considered "sustained". The Conservation District might facilitate such discussions with other stakeholders.

Energy

In addition to the sunlight that powers all marine production, shellfish aquaculture primarily uses energy directly in the form of fossil fuel for marine outboard motors. The amount of energy/fuel used can be impacted by either a change in the number of trips taken for aquaculture purposes or by changing the fuel efficiency of the outboard motor.

An indirect source of energy consumption is the use of disposable tools and gear. An increase in the amount of gear used over a period of time will increase the operation's indirect energy consumption. More gear used would mean more energy required to produce and transport that gear.

IV. Shellfish Aquaculture Management

NRCS Interim Conservation Practice Standard

Definition. According to the NRCS interim practice standard for Massachusetts (Appendix A), *Shellfish Aquaculture Management* is "applying environmentally sound management and sustainable aquaculture practices in the husbandry of bivalve mollusk species."

Purpose. The Massachusetts practice standard states that the purposes of *Shellfish Aquaculture Management* are to:

- Enhance the sustainability of aquaculture;
- Minimize adverse impacts of shellfish farming on water, plant, animal and human resources;
- Ensure dependable quantity and quality of water to support shellfish production; and
- Ensure adequate quantity and quality of food to support shellfish production.

Best Management Practices. The practice standard references the "Best Management Practices for the Shellfish Culture Industry in Southeastern Massachusetts" (Leavitt, 2004) and requires the development of a Shellfish Aquaculture Management Plan addressing all of the identified resource concerns, including, but not limited to:

- Water quality;
- Water quantity;
- Protection of important, threatened, rare and endangered species; and
- Compatibility with other coastal uses.

Plans are also required to describe site-specific requirements for applying practices and an operation and maintenance plan.

Beyond the Practice Standard – the EQIP Pilot Project

NRCS in Massachusetts has encouraged accelerated adoption of certain BMPs by providing financial assistance to shellfish producers. Through this financial assistance, primarily in the form of incentive payments, NRCS shares the increased cost of implementing a new BMP so that the producer will see the resulting environmental and other benefits and continue use of the BMP in the future. An aquaculture management plan (synonymous with a "Farm Management Plan") is required for each participant in the pilot project, based upon an assessment of resource concerns on the participant's operation. Participants are also required to practice proper winter management of gear and are provided incentive payments to carry out any combination of nine Best Management Practices as described in their Shellfish Aquaculture Management Plan and EQIP Schedule of Operations. Descriptions of each component of the EQIP pilot project available to participating shellfish producers are provided in Appendix B.

Benefits of NRCS Assistance

Shellfish aquaculture in Massachusetts appears to produce a mix of beneficial and adverse impacts upon the environment. The magnitude of the impacts will vary between shellfish operations, depending upon site-specific environmental and management factors. Conservation practices established with financial and technical assistance from NRCS are designed to minimize or mitigate adverse environmental impacts and/or produce beneficial effects upon one or more natural resources. A summary of the expected environmental impacts resulting from NRCS participation in Shellfish Aquaculture Management in Massachusetts is provided in Appendix C. As referenced in the interim practice standard (Appendix A), the foundation for NRCS assistance and any impacts that may occur is the Farm Management Plan, developed through the nine-step NRCS Conservation Planning Process, discussed below.

The Farm Management Plan. The Farm Management Plan is equivalent to the Conservation Plan that NRCS provides to other agricultural producers. These plans are the product of a natural resource problem solving and management process, based on the premise that clients will make and implement sound decisions if they understand their resources, natural resource problems and opportunities, and the effects of their decisions (NRCS, 2003).

A properly prepared Farm Management Plan provides a record of the producer's decisions and the information and guidance necessary to implement the BMPs that the producer has selected. The plan encourages the producer to implement BMPs by providing a reference for when and how these planned activities should be carried out, supplying necessary information for continued operation and maintenance, and assisting the producer in scheduling and record keeping. The plan may also help the producer to stay in compliance with any number of local, state, and federal regulations and laws.

In developing the Farm Management Plan and EQIP Schedule of Operations, NRCS assesses and records resource concerns on individual shellfish operations. NRCS also receives updates from producers as they complete BMPs on their EQIP Schedules of Operation. NRCS staff can use this information to determine:

1. Number and percentage of shellfish producers participating in the EQIP Pilot Project;
2. Number and percentage of aquaculture acreage potentially impacted;
3. Number and percentage of EQIP participants
    a. carrying out BMPs as scheduled, and
    b. failing to carry out BMPs as scheduled;
4. BMPs that have been
    a. readily adopted, and
    b. not readily adopted (e.g., item 3b above);
5. Potential (but often qualitative) improvements in identified resource concerns.

Soil. Adverse impacts of aquaculture upon marine sediments present on the tidal flats are generally minimal and are mitigated by the dynamic hydrologic system in which shellfish operations are placed. Diurnal tides "flush" excess nutrients, organics, and disturbed sediments from the shallow embayments along the Massachusetts coastline. Sediment disturbance and adverse impacts to benthic organisms are greatly increased if hydraulic raking is used for harvest.

Potential beneficial impacts to substrate stability have been identified as resulting from shellfish aquaculture. Periodic removal of gear for maintenance (*Net Cycling*) and *Winter Management* may reduce substrate stability. However, without proper removal of shellfish gear as part of *Winter Management*, gear left on the tidal flats over the winter would likely be ripped from the substrate by ice, producing an even greater adverse impact to stability.

Establishment, maintenance and removal of nets and other shellfish gear during *Net Cycling* and *Winter Management* may disturb sediments and result in associated adverse impacts. However, as noted above, greater adverse impacts are likely to result if gear is not removed through *Winter Management*. Designated unfarmed *buffers* within shellfish plots provide areas that are not disturbed and may mitigate some of the adverse impacts.

Benthic communities can be adversely impacted by shellfish aquaculture practices. Establishment of *buffers* within shellfish plots benefits benthic communities by providing a refuge for these organisms. *Net Cycling* and proper *Disposal of Gear Waste* also benefit benthic communities by restoring water flows and reducing the potential for on-site accumulation and decay of organic materials associated with biofouling.

Water Quantity. Shellfish aquaculture does not impact water quantity in the environment per se. However, other factors such as biofouling may adversely affect the quantity of water available for shellfish and other benthic health and productivity. The presence of structures used for aquaculture may also facilitate ice formation on the tidal flats in winter.

Figure 16: Net Cycling provides incentives for producers to purchase extra gear so that gear can be "cycled" and taken off-site for removal of biofouling organisms

When nets and other gear used in off-bottom culture becomes fouled with microorganisms, plants and animals, water flow critical to shellfish production is restricted, and the gear must be cleaned. Cleaning can be accomplished by removing the biofouling organisms on-site or replacing nets with new material. The EQIP pilot project provides an incentive for *Net Cycling*, assisting off-bottom shellfish producers to purchase enough redundant gear to replace at least 20% of their existing gear (Figure 16). This allows producers to regularly remove biofouled gear to an upland site for air drying or treatment with a concentrated saline dip. Regular cycling of gear to remove biofouling organisms benefits shellfish, shellfish producers, and the marine environment by maintaining an adequate water flow for health and productivity of shellfish and other benthic organisms.

Adverse impacts of shellfish aquaculture related to ice formation can be mitigated through proper *Winter Management*. Removal of structures prior to ice formation eliminates any increase in ice formation around the structures. Similarly, incentive payments for proper *Disposal of Gear Waste* encourage producers to remove and dispose of nets and other gear prior to ice formation. Inclusion of unfarmed b*uffer* strips within shellfish plots may also provide a slight benefit in reducing ice formation by providing larger spaces between structures.

Observation of sea ice formation as part of *Environmental Monitoring and Recordkeeping* can help producers in determining when shellfish can be returned to the tidal flats in the spring and provide a deadline by which shellfish and gear should be removed for winter management. Recording this information over a number of years allows producers to establish “normal” dates for access to the tidal flats in the spring and by which management must be completed to prepare for winter.

Water Quality. Shellfish aquaculture has both beneficial and adverse impacts upon water quality. Increasing shellfish populations in an area can benefit water quality, while the boat motors used in accessing shellfish plots are a significant contributor of petroleum products in the marine environment.

Figure 17: Filter-feeding shellfish benefit water quality.

As filter-feeders, shellfish draw in food and oxygen from surrounding waters and filter algae, nutrients, sediments, and other particulates (Figure 17). This biofiltration can be enhanced by *Net Cycling* at proper intervals to remove biofouling organisms and restore water flow to shellfish.

The boats and associated outboard motors that power them can adversely impact the marine environment, through direct loss from the engine and spills. Between 20 and 30 percent of the fuel and oil used by older two-stroke outboard engines gets discharged into the water through the exhaust port unburned, releasing gasoline, oil, and potentially toxic and carcinogenic compounds. *Engine Exchange*, providing incentives for producers to replace carbureted two-stroke engines with cleaner, more efficient four-stroke or direct inject two-stroke engines, will benefit the marine environment by greatly reducing the discharge of petroleum products.

The U.S. Coast Guard (2003) reports that 87.6% of all spills of petroleum products that occurred from 1973 - 2001 were between 1 to 100 gallons. In 2001, the Coast Guard reported that there were 136 fuel/oil spills in Massachusetts and that the median size spill was 1 gallon (USCG, 2003). Once a spill does occur fast action can help prevent the spread of harmful petrochemicals. Absorbent pads are available in a multitude of shapes, sizes and prices. These products are designed to absorb and trap hydrocarbons for easy disposal. They are primarily used for quickly cleaning up light fuel spills by throwing them into the oil slick and retrieving them once they are saturated. Pads can absorb up to

25 times their weight in petroleum products while still floating. Quick deployment of floating absorbent pads following a fuel/oil spill can significantly reduce the spread of a spill into the marine environment.

Many spills result from fueling operations or as a result of poor maintenance practices. It is not uncommon to see fuel and/or oil in a boat's bilge. A bilge "sock" can be used to absorb and contain these petrochemicals so that they are not washed overboard into the marine environment.

The EQIP pilot project provides assistance to producers in purchasing *Fuel/Oil Spill Prevention Kits*. Having a fuel/oil *Spill Prevention Kit* on board boats used by shellfish producers at all times benefits water quality by making it relatively easy to contain both smaller spills and larger spills that may result from damaged engines or accidents. However, a "sock" in the bilge, a required component of the *Spill Prevention Kit*, will only absorb a certain quantity of petrochemicals. It is important for shellfish producers to replace pads once they are no longer functioning in order for continual benefits to be achieved.

Air. Currently Massachusetts does not meet Federal attainment of the ozone air quality standard according to EPA Office of Air Quality Planning and Standards. Significant reductions in smog forming pollution can be achieved through the exchange of less efficient carbureted two-stroke outboard motors for either direct injection two-stroke outboard motors or conventional four-stroke outboard motors (*Engine Exchange*).

Table 1: Smog forming pollution (Reactive Organic Gases and NOx) from a 90 hp outboard motor (CA EPA, 1999).

Carbureted two-stroke	Direct inject two-stroke	Conventional four-stroke
164 grams/kilowatt-hour	45 grams/kilowatt-hour	11 grams/kilowatt-hour

Table 1 above shows the amount of smog forming pollution emitted by a typical 90 hp outboard motor of each different type, carbureted two-stroke, direct injection two-stroke, and conventional four-stroke outboard motors. Exchange of a carbureted two-stroke outboard motor for a direct injection two-stroke outboard motor results in a 73% reduction in smog forming pollution. Exchange of a carbureted two-stroke outboard motor for a conventional four-stroke outboard motor results in a 93% reduction in smog forming pollution

Plant. Shellfish aquaculture has the potential to benefit seagrasses, biofouling organisms, and grazers who feed upon them. However, in a well managed operation, beneficial impacts to biofouling organisms are short-lived, lasting only from the time a new net or other gear is colonized until the gear is removed for cleaning. *Net Cycling* may reduce the interval in which biofouling and associated organisms are allowed to grow. Seagrasses may benefit from water quality improvements related to *Engine Exchange* and *Spill Prevention Kits*.

Animal. The wildlife species that depend upon the tidal flats used for shellfish aquaculture may be adversely impacted by entanglement in shellfish nets and gear, behavioral changes from placement of gear and increased human presence, and diseases introduced by densely populated commercial shellfish populations. These effects can be mitigated through the use of several conservation practices.

Winter Management has perhaps the most significant potential to mitigate adverse impacts to shellfish aquaculture upon wildlife. This practice reduces hazards and mortality to marine mammals, birds, and fish from entanglement in and ingestion of gear otherwise left on the tidal flats during the winter.

Net Cycling and *Disposal of Gear Waste* also benefit wildlife populations by increasing the amount of gear that is removed from the marine environment for disposal (Figure 18), decreasing the amount of free-floating gear in which entanglement may occur, and therefore reducing injury and mortality resulting from entanglement. Health and productivity of commercial shellfish populations and associated benthic organisms benefit from improved water flow resulting from replacement of nets and gear as well (Figure 19).

Figure 18: Proper off-site disposal of biofoulded nets reduces the potential for entanglement of wildlife

Figure 19: Newly installed anti-predator netting.

Establishment of *buffer* zones or unplanted strips between adjacent shellfish growing areas helps limit disease transmission. Isolation by distance is a highly effective means of controlling disease outbreaks of pathogens known to devastate shellfish operations (e.g., Multinucleated Spheroid Unknown, Quahog Parasite Unknown, Juvenile Oyster Disease, and Hematopoietic neoplasia). Incorporation of *buffers* within their respective plots protects individuals from total loss and adjacent farmers from financial damages associated with a disease outbreak on a neighbor's plot. In addition, isolating potential disease outbreaks also protects adjacent wild animals from the ravages of parasites, viruses, and bacteria introduced by shellfish growers.

Unfarmed *buffers* also likely provide migration corridors for benthic marine organisms, and landing areas for shorebirds and migratory waterfowl transiting the area. Without these strips, local fauna might encounter large plots of tidal areas covered with shellfish aquaculture equipment and be forced to crawl around or seek landing and resting spots in adjacent, possibly less suitable areas. Leaving *buffers* preserves natural areas of tidal zones for native fauna and likely limits adverse impacts associated with migration, resting, foraging, and rearing. Further, *buffers* provide relatively undisturbed habitat that likely encourages biodiversity and a healthier ecosystem.

An incentive payment is offered to shellfish producers who agree to *Monitor and Record Wildlife Sightings*, including rare, threatened and endangered species, predators, and pests. Shellfish growers should be aware of rare, threatened and endangered wildlife species protected by local, state and federal laws. The NRCS interim practice standard encourages producers to use a wildlife identification field guide and keep a journal to log sightings. EQIP pilot project participants are provided with Fact Sheets on rare, threatened and endangered species known to occur in the vicinity of their shellfish leases so that these wildlife species can be identified and interactions minimized. Wildlife observations are recorded when they occur.

Rare, threatened and endangered wildlife species are anticipated to benefit when shellfish producers are familiar with them, minimize interactions, and record sightings. Minimizing interactions should result in fewer changes in behavior or other impacts upon these species. Data collected by NRCS might also be useful in future studies and evaluations of species in the area.

Predatory species can adversely impact the production of shellfish farms. A wide variety of animals prey on shellfish, including marine crabs, predatory snails, other fish, and avian species such as winter ducks and shore birds. Many of the predators that shellfish producers observe and control are natives and occur naturally in the area (Woods Hole and Cape Cod Extension, 2005a). Since the distribution of predators can vary both seasonally and by locality, their control will depend on the species of predator present. By monitoring and recording the presence of predators, growers can anticipate and plan for future problems by learning about predator behavior and seasonality, inspecting sites and maintaining exclusion barriers at critical times.

Wild and commercial shellfish production can also be impacted by exotic, invasive and other nuisance species. These include algae and invertebrates (Woods Hole and Cape Cod Extension, 2005b). These pest species can foul or infest shellfish and adversely impact other marine resources. Once exotic or invasive species become established, eradication is extremely difficult. Monitoring and recordkeeping not only aids shellfish producers in predicting and treating pest infestations, but also provides information that may be valuable in identifying and eradicating exotic and invasive species before they become established throughout the local area and potentially impact native shellfish and other aquatic resources. Exotic or invasive species often have a competitive advantage over the plants and animals that have historically populated a habitat, resulting in decreased biodiversity. Observation and recording of pests and other nuisance species may benefit native aquatic species and habitats over time, but, in the absence of a specific threat is not quantifiable.

Shellfish producers are the first line of defense to stopping disastrous disease outbreaks and protecting wild shellfish. Identifying and containing the spread of pathogens is essential to protect the financial interests of farmers as well as native marine resources. On the water daily during the growing season, shellfish producers are likely to observe any change in the marine environment. Producers who *Monitor and Record Disease* are better prepared to control diseases within their shellfish lease and, therefore, reduce the risk of diseases spreading to adjacent wild populations.

Improvements in water quality achieved through *Engine Exchange* and the use of *Spill Prevention Kits* may also benefit wildlife populations. Reductions in petrochemicals released to the environment will reduce the potential for behavior change resulting from "oil slicks" and adverse health effects of exposure to these chemicals. Health and production of both wild and commercial shellfish should be improved with improved water and air quality.

Human Considerations. The Massachusetts Shellfish Aquaculture Project is primarily focused on environmental concerns. Several of the human considerations discussed above are beyond the scope of the interim practice standard and EQIP pilot project. However, several of the EQIP components produce beneficial effects on aesthetics and navigation concerns.

Winter Management reduces the amount of gear "lost" to winter conditions and therefore benefits recreational and other boaters through a reduction in navigational hazards (Figure 20). Shellfish producers have to spend additional time and energy up front for winter gear removal, but time and money required for retrieval and purchase gear in the spring are reduced. *Winter Management* also has a beneficial aesthetic effect, with less free-floating gear and other trash present in marine waters and along the shoreline in the spring (Figure 21).

Figure 20: Shellfish gear that is left on the tidal flats over the winter…

Figure 21: …May become someone else's environmental and navigational hazard as well as an aesthetic problem in the spring.

Establishment of *buffer* zones or unplanted strips between adjacent shellfish growing areas provides space for site access and gear manipulation. *Buffers* may also provide improved aesthetics and public access for fishing and fowling.

Shellfish producers participating in the EQIP pilot project are provided with an Annual Observation Checklist for *Environmental Monitoring and Recordkeeping*. The Checklist is used to record water temperatures four times each year, first and last observations of sea ice formation, any storms that impacted the shellfish operation, and information regarding replacement of nets. These records can help producers improve management of shellfish and equipment, particularly in preparation for winter to reduce gear damage and loss.

Water temperatures change gradually in response to seasonal change. Below a certain temperature, shellfish will no longer feed and grow. Producers want shellfish growing on the tidal flats as long as possible in order to achieve additional production during the growing season. Recording water temperatures also assists producers in maximizing production while scheduling shellfish placement and removal at appropriate times. These records may also be helpful to NRCS in determining appropriate times for spot checking to ensure that EQIP participants are practicing proper winter gear management. In the future, NRCS or local shellfish boards might use the information collected to establish recommended dates or deadlines for completing winter management.

Recording the dates that nets are set and retrieved helps producers plan operations and better manage their gear. These records are also useful to NRCS where financial assistance is provided for Off-Bottom Culture *Net Cycling* and Bottom Culture *Disposal of Gear Waste*.

The delineation of shellfish leases with *Standard Navigational Aids* benefits shellfish producers, the public and the marine environment. Corners of leases, or groups of leases, are clearly marked with yellow buoys, 20 inches in diameter (Figure 22), helping shellfish producers to comply with local and state regulations (MGL Chapter 130 Section 61).

Figure 22: Standard navigational aids at the corners of aquaculture leases may reduce damage to aquaculture gear and boats resulting from collisions. This benefit to navigation may, however, have an adverse visual impact.

Clearly marking aquaculture areas should reduce navigational mishaps. The success rate is not known, but can be surmised to be relatively high. The benefits of clear navigational markers accrue to both the shellfish farmers, in the form of less gear loss, and less damage to shellfish stocks, and other boaters and users of the coastal zone, who would probably suffer less hull and engine damage from hitting or fouling shellfish gear and equipment. There would also be a potential for less fouling of fishing lines with aquaculture gear if the aquaculture areas were well marked. Less damage to shellfish gear results in less gear damaged and lost into the marine environment where it may entangle and harm wildlife. In addition, less damage to recreational and commercial vessels reduces the potential for gasoline and oil spills and the resulting damage to the marine environment.

The introduction of artificial structure, especially large, bright yellow buoys, however, into previously "natural" areas, such as tidal flats, is a source of potential adverse impact and concern. The Cape Cod area, has built a world-wide reputation on its scenic shorelines, bays, and waterfronts. The visual impacts may be mitigated by reducing the number of buoys so that only the corners of groups of leases are marked with standard navigational aids, rather than individual leases. NRCS in Massachusetts has already recognized this potential impact and implemented this mitigation strategy.

Energy. Shellfish producers consume energy directly, in the form of gasoline, to travel to and from aquaculture leases. The use of disposable tools and gear is an indirect form of energy consumption.

The amount of energy/fuel used directly by shellfish producers can be impacted by either a change in the number of trips taken for aquaculture purposes or by changing the fuel efficiency of the outboard motor. Upgrading from a carbureted two-stroke marine outboard motor to either a direct inject two-stroke motor or a four-stroke motor (*Engine Exchange*) will improve fuel efficiency by as much as 15 to 30%. Over the course of a year, this can result in significant fuel savings as well as a reduction in the petrochemicals discharged into the marine environment.

If you exchange a carbureted two-stroke outboard motor for either a direct injection two-stroke outboard motor or a conventional four-stroke outboard motor, for every 10 gallons of gas you would have used in the original engine, more than 2 gallons <u>less</u> fuel would be required. With the carbureted two-stroke engine, these 2 gallons would likely have been discharged unburned into the marine environment. The more energy efficient engines burn a much higher percentage of the fuel, greatly reducing the amount that ends up in the water.

Winter Management results in additional trips to and from the aquaculture lease site to transport gear, increasing direct energy consumption; however, this same practice also reduces indirect energy consumption that would have been required for production of replacement gear.

Net Cycling and *Disposal of Gear Waste* may also increase the number of trips required to transport gear. Additional energy consumed should not approach that saved with the large improvement in efficiency resulting from *Engine Exchange*.

Quantifying Benefits

Many of the benefits described above are qualitative in nature and difficult to quantify. Often there are few data available which directly address the potential benefits. In some cases, it may be possible to query shellfish producers in a consistent manner, through interviews, surveys, or some other manner, to determine changes in their operations under the EQIP pilot project, e.g., determine an average amount of gear that no longer has to be replaced in the spring. However, without direct links between the available information and the environmental benefits desired or anticipated, accurate quantification of benefits is not possible.

It is possible, however, to estimate net beneficial fuel savings and reductions in hydrocarbon emissions resulting from the exchange of carbureted outboard engines for cleaner, more fuel efficient engines. These benefits can be calculated using information provided by the shellfish producers in conjunction with known efficiency and emissions factors.

The net beneficial fuel savings for the project could be estimated by determining the number of motor exchanges that occur and multiplying this value time the average annual gallons of fuel usage prior to exchange times 20 percent as shown in the equation below.

Gallons saved annually = # engines x gallons of fuel/engine x 0.20

For example:

10 engines exchanged x 200 gallons of fuel used annually prior to exchange x 0.20
= 400 gallons saved annually from 10 engines exchanged

Surveys of shellfish producers would be required to determine the average annual fuel consumption.

Similarly, the net reduction in hydrocarbon emissions could be estimated for each engine exchanged by multiplying the engine horsepower by the annual hours of engine operation and then multiplying the result by the appropriate emission factor from Table 2, as shown in the equation below. Emission factors are not significantly different for 25 and 40 hp engines. Surveys of shellfish producers would also be needed to determine the average annual hours of engine operation for each engine exchanged.

Table 2: Hydrocarbon Emission Factors for 25 to 40 hp Outboard Engines (EPA, 2005).

Two-Stroke Carbureted	Two-Stroke Direct Injection	Four-Stroke Carbureted	Four-Stroke Direct Injection
126.53 g/hp-hr	18.03 g/hp-hr	5.31 g/hp-hr	4.00 g/hp-hr

Hydrocarbon emissions = hp x emission factor x hours of use

For example:

Prior to engine exchange, emissions for a 25 hp two-stroke carbureted engine, with an estimated annual use of 60 hours =
25 hp x 126.53 g/hp-hr x 60 hours = 189,795 g = 190 kg annually

After engine exchange, emissions for a 25 hp four-stroke direct injection engine with an estimated annual use of 60 hours =
25 hp x 4.00 g/hp-hr x 60 hours = 6,000 g = 6 kg annually

Net reduction from one engine exchange = 190 kg – 6 kg = 184 fewer kg emitted annually

V. Conclusions and Considerations

The NRCS involvement in shellfish aquaculture in Massachusetts appears to be generating beneficial environmental impacts across the spectrum of natural resources. Most of these impacts are qualitative in nature and the magnitude of the benefits is presently unknown. Extensive survey and research efforts are required to establish baselines and obtain comparison data for quantification of the majority of the benefits.

In reviewing the Massachusetts Shellfish Aquaculture interim standard and EQIP pilot project, the ENTSC team has proposed several actions for consideration to enhance the program. These can generally be grouped into: (1) Farm Management Plans, Conservation Practice Standard, Operation and Maintenance, and Annual Observation Checklist; (2) Human Considerations, and (3) Assessment of Effects.

Further assistance in assessing community perceptions and attitudes about shellfish aquaculture is available from the NRCS Social Science Team. In addition, ENTSC staff can provide assistance in establishing appropriate Quality Criteria for conservation planning, designing data collection instruments for establishing baseline conditions, assessment and monitoring design, assuring full compliance with the National Environmental Policy Act, Endangered Species Act, and Executive Order 13175, Consultation and Coordination with Indian Tribal Governments, and other technical issues.

Actions for Consideration

Farm Management Plans, Conservation Practice Standard, Operation and Maintenance, and Annual Observations Checklist

1. Expand the content of the Farm Management Plans. The plans prepared for the pilot relied heavily upon the Massachusetts State BMPs, and the ones provided to the ENTSC staff had few details about the individual operations or the requirements of the various components of the EQIP pilot project. A more comprehensive plan containing detailed information about the shellfish operations could be useful later in establishing baselines and determining benefits. In addition, the collection of detailed information about resource concerns and management activities might bring to light other needs that could be addressed through NRCS assistance.

2. Strengthen the focus on continued operation and maintenance (O&M). The local district conservationist has observed cases of inadequate maintenance of cost-shared practice components during field visits. Additional O&M information would be

helpful to producers, especially as it relates to O&M for boat motors or spill kits. The field office staff stated their intent to address this issue partially through more complete documentation in practice narratives and/or development of job sheets.

Additionally, NRCS might consider adding a section to the Annual Observations Checklist for recording of dates when bilge socks were placed in and removed from bilges. This would assist in documenting proper O&M and serve as a reminder to shellfish producers that periodic replacement is needed.

3. Use the Annual Observation Checklist as a 'monitoring tool' to establish average and extreme dates for removal of shellfish and equipment in preparation for winter conditions. This information would assist NRCS in scheduling field visits to confirm that EQIP participants have completed Winter Management and could also be used by NRCS or local shellfish boards in establishing recommended date- or temperature-driven deadlines for completing this important activity.

4. Provide additional specific actions to take (or not take) when sensitive species are in the local area or in the event that an individual belonging to a rare, threatened or endangered species is spotted in distress (e.g., tangled in free-floating nets). Currently, EQIP participants are provided fact sheets on rare, threatened and endangered species that are known to occur in the local area, but little or no guidance is provided on appropriate actions.

5. Modify the interim *Shellfish Aquaculture Management* practice standard to require removal of collected biofouled material from the marine environment within a reasonable, specified time period after removal from shellfish plots. It has been observed that some growers are delaying removal of fouled gear from lease areas until designated trash days. These are days when the growers can have the volume of trash weighed for EQIP purposes. The resulting trash piles are unsightly and subject to loss into the marine environment under certain conditions. Timely removal of biofouled material will improve community acceptance and help fulfill the stated purposes of the conservation practice standard.

Human Considerations

6. Furnish informational signs at boat landings to educate recreational boaters about shellfish aquaculture areas, marker buoys and the EQIP pilot project in order to improve community acceptance and, therefore, the sustainability and longevity of the local shellfish industry. Signage would also increase visibility of the aquaculture area and help further reduce damaged gear caused by boat collisions.

7. Encourage program participants to initiate dialogue with tribal nations, recreational fishers and other locals regarding potential reduced access to tidal flats that have traditionally been considered a public resource. Open discussions about proposed exclusionary uses of intertidal flats or other privatization issues may reduce adversarial situations.

Assessment of Effects

8. Establish realistic quantitative goals for the Shellfish Aquaculture Project. A review of the existing Quality Criteria for those resource concerns identified as impacted by shellfish aquaculture and the EQIP pilot project to ensure that appropriate criteria are described for the conditions existing on shellfish aquaculture leases could be a first step in this process. As noted by the Blue Ribbon Panel conducting an external review of the USDA Conservation Effects Assessment Project (CEAP), establishment of environmental goals is important for any program: "Knowing what was accomplished…is not useful unless we know what should or could have been accomplished" (SWCS, 2006). Quantifiable goals directly related to the resource concern impacted can be established in some cases, e.g., tons of hydrocarbons or gallons of gas and oil no longer released into the environment. For other resources, substitute measures may have to be used, e.g., tons of nets properly disposed of in landfills and no longer presenting a threat to marine wildlife.

9. Collect more rigorous baseline information at each aquaculture plot at the outset of assistance to enable monitoring and evaluation of aquaculture effects. Additional baseline data is needed for more comprehensive assessment of the benefits provided through NRCS assistance to shellfish aquaculture producers. Changes observed throughout the EQIP contract could be recorded as well.

10. Continue to target assistance to the entire ecological system, upland and marine. This two-pronged approach focuses on improving management by shellfish producers and also mitigating human activities on the upland that have the highest potential to negatively impact the natural resources upon which sustainable shellfish aquaculture depends. Sustainable shellfish aquaculture is dependent upon high quality natural resources, especially clean water. These resources are impacted by activities along the shoreline and in the uplands.

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VII. Appendices

Appendix A: Massachusetts *Shellfish Aquaculture Management* Interim Conservation Practice Standard

Appendix B: Components of the NRCS Shellfish Aquaculture EQIP Pilot Project

A. Farm Management Plan
B. Winter Management
C. Buffers
D. Environmental Monitoring and Recordkeeping
E. Monitor and Record Wildlife Sighting
F. Monitor and Record Disease
G. Exchange 2 to 4 stroke Engine (25 HP and 40 HP)
H. Fuel/Oil Spill Prevention Kits
I. Grant Delineation with Standard Navigational Aids
J. Off-Bottom Culture Net Cycling
K. Bottom Culture Netting Disposal of Gear Waste

Appendix C: Summary of Environmental Impacts (Beneficial and Adverse) of Shellfish Aquaculture and Components of the NRCS Shellfish Aquaculture EQIP Pilot Project

Appendix A: Massachusetts Shellfish Aquaculture Management Practice Standard

NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

SHELLFISH AQUACULTURE MANAGEMENT

(Acre)
CODE 706

DEFINITION

Applying environmentally sound management and sustainable aquaculture practices in the husbandry of bivalve mollusk species.

PURPOSE

- Enhance the sustainability of aquaculture
- Minimize adverse impacts of shellfish farming on water, plant, animal and human resources
- Ensure dependable quantity and quality of water to support shellfish production
- Ensure adequate quantity and quality of food to support shellfish production

CONDITIONS WHERE PRACTICE APPLIES

Intertidal and subtidal areas where propagation and aquaculture of shellfish is licensed and/or permitted by the governing regulatory authorities

CRITERIA

General Criteria

All forms of shellfish aquaculture must comply with federal, state, and local regulations. Shellfish farming is licensed by the local municipality, the Massachusetts Division of Marine Fisheries (Mass. General Law – Chapter 130, Sections 57 through 67; and the U.S. Army Corps of Engineers (Section 10 of the Rivers and Harbors Act of 1899; and Section 404 of the Clean Water Act through the Massachusetts Programmatic General Permit.

All shellfish farming areas or licensed shellfish growing sites must be properly sited in approved waters, and adequately marked and recorded with the appropriate regulatory authority.

Implementation of the prescribed best management practices shall satisfy the criteria set forth in the current *Best Management Practices for the Shellfish Culture Industry in Southeastern Massachusetts* (South Eastern Massachusetts Aquaculture Center, and Massachusetts Department of Agricultural Resources, 2004).

A Shellfish Aquaculture Management Plan shall be developed that addresses all of the identified resource concerns, including, but not limited to, the following:

Water Quality and Water Quantity

The successful growth and harvesting of food-quality shellfish requires high water quality--quality that is vulnerable to the effects of myriad of coastal uses. Chronic degradation of water quality and associated substrate can threaten the health and survival of shellfish.

Bottom-dwelling shellfish, by their very nature, are capable of filtering, along with their traditional nutrients, pollutants and wastes from the surrounding water and substrate.

Improvement of water quality is largely dependant on balancing marine resource uses and fostering biodiversity. More direct action by growers shall include the following:

- Ensure that any manipulation of sediment or defouling removal activities do not impact sites downstream.
- Combustion engines used in the shellfish growing area must be in good repair, with fuel and oil properly contained and chemical contaminants avoided.

Maintaining adequate water flow through the growing area is critical and involves the following management activities:

- Monitor nets and other equipment regularly for biofouling.
- When bio-fouling restricts water flow to cultured shellfish, clean and remove the fouling organisms to facilitate shellfish health and growth, or replace the nets with new and/or clean material.
- Use of in-water cleaning methods must not result in accumulation of removed materials downstream where they may cause local degradation of the environment.
- Cycle off-bottom equipment with redundant gear for cleaning and air drying.

Protection of Important, Threatened, Rare and Endangered Species

Risk of accidental loss of aquaculture gear into the environment, due to inadequate securing, excessive fouling and ice damage, shall be managed through adoption of the following management strategies:

- Netting, cages and/or other shellfish containment systems must be secured and well maintained.
- Monitor weather and seasonal conditions (severe storms, ice masses, very low water/air temperatures).to allow proper scheduling of equipment removal or movement.
- Remove or move gear to deep water licensed shellfish growing sites during winter to avoid damage, loss and transport of gear into the environment.
- Cycle redundant gear off-site to reduce excessive fouling.
- Replace nets in a timely manner.
- Collect and properly disposal of nets.
- Keep records of net cycling, replacement, removal and movement.

Use of the Intertidal area for bottom culture raises concern over the potential loss of resting and feeding areas for migratory birds. The use of nursery trays, netting and pens on the flats may threaten the Intertidal ecosystem by promoting monoculture. To address this concern, buffers shall be established between adjacent shellfish growing areas to provide relative undisturbed habitat for wildlife corridors and to encourage biodiversity for a healthier ecosystem.

Compatibility with Other Coastal Uses

Shellfish growing areas shall be marked with standard U.S. Aids to Navigation to improve public safety and reduce boat strikes, and thereby reduce the risk of petrochemical spills, loss of gear and livestock. A log book shall be kept of buoy maintenance and replacement.

Spacing within an aquaculture area shall allow for normal operations and maintenance on the site, without impairing or interfering with activities within and around the farmed area.

Buffer zones or unplanted areas between adjacent shellfish growing areas shall be established to provide space for site access and gear manipulation, while providing barriers to infective disease transmission.

Rafts or other floating equipment must be maintained so as not to impede normal navigation through the area.

CONSIDERATIONS

Wherever possible, avoid areas that contain significant amounts of submerged aquatic vegetation, or areas within designated critical or priority habitat for aquatic or upland species identified as important, threatened, rare or endangered.

Wherever possible, avoid selecting growing areas that are in close proximity to pollution sources or areas with the potential for reduced water quality.

Access routes to sites should be planned to minimize the need for motorized transport, and transport over private property.

If wetland buffer zones are involved in the accessing of sites, proper permitting must be obtained by the grower.

Layout and placement of gear should be designed to minimize impact on the natural function of the ecosystem, while allowing for normal activities of the farmer.

Consider using biodegradable materials when available to reduce the environmental risk of accidental losses.

Keep records of all notifications filed with local harbor masters and other regulatory authorities.

Design measures to avoid depredation by birds or other animals.

Growers should be aware of locally important, state and federally listed species that may be encountered in the area. Consider using a wildlife identification field guide, and keeping a journal to log sightings of protected or endangered wildlife species in and around the growing area.

PLANS AND SPECIFICATIONS

Plans and specifications for shellfish aquaculture management shall be in keeping with this standard and shall describe the site-specific requirements for applying the practice to achieve its intended purpose.

Shellfish aquaculture management plans shall include the following:

- Plan map, showing gear layout, access points, buffer zones, and any other relevant information.
- Identification and location of environmentally sensitive areas.
- Location of priority or estimated wildlife habitat, and identification of protected or endangered species.
- Plan narrative, describing management strategies and activities that are planned to achieve the purpose and criteria of the practice.
- Shellfish Aquaculture Management Plan Schedule of Operations.
- Guidance documents necessary to aid the grower in implementation of the practice.

OPERATION AND MAINTENANCE

A plan for operation and maintenance shall be prepared for use by those responsible for the system. This plan shall provide for inspection, operation, and maintenance of the aquaculture management system. O&M plan components shall include, but are not limited to the following:

- Maintain site markers, particularly during periods of high use of the coastal zone.
- Do not exceed the 18 inch elevation limit on structures placed on the site.
- Remove all unused or unnecessary equipment from the site.
- Mark all equipment left on the flats with distinctive marks for identification (i.e. name and permit number), and secure it properly to minimize risk of damage or offsite movement.
- Inspect growing areas following storm events, and repair any damage.
- Monitor and keep records of the following:
  - net replacement cycles
  - water temperatures and weather conditions
  - disease episodes
  - wildlife sightings
- Winter maintenance:
  - Position all equipment and materials flush with the sediment surface.
  - Carefully secure all netting and other materials to the substrate with supplemental attachment devices during winter or remove materials off-site to an upland or deep water licensed shellfish growing site.
  - Ensure that any net or other gear left on the flats during the winter is free from fouling to reduce the potential for attachment of ice to netting.
  - Replace marker buoys on-site with winter sticks or other marking devise that is approved by the appropriate authority to minimize the risk of movement by ice.

REFERENCES

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Appendix B: Components of the NRCS Shellfish Aquaculture EQIP Pilot Project

A. Farm Management Plan (required). The Farm Management Plan is the Shellfish Aquaculture Management Plan referenced in the practice standard. A required component for all participants in the EQIP pilot project, it documents plans and schedules for environmentally sound management and sustainable aquaculture practices. In addition to site-specific requirements, the practice standard states that plans will include:

- Plan map, showing gear layout, access points, buffer zones, and any other relevant information;
- Identification and location of environmentally sensitive areas;
- Location of priority or estimated wildlife habitat, and identification of protected or endangered species;
- Plan narrative, describing management strategies and activities that are planned to achieve the purpose and criteria of the practice;
- Shellfish Aquaculture Management Plan Schedule of Operations; and
- Guidance documents necessary to aid the grower in implementation of the practice.

Preparation of a plan for operation and maintenance for use by the shellfish producer is also required. Under the NRCS standard, operation and maintenance plan components will include, but are not limited to:

- Maintenance of site markers, particularly during periods of high use of the coastal zone;
- Non-exceeding the 18-inch elevation limit on structures placed on the site;
- Removal of all unused or unnecessary equipment from the site;
- Marking of all equipment left on the flats with distinctive marks for identification (i.e. name and permit number), and securing equipment properly to minimize risk of damage or offsite movement;
- Inspecting growing areas following storm events, and repairing any damage;
- Monitoring and recordkeeping; and
- Winter maintenance.

B. Winter Management (required). Winter conditions can relocate and damage or destroy shellfish aquaculture equipment placed in tidal areas. Severe storms, ice masses, extreme air and water temperatures, and wind-driven waves often occur singularly or in combination and frequently lead to damage and loss of gear in shellfish plots. For example, bottom culture netting exposed to air at low tide can become encased in ice. When the tide returns, the ice-encrusted netting is ripped free of the sediment as the ice floats in rising water. Netting liberated in this manner is then free and floating in the marine environment, posing a hazard to navigation and marine animals.

Winter Management is a required component for all participants in the EQIP pilot project. BMPs for winter management include (Leavitt, 2004):

- Removal of all elevated and/or unnecessary equipment, including rebar racks and damaged or discarded nets, from the area during winter;
- Positioning all remaining equipment and materials flush with the sediment surface to prevent ice damage and transport;
- Securing all netting and other materials to the substrate with supplemental attachment devices during winter;
- Ensuring that any nets left on the flats during the winter are free from fouling to reduce the potential for attachment of ice to the netting;
- Replacement of marker buoys on-site with winter sticks to minimize the risk of the ice moving marker buoys;
- Surveying and maintaining the area whenever possible during winter, and removing any and all damaged materials;
- When reasonable, organizing local shellfish farmers to police the surrounding marine resource areas for damaged and displaced aquaculture materials following winter; and
- Removal of damaged material in the marine environment at all times of the year to minimize risk of impact to other marine resources or users of the coastal environment.

C. Buffers. Unplanted buffer zones between adjacent shellfish growing areas are required by the NRCS interim practice standard and are recommended as a BMP for shellfish production (Leavitt, 2004). These are areas of bare tidal flat sediments where shellfish are not established. Under the NRCS pilot project, buffers five feet in width along the sides of the lease areas are required in order to provide:

- Space for site access and gear manipulation,
- Corridors for wildlife use and increased biodiversity, and
- Barriers to deter transmission of infectious disease.

D. Environmental Monitoring and Recordkeeping. Monitoring and recordkeeping is important in any successful agricultural operation to insure that anticipated benefits are occurring. The NRCS practice standard requires:

- Monitoring of weather and seasonal conditions to allow proper scheduling of equipment removal and movement;
- Keeping records of all notifications filed with local harbor masters and other regulatory authorities; and
- Monitoring and recordkeeping of net replacement cycles.

Shellfish producers participating in the EQIP pilot project are provided with an Annual Observation Checklist to record water temperatures four times each year, first and last observations of sea ice formation, any storms that impacted the shellfish operation, and information regarding replacement of nets. A producer must complete the appropriate section of this checklist and returned it to NRCS before the payment is approved for monitoring and recording environmental conditions, wildlife sightings, or disease.

E. Monitor and Record Wildlife Sightings. The NRCS interim practice standard requires monitoring and recording wildlife sightings as part of the operation and maintenance plan for a shellfish operation. The Annual Observation Checklist provided to shellfish producers participating in the EQIP pilot project includes observations of:

- Rare, threatened and endangered wildlife;
- Predators; and
- Pests.

F. Monitor and Record Disease. Shellfish producers participating in the EQIP pilot project record suspected disease on the Annual Observation Checklist provided by NRCS. Early detection of diseases is the best prevention; therefore, disease monitoring and associated recordkeeping is required by the NRCS interim practice standard and is a recommended Massachusetts BMP (Leavitt, 2004).

G. Exchange Carbureted Two-stroke Engine. The majority of shellfish producers use boats with combustion engines to transport equipment and travel to and from their lease sites, with at least one round trip made per day during the growing season. The NRCS interim practice standard requires producers to keep engines in good repair, properly contain fuel and oil, and avoid release of chemical contaminants into the marine environment. The EQIP pilot project provides incentive payments to producers who exchange older two-stroke carbureted engines for cleaner and more efficient four-stroke or two-stroke direct injected outboard engines in either 25 or 40 horsepower. Although the newer engines are more expensive, heavier and complex, the incentive payments make upgrading to this more environmentally friendly technology appealing to shellfish producers. Before the incentive payment is made, NRCS must receive proof that the older engine has been removed from the system and is no longer used.

H. Fuel/Oil Spill Prevention Kits. Massachusetts BMP recommendations include carrying oil absorbent pillows on each boat to absorb oil and gas residues in the bilge, careful handling of all fuels and oils, and reporting petrochemicals or other chemical spills in the marine environment immediately to the nearest U.S. Coast Guard office (Leavitt, 2004). The EQIP pilot project will provide up to three Fuel/Oil Spill Prevention Kits to each participating shellfish producer to reduce the risk of petrochemicals entering the marine environment. Kits include one bilge sock absorber, two oil sorbent sheets, one fuel splash absorbing collar, and one fuel spill warning label.

I. Grant Delineation with Standard Navigational Aids. Shellfish producers are required by state law to plainly mark the areas covered by their leases (MGL Chapter 130 Section 61). Massachusetts BMPs recommend marking aquaculture sites using the U.S. Aids to Navigation System with a 20-inch diameter yellow ball (Leavitt, 2004) so that there is less navigational conflict and, thus, less free-floating gear from collisions in the marine environment. The EQIP pilot project provides an incentive payment to participating shellfish producers to purchase and install these standard navigational aids, one for each corner of a lease. In 2006, funds are restricted to use for standard navigational aids only for outside corners on groups of leases, allowing adequate marking for navigational purposes while limiting the number of large yellow buoys placed in the viewshed.

J. Off-Bottom Culture Net Cycling. The NRCS practice standard requires and Massachusetts BMPs recommend monitoring nets regularly for biofouling (Leavitt, 2004). Cleaning of nets and other off-bottom gear to remove biofouling is a primary activity for shellfish producers during the growing season. When water flow to shellfish becomes restricted, gear must be cleaned, either by removing the biofouling organisms on-site or replacing nets with new material. Cleaning gear in the water may lead to an accumulation of decaying organic materials on-site and an increased oxygen demand. This can be prevented by removing gear to an upland site for air drying or treatment with a concentrated saline dip. If gear is removed for treatment off-site, additional replacement gear is needed. The EQIP pilot project provides an incentive payment for participating shellfish producers for purchase of redundant gear, allowing them to cycle gear for treatment off-site. Producers must purchase and maintain enough redundant gear off-site to replace at least 20 percent of their existing gear.

K. Bottom Culture Netting - Disposal of Gear Waste. Collection and proper disposal of the nets used in bottom culture to contain shellfish and exclude predators is required by the NRCS interim practice standard. The Massachusetts BMPs recommend that nets be replaced as shellfish size increases to provide optimal conditions for water and food flow and when nets become damaged beyond repair. Nets may also be replaced for off-site cleaning to remove biofouling. To reduce the risk of fouled nets being released into the marine environment, the EQIP pilot project offers an incentive payment to participating producers for proper off-site disposal of gear waste. A flat rate payment is provided for each pound of used plastic gear delivered to the local dump.

Appendix C: Summary of Environmental Impacts (Beneficial and Adverse) of Shellfish Aquaculture and Components of the NRCS Shellfish Aquaculture EQIP Pilot Project

KEY to environmental impacts:

unknown	□		
slight	○	*beneficial*	(+)
moderate	●	*adverse*	(-)
important	◙		

Resource Concerns	Shellfish Aquaculture	Winter Management	Buffers	Environmental Monitoring	Wildlife Monitoring	Disease Monitoring	Engine Exchange	Spill Prevention Kits	Standard Grant Delineation	Net Cycling	Disposal of Gear Waste
SOIL											
Substrate Stability	○ (+)	○ (+/-)								○ (-)	
Sediment Disturbance	○ (-) / ● (-) [1]	○ (+/-)	○ (+)							○ (-)	
Benthic Communities	○ (-) / ● (-) [1]		● (+)							○ (+)	○ (+)
WATER QUANTITY											
Ice Formation	● (-)	● (+)	○ (+)	● (+)[2]							○ (+)
WATER QUALITY											
Biofiltration	◙ (+)									◙ (+)	○ (+)
Marine Engine Discharge	◙ (-)	○ (+)					◙ (+)	● (+)	○ (+)		○ (+)
AIR											
Marine Engine Discharge	◙ (-)						◙ (+)				
PLANT											
Seagrasses	□ (+)						○ (+)	○ (+)			
Biofouling	● (+/-)									◙ (+/-)	○ (+/-)
ANIMALS - Wild											
Entanglement	◙ (-)	◙ (+)		● (+)[2]					○ (+)	○ (+)	◙ (+)
Behavioral Change	● (-)	□	● (+)		○ (+)		□ (+)	□ (+)			○ (+)
Health/Disease Reduction	○ (-)		● (+)	● (+)	○ (+)	● (+)	□ (+)	□ (+)			
ANIMALS - CommercialShellfish											
Health/Disease Reduction	n/a		● (+)	◙ (+)	● (+)	◙ (+)	□ (+)	□ (+)		◙ (+)	○ (+)
HUMANS											
Access/Land Use/Property	□		○ (+)								
Aesthetics	□	● (+)	○ (+)	● (+)[2]			○ (+)	○ (+)	○ (+/-)	● (+)	● (+)
Navigation	◙ (-)	● (+)		● (+)[2]					◙ (+)	○ (+)	● (+)
Regulatory Environment	n/a								◙ (+)		
Treaty Rights/Tribal Nations	□										
Cultural Concerns	● (+)										
Site Management/Sustainability	n/a	● (+/-)	● (+)	● (+)		● (+)	● (+)		○ (+)	● (+)	● (+)
ENERGY											
Direct Consumption	● (-)	○ (-)					◙ (+)			○ (-)	○ (-)
Indirect Use	□	● (+)								○ (+/-)	

[1] Magnitude of effects on sediment disturbance and benthic communities are dependent upon the harvest method used

[2] Benefits directly related to improved Winter Management resulting from data collected through Environmental Monitoring and Recordkeeping