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Memorandum

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Subject	**Town of Orleans, MA** **Water Quality and Wastewater Planning** **Task Number 10.1.B.1 – Demonstration Projects-Design and Implementation – Shellfish/Aquaculture – Draft Enhanced Aquaculture Technical Memorandum**
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Approvals	Date	Signature / Initials
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Executive Summary

This Technical Memorandum describes an enhanced aquaculture demonstration program (Program) to increase the biomass of oysters annually harvested from Pleasant Bay. Cultivating this additional number of oysters is accomplished by working with existing growers in this estuary. Future growers currently on the Town's waiting list could also be included in this program. Section 1 provides the context and rationale for this initiative. It details the process that was used for deciding to pursue a demonstration that evaluates the feasibility of collaborating with the Town's existing shellfish growers.

The first step in this evaluation process required understanding the perspectives of these growers. Sections 2 outlines the methodology used to send a questionnaire to all holders of shellfish grants in Pleasant Bay and schedule individual follow-up interviews with the six growers who responded. Section 2 also documents the specific input that was communicated through both the questionnaire as well as meaningful conversation during hour-long meetings.

This information-sharing helped build an understanding of the practical extent to which current shellfish farms can increase production. The opinions and concerns of growers also assisted in defining the extent to which they might help meet the town's numerical goals for nitrogen-removal using shellfish.

Feedback from growers indicated interest in cultivating additional quantities of oysters, as well as highlighted the several key constraints to enhanced aquaculture in Pleasant Bay. These constraints are described Section 3 and generally include:

- Limitations on financial resources to purchase more oyster seed;
- Limitations on financial resources to purchase additional gear to grow the seed;
- Lack of space on grants to install the gear; and
- The near-retirement age of some grant holders.

The Section 4 and Table 1 present the details of a Program that seeks to overcome the current hurdles to having existing growers increase the number of oysters they bring to market. Incentives as well as other elements of this Program are presented. Section 5 considers the option of including new growers who are currently on the Town's "shellfish grant lease" waiting list.

Key features of the proposed Program include:

- The expected enhanced production per participating grower is an additional 150,000 oysters brought to market;
- If six growers participate, this almost doubles the number of harvest-size oysters being grown annually in Pleasant Bay;
- Seed as well as the gear needed to grow the seed is included in the incentive;
- Growers provide an in-kind contribution in the form of the labor to assemble the gear and to cultivate and sell the oysters;
- Two financial cost-sharing options are presented;
- A floating bag system for gear is specified;
- This is a six-year Program for costing purposes so that the gear costs can be amortized over its lifetime;
- The additional growing space required will be determined by working with the Shellfish Constable and growers on a site-specific basis. Standard permitting requirements apply to providing additional growing area for this Program; and
- To ensure equitable treatment of all growers, providing the additional growing space is achieved by creating individual project areas that are separate from current grants.

Section 6 reviews key metrics of the Program. An important goal of this analysis is to determine the cost per kilogram of nitrogen removed for a Program involving existing growers. This cost metric varies depending upon the level of incentive offered by the Town and the amount of denitrification attributed to oyster cultivation. If the Town purchases all of seed and gear required, and increased denitrification is factored into the nitrogen-removal, the cost is $112 per kilogram of nitrogen removed. In addition to increasing the uptake of nitrogen by shellfish during the project period, this Program also validates that a certain density of shellfish biomass can be grown and successfully marketed in the area of Pleasant Bay where aquaculture grants currently exist.

Section 7 outlines the next steps in Program implementation. The first step is to discuss this Draft Memo with the Shellfish Working Group, current holders of shellfish grants in Pleasant Bay and other stakeholders prior to finalizing. If the Town decides to move forward, the recommended tasks and timeline are also outlined in Section 7.

The state Division of Marine Fisheries (DMF) refers to a specific location permitted for aquaculture as a municipal aquaculture license site. In Orleans, these sites are usually called "grants", but are sometimes referred to as leases. The term "grant" is used in this Memo.

1. Purpose and Background

A. Overall Purpose of Shellfish Demonstrations

The overall purpose of the Town's shellfish demonstration projects is to monitor the nitrogen-removal impacts of both *Crassostrea virginica* (oysters) and *Mercenaria mercenaria* (hard clams) and utilize these measured results to develop full-scale plans for shellfish cultivation that help meet regulatory standards for nitrogen. The Town must achieve specific, quantitative goals for removing nitrogen within each of its estuaries to meet the Total Maximum Daily Load (TMDL). The design of a full-scale shellfish project for a particular waterbody to meet a prescribed nitrogen-removal target must be based on certain site-specific values, such as total annual growth in shellfish biomass and enhanced denitrification rates. The size and spatial configuration of a full-scale project are directly related to the values measured through these demonstrations.

Demonstrations are designed to:

- Evaluate the efficacy of oysters and quahogs in achieving reduced nitrogen concentrations within the Town's impaired waters;
- Determine the most advantageous approaches for growing the quantities of shellfish prescribed to meet nitrogen removal goals; and
- Develop realistic cost estimates for the preferred approaches to growing shellfish to meet nitrogen removal goals in specific waterbodies.

These demonstrations will help determine the role of shellfish in the overall strategy for reducing the nitrogen loads within the Town's impaired estuaries as was presented in the Town's ACWMP (2017).

B. Specific Purpose of the Enhanced Aquaculture Demonstration Program (Program)

The first goal of the Program is to determine the feasibility of working with Orleans's Pleasant Bay shellfish farmers, also called "growers", to raise a portion of the shellfish biomass that is needed to meet the Town's TMDL-based nitrogen reduction targets. There are currently nine active shellfish growers within Pleasant Bay in Orleans. These grant holders are at different stages of work life, with some mid-career and others nearing retirement. While there is a range, most local growers have decades of field experience working in Pleasant Bay, and have learned how to manage and operate within the varying conditions in this location. They have evolved systems based on trial and error for anticipating weather and other events that impact shellfish survival. Successful farming requires local knowledge, and implementation techniques need to be tailored to a given site. Growers also have a unique understanding of obstacles or challenges that exist which may be limiting production and what steps might help reduce those challenges. Therefore, hearing from these local experts was seen as a critically important to defining the role of shellfish aquaculture in removing nitrogen in this area.

The second goal of this Program is to present a specific set of implementation steps and costs for increasing the biomass of oysters grown by shellfish farmers in Pleasant Bay, above and beyond what is currently being harvested. This Draft Memo describes the details of a Program that is based on the feedback received from growers regarding the constraints they currently experience. The Program seeks to be responsive to the growers' perspectives while at the same time achieve meaningful increases in the total biomass of oysters that reach harvestable size in Pleasant Bay's existing Aquaculture Grant Area.

C. Background of the Enhanced Aquaculture Demonstration

The approach of working with existing growers to expand shellfish biomass in Pleasant Bay was first described in the shellfish component of the Orleans Consensus Agreement (2015), and was further discussed during the Town-sponsored June 2015 Shellfish Forum where scientists, engineers, growers and regulators met to review the shellfish component of the Consensus Agreement. The Phase I: Orleans Shellfish Operations and Program Expansion Plan dated June 2015, available on the Town's website, documents the trends and water quality impacts of the current level of aquaculture activity in Orleans, and summarizes the outcomes of the Shellfish Forum. Based on this

prior work, the first phase of analysis for the enhanced aquaculture demonstration by the AECOM technical team included review of the existing shellfish grant sites as a proposed demonstration site. The AECOM Technical Team includes representatives from AECOM, Science Wares, Biomimicry New England/UMass Boston, and MT Environmental/Beach Point Shellfish.

The second phase of review for the Enhanced Aquaculture demonstration included a peer review of the Draft Technical Memorandum on Site Characterization prepared by the AECOM Technical Team to finalize the sites that should be included for shellfish demonstration projects. This in-depth critique involved review and comments from several outside experts as well as several meetings with a Town of Orleans Shellfish Working Group that consists of the Shellfish Constable/Harbormaster and representatives from the Shellfish and Waterways Advisory Committee, Orleans Marine and Freshwater Quality Task Force, Orleans Pond Coalition, Citizens Peer Review Committee, and Orleans Water Alliance.

Outside experts that reviewed the Draft Site Characterization Technical Memorandum included:

- Diane Murphy, Barnstable County Cooperative Extension;
- Josh Reitsma, Barnstable County Cooperative Extension;
- Sandy MacFarlane, former Orleans Shellfish Constable;
- Henry Lind, former Eastham Shellfish Constable;
- Chatham Shellfish Propagation Department; and
- Dave Slack, Shellfish and Waterways Committee.

After this two-step, detailed evaluation process, four demonstration programs were selected, including enhancing oyster aquaculture in Pleasant Bay by working with existing growers. These four demonstrations are described in detail in the Technical Memorandum on Final Site Characterization and Evaluation for Aquaculture/Shellfish Propagation (evaluation criteria and ranking) dated March 13, 2016 (available on the Town's website). Written comments from the outside experts and responses from the Shellfish Technical Team are included in Appendix A of the Site Characterization Technical Memorandum.

D. Rationale for Use of Oysters

Orleans is pursuing oyster cultivation as the first demonstrations because many scientific papers published in peer-reviewed journals demonstrate the nitrogen uptake and water quality improvements caused by oyster cultivation. (Bricker 2015; Carmichael et al. 2004; Higgins et al. 2011; Kellogg et al. 2013, 2014; Nelson et al. 2004; Porter et al. 2004).

Oysters feed by filtering algae and other particles that contain nitrogen out of the water column. Through this filter-feeding process, oysters both improve water clarity and impact nitrogen concentrations (Newell et al. 2002, 2004, 2005; Officer 1982). The four main pathways by which oysters interact with the mass of nitrogen in an estuary are:

- Uptake into shell and soft tissue;
- Packaging of particles into feces and pseudofeces (biodeposits), which sink to the estuary bottom;
- Excretion of inorganic nitrogen; and
- Enhancement of sediment denitrification.

It is important to remember that all the nitrogen that is sequestered in the body of an oyster, as well as the nitrogen contained in biodeposits and excretions, comes originally from the water column. Following the principle of the conservation of mass, oysters do not contribute new nitrogen, but instead both sequester and reformulate the nitrogen already contained in an ecosystem. Biodeposition and excretion of inorganic nitrogen does not add any new nitrogen to the water column. The nitrogen was already there.

Removing the oysters that have grown in the water column directly removes a mass of nitrogen that was previously in the water. This nitrogen-removal value can be measured directly by weighing the shell and soft tissue and applying a measured value for the percent nitrogen contained therein.

As oysters filter nitrogen-containing particles out of the water column, some of this nitrogen is reformulated into feces and pseudofeces (biodeposits). While feces and pseudofeces technically remove nitrogen from the water column, these biodeposits do not remove nitrogen from the system because these deposits become part of the sediment. The pathway by which additional nitrogen is removed that relates to biodeposition is called denitrification. Feces are the by-products of metabolized particles, while pseudofeces are particles that are not ingested or metabolized by an oyster. These particles are collected on the oyster's gills and coated in mucus. Biodeposits are heavier than water and rapidly sink to the sediment, where the organic nitrogen that was contained in the original particles is buried. Biodeposition is proportional to the weight of an oyster as well as the temperature of the system and the total suspended solids in the water column (Powell et al., 1992; Sisson et al, 2011). The long-term fate of the nitrogen in these biodeposits is difficult to assess, and will vary depending on the bottom chemistry and sediment type. At this time, it is not possible to state conclusively how much nitrogen is permanently removed from the water column by biodeposition. Therefore, it is assumed that there is no long-term removal of nitrogen from the water column by biodeposition alone. The pathway by which additional nitrogen is removed that relates to biodeposition is called denitrification.

Biodeposits introduce materials to the bottom sediment that can stimulate additional, permanent removal of nitrogen from these sediments in form of nitrogen gas, effectively removing it from the estuarine ecosystem permanently. Nitrogen removal within benthic sediment is a process driven by microbes that either produce nitrates (nitrifying bacteria) or metabolize nitrates (denitrifying bacteria). First, bacteria that prefer oxygen-rich environments produce NO_3 (nitrates) as one metabolic by-product. Then, bacteria that prefer oxygen-depleted environments metabolize nitrates, using the oxygen and releasing the nitrogen as a gas. Denitrification within the sediment can be increased by oyster biodeposits that feed a population of these bacteria. This biological process is also used in advanced septic systems and Permeable Reactive Barriers to reduce the total concentration of nitrogen that is in groundwater, and which ultimately flows into the Town's estuaries.

Inorganic nitrogen (primarily ammonium) is excreted by the oysters to the water column, where it is typically incorporated in organic matter, some of which becomes food for organisms including oysters. Oysters have not imported this nitrogen into the water column, they have simply taken it from one organic material already in the water column to another organic material in the water column. When the nitrogen contained in ammonium excreted by oysters returns to another organic material in the water column, there has been no net change in the ecosystem from a nitrogen balance perspective.

The Cape Cod Cooperative Extension conducted an extensive study on the nitrogen content of both oysters and quahogs (Reitsma, Murphy and Franklin 2014). To accomplish this research, oysters and quahogs were collected throughout Cape Cod and the nitrogen content was analyzed. This study documented the mass of nitrogen sequestered in the shell and soft tissue of market size oysters. The average size of the animals involved in the study was approximately 3.2-inch/2.3-ounce (84mm/66g). Key findings include:

- The nitrogen content is typically 0.21 percent of the shell dry weight and 7.95 percent of the tissue dry weight per adult oyster grown in off-bottom gear on Cape Cod. These values are consistent with those reported from the Chesapeake at 0.17 percent of the shell dry weight and 7.28 percent of the tissue dry weight per adult oyster (Higgins et al. 2011);

- The average nitrogen content of market size oysters grown in off-bottom gear on Cape Cod was approximately 0.42 percent of their live weight. For a 3.2-inch (84mm) oyster weighing 2.3 ounce (66 g), this would equal 0.01 ounce (0.282g);
- The average nitrogen content in the soft tissue of market size oysters grown in off-bottom gear in Pleasant Bay was approximately 0.49 percent of their live weight. For a 3.1-inch (79mm) oyster weighing 2.1 ounce (60 g) wet, this would be 0.01 ounce (0.3g);
- The nitrogen densities of oysters and quahogs is similar, but because adult oysters are larger and heavier than littleneck sized quahogs (average shell length 2.2-inch [56.1mm], 31.2g shell weight and 2.22g dry tissue weight), removing a single oyster will extract more nitrogen than removing a single littleneck sized quahog;
- Both oysters and quahogs have a higher nitrogen density in the fall, partly because the mass of the soft tissue at this time of year is a larger fraction of the animal's total weight; and
- The nitrogen content of oysters is impacted by the type of growing system used, which primarily affects shell thickness. Wild oysters and oysters grown on the bottom had higher nitrogen content than cultured oysters grown off the bottom.

While the amount of nitrogen sequestered in the shell and tissue of adult oysters is reasonably consistent, rates of enhanced sediment denitrification vary widely and are highly site-specific (Kellogg et al. 2013). In some locations, denitrification is minimally increased by oysters (Higgins et al. 2013). In other studies, denitrification is significantly increased (Humphries et al. 2016; Kellogg et al. 2013). Some studies have shown that the nitrogen removed by the increase in denitrification caused by oysters is equal to the mass of nitrogen contained in the oyster (Newell et al. 2005; Kellogg et al 2013). Sediment chemistry and dissolved oxygen concentration at the sediment surface, as well as overall oyster biomass density are key factors that impact the likelihood that oysters will enhance denitrification (Burkholder et al. 2011).

There is a strong scientific basis for using oyster cultivation to decrease water column nitrogen concentration and improve water clarity. Demonstration projects focusing on oysters were seen as an important first step in order to validate the quantities of nitrogen removed through uptake in the body of the oyster and enhanced denitrification in local waters. These projects provide the field-verified basis for including oyster cultivation in the Town's wastewater plans.

2. Information Gathering Approach and Results

A. Approach Used

The proposed Program was informed by local expertise through:

- Developing and disseminating a questionnaire to determine whether growers are interested in working with the Town to expand cultivation of oysters and other shellfish through aquaculture, for the purpose of water quality improvement;
- Meeting with growers to discuss the answers to the questionnaire; and
- Studying relevant peer-reviewed papers and reports.

The first step in planning this Program was to communicate with existing aquaculture grant holders through a questionnaire (Appendix A). This questionnaire was developed by the Shellfish Team and reviewed carefully by the SWG. The Orleans Shellfish Constable contacted each grant holder individually and requested that they fill out the survey and return it to his office. Anonymous responses were allowed. Six of the eight growers who hold the nine active grants in Pleasant Bay responded to this questionnaire, due in large part to the personal outreach used in distribution.

Once the results of the questionnaire were reviewed, follow up phone calls were made and one-on-one meetings were scheduled with the six growers who responded. Members of the Shellfish Team and the Shellfish Constable met with each grant holder individually, in response to an expressed preference for the one-on-one meeting format. Each of these individual meetings lasted approximately one hour and included detailed discussions relating to comments and responses to the questionnaire. Some of the meetings resulted in follow up phone calls. Finally, the results of these information-gathering meetings were evaluated to identify constraints to enhancing aquaculture, and the stated needs of these local growers. Relevant documents include state shellfish regulations, the Town's current shellfish regulations and the 2013 Pleasant Bay Alliance Resource Management Plan.

B. Results of Information Gathering Process

There are currently nine active growers in Pleasant Bay with an average grant size of 1.75 acres. Typically, single oysters are raised from seed that is purchased from shellfish hatcheries. The preferred starting seed size is approximately 3 mm, and is grown to harvest size in trays, bags and cages. Larger seed that is nominally 12 mm is sometimes purchased. Oyster seed of approximately 3 mm is started in bags with a mesh size that will retain the small stock. In total, growers are harvesting approximately 1,000,000 oysters annually from all grants combined in Pleasant Bay. Harvesting occurs year-round, but peaks during summer months. To avoid ice damage over the winter, shellfish are submerged to deeper depths or are bottom-planted. Figure 1 shows the locations of the current shellfish grants of these nine growers in Pleasant Bay.

Figure 1 - Location of Existing Grants in Pleasant Bay

An important finding of this information gathering process was that five growers stated that they were willing to increase the quantity of shellfish they grew in order to assist the Town in meeting nitrogen reduction goals. One significant factor listed by one grower for not wanting to increase shellfish production was that he is approaching retirement age. This factor was reiterated by other growers as well, but not as a reason for not wanting to increase production. The perspectives of the two growers who neither responded to the questionnaire nor agreed to meet to discuss this demonstration are unknown.

Through the questionnaire and interview process, growers expressed several limitations to producing more shellfish. The main reasons are space limitations, costs for gear and seed, and labor availability. As stated by the growers, constraints to expanding operations include:

Space and material constraints:

- Insufficient space on grant sites;
- Costs associated with purchasing seed and gear;
- Availability of a reliable, local source of quality seed; and
- Mortality rates caused by predation.

Labor Issues:

- Level of effort required to control fouling and predation, and other maintenance issues;
- Lack of labor pool;
- Lack of desire to hire help; and
- Near-retirement age of grant holders.

Growers also identified potential issues if shellfish aquaculture expanded, and gave suggestions related to shellfish planning in general. These infrastructure concerns and other suggestions are as follows:

Infrastructure concerns:

- A reliable local market for the shellfish grown, particularly if widespread health-related closures become more frequent;
- Space availability at public landings if all grants expanded production and hired additional labor; and
- Regular maintenance (dredging) of the access channels into terminal ponds and Nauset Harbor in order to allow access to grant areas regardless of tidal cycles.

Other suggestions that were made regarding shellfish planning in general:

- Protection of productive shellfish areas for wild harvest should be a priority;
- Focus on native shellfish species; and
- Increase municipal propagation of quahogs.

Important considerations expressed by the Orleans Shellfish Constable:

- The currently used aquaculture area shown in Figure 1 (north of Sampson Island) can accommodate an expansion of the current grant areas to a maximum of two acres per grower, as allowed by the current Town shellfish regulations;
- Four of these existing grants seem to have already expanded to the two-acre per grower maximum size;

- From the perspective of water surface area, the currently used aquaculture area shown in Figure 1 (north of Sampson Island) should be able to accommodate additional sites for gear-based aquaculture;
- As shown in Figure 2, there is a designated aquaculture area west of Hog Island as well as two other sites in Pleasant Bay which show additional water surface area for aquaculture;
- To address biologic productivity, eelgrass, navigation, and other use issues, any additional areas potentially used for aquaculture will need to be laid out by the Town after a site evaluation and biologic assessment;
- There are twenty-five people currently on the waiting list for aquaculture grants in Pleasant Bay, although some letters of interest are over twenty years old, and;
- The Town needs to decide how to allocate any additional space that is available for aquaculture (based on both water surface area as well as biologic and other assessments) between this Program and the existing waiting list for aquaculture grants.

C. Space and Material Constraints

Many of the growers feel that they have currently maximized oyster production on their existing grants and would need additional area to enable more shellfish to be grown by them in Pleasant Bay. Oyster aquaculture in gear that is located off the bottom was suggested as the best method of growing oysters in this area due to the large population of predatory Atlantic oyster drills (*Urosalpinx cinerea*). Macroalgae that could smother oysters is another constraint to planting directly on the bottom. Gear that controls predation during overwintering is also critical to survival rates. Most grant holders stated they have already fully developed their sites with gear. Increasing the quantities of oysters being grown by local farmers requires additional gear. This gear takes up additional space. There is also a capital expense associated with purchasing gear.

Directly related to the need for space to grow shellfish is the need for oyster seed. Entities that sell seed in Massachusetts must be approved by DMF. Seed comes from hatcheries in a range of nominal sizes from 1.5 mm – 12 mm. Some hatcheries and wholesalers authorized to sell seed offer larger seed (up to 36 mm). Depending on the starting size, different gear is needed to grow this seed. Smaller (approximately 3 mm) seed is started in bags with mesh size that will retain it and is then transferred into gear with larger size mesh as the oysters grow. Starting with larger seed avoids the need to manage this first stage of grow-out in fine mesh bags.

The only on-Cape hatchery is Aquaculture Research Corporation (ARC) in Dennis, MA. In 2015, this facility transitioned to new ownership and new hatchery facilities were constructed. The quality and availability of seed is expected to meet the needs of Cape growers, but additional experience with the new ownership is required before being comfortable with this expectation. Some growers have a strong preference for seed that comes from a local hatchery and feel that ARC should be the only source for seed used in Orleans. However, a number of other hatcheries are certified by DMF to provide seed. These other hatcheries are used by some private growers in Orleans, and are widely used by growers as well as municipal propagation programs throughout Cape Cod. From a risk-management perspective, it is important to source seed from several hatcheries.

Regardless of hatchery and starting size, a batch of seed will grow at different rates. A fraction of the seed grows so quickly that it reaches harvestable size in a little over one year. The majority of the seed grows adequately and is a harvestable size in approximately 18 months. A fraction of the seed is slow-growing and can take over two years to reach market size. The result is that different size classes of oysters are growing at the same time on a farm. Growers sometimes sacrifice the slowest-growing seed because they feel that the labor and materials required to grow it to market size exceeds its market value. In order to discard the slowest-growing seed, more seed is purchased than the desired harvestable numbers.

Figure 2 - Pleasant Bay Resource Management Plan Map of Aquaculture Grant Areas in Pleasant Bay

Additional space as well as gear and seed are needed for enhanced production. The space requirements and costs for additional seed as well as gear are key issues that must be addressed before aquaculture operations can be enhanced in Pleasant Bay.

D. Labor Needs

Shellfish farming requires significant skilled physical labor in often challenging conditions. Workers must be physically strong as well as have the ability to handle small powerboats, build and maintain gear and understand shellfish husbandry. Working in varying conditions where wind and weather dramatically impact the environment presents unique challenges, even for those with years of experience working on the water and handling small powerboats. The level of effort required to control fouling from algae and other epiphytes as well as other maintenance issues is substantial. Some growers observed that it was difficult to find workers with the skills needed to manage an oyster farm. Others prefer a scale of operation that could be handled without hiring additional labor. While growers did not provide an estimate of the labor requirements of their grants in terms of hours, most emphasized that their operations were already a full-time undertaking.

A key factor with respect to enhanced aquaculture within the existing Pleasant Bay grants is that several of the growers pointed out they are relatively close to retirement, and their business goals are focused on developing a viable exit strategy, not investing in expanded operations. Growers that are near retirement age are reluctant to invest in higher quantities of seed because of the added capital expense of additional gear in which to grow it. Existing growers would need a way to transition out of farming that recovers the stranded investments related to existing and enhanced aquaculture for the purposes of nitrogen-reduction.

E. Infrastructure Concerns

In Orleans, there are five public landings with access directly to Pleasant Bay: PawWah Pond, Lonnie's Pond, River Road, Barley Neck (Meetinghouse Pond) and Quanset Pond. All are used by growers, with PawWah Pond, Lonnie's Pond and Barley Neck preferred due to proximity to grant locations. The Quanset Pond landing is used less than the others due to the difficulty of the return boat trip at the end of the day caused by prevailing southwest winds. Parking at the public landings is limited in the summer and may become a longer-term constraint if the overall scale of aquaculture operations significantly increases. Systems (e.g. carpooling) for managing the number of vehicles that park at boat landings during periods of low tide when farms are typically worked may need to be instituted if all the grants were to expand operations. Additionally, in order to maintain boating access to shellfish grants, growers feel that regular maintenance (dredging) of the access channels from the terminal ponds and Nauset Harbor is needed.

F. Other Suggestions

In addition to information related to current oyster farming practices and constraints, growers shared concerns related to shellfish cultivation in general. Maintaining the ability to wild harvest native species in productive areas was emphasized. Potential new aquaculture grants should be evaluated for the productivity of the bottom underneath. New grants cannot, under state law, adversely affect shellfish or other natural resources including productive wild harvest areas in the public domain.

Suggestions for maintaining wild commercial harvests included enhancing the municipal propagation of native species, including both hard and soft-shelled clams. Other native species of interest are scallops and mussels. Although there is a perception that oysters are not native to Orleans, published literature (Ingersoll 1881, Fiske 1967) indicates that historically oysters were ubiquitous throughout the lower Cape in general and in Pleasant Bay. Hard clam populations were significantly larger, but oysters did exist naturally. The Town Cove quahog demonstration project is focused on developing strategies for enhanced municipal propagation and harvest of hard clams and is the subject of a separate Technical Memorandum. That TM will include a discussion of the soft-shelled clam propagation alternative.

Important considerations expressed by the Orleans Shellfish Constable relate to the fact there are currently twenty-five people on the waiting list for aquaculture grants in Pleasant Bay. Although this list has letters of interest that are over twenty years old, there are still likely interested persons on this wait list. Expansion of existing grant areas to a maximum of two acres, as allowed by Town shellfish regulations, is possible within the main aquaculture area shown in Figure 1. It may be possible to fit additional growing locations within this area as well, but DMF certification is required before a final determination is possible. The area west of Hog Island may also provide new growing locations for the Town of Orleans, subject to DMF certification. The total area designated for aquaculture in Pleasant Bay is forty acres (Pleasant Bay Resource Area Management Plan 2013) and is shown in Figure 2.

A key consideration is how to allocate any new aquaculture sites between this Program and the current waiting list. These recommendations should be discussed as part of the review of this Technical Memorandum.

3. Interest in and Constraints to Enhanced Aquaculture

A. General Discussion

While most growers expressed interest in growing more oysters, they also identified a number of constraints to increasing the total number of oysters grown on their current farms. Section 2 describes these issues in detail. To enlarge the quantity of oysters cultivated for nitrogen-removal in Pleasant Bay, key barriers to greater production levels of shellfish, particularly oysters, need to be addressed. The proposed Program for expanding oyster cultivation addresses key barriers by providing the following incentives to existing grant holders:

- Additional oyster seed;
- Additional gear to grow the seed;
- Additional space on the water to install the gear;
- Provision of crop insurance to help minimize risk, if desired as part of participation.

B. Seed, Gear and Insurance

Most growers in Orleans expressed a preference for starting their growing season with oyster seed that is approximately 3 mm, although some purchase larger oyster seed that is approximately 11 to 16 mm. Approximately 3 mm seed is started in lightweight spat bags with a small enough mesh size to contain the small seed. These spat bags are then placed in floating bags. As seed grows, it is relocated into larger mesh bags. A strategy of purchasing more seed than the desired endpoint yields allows growers to sacrifice the slowest-growing seed which optimizes productivity of gear and space. Along with seed, the materials for gear and space needed to grow this seed is recommended to be provided by the Town. In addition, national crop insurance programs provide a way to mitigate against the risk associated with expanding operations.

C. Additional Space on the Water

The amount of biomass that can be grown at a given location is highly dependent on food availability, which includes both algae and particulates. Where the availability of food is not limited, a second factor that influences the biomass that can be grown is the type of gear used. The density of oysters that can be harvested per acre is also impacted by whether bottom planting is possible. If oysters that have already grown for one season (first-year oysters) can be grown to harvestable size on the bottom, stocking densities are much higher than if oysters need to be maintained in floating bags until they reach market size. The Cape Cod Commission Technology Matrix assumes 1 million oysters can be harvested per acre. This likely assumes bottom-planting. Published numbers in the Three Bays Shellfish Master Plan (2016) from Barnstable growers indicate that 400,000 first-year oysters can be grown through bottom-planting to harvestable size on one acre of hard bottom. Information from an off-Cape growing consortium indicates that between 500,000 and 1 million first-year oysters can be grown to harvest size on one acre of hard bottom.

In Pleasant Bay, oysters are grown in gear until they reach marketable size. In 2015, the average density of harvested oysters was approximately 130,000 per acre with the total number of oysters growing within active grants reported to be approximately 300,000 per acre. These densities are similar to estimated values for gear-based aquaculture in Long Island Sound (Bricker 2015). A major difference between the harvest-size densities of commercial operations in Pleasant Bay and those in other areas is the lack of hard bottom that is free of predators. Pleasant Bay growers often cannot successfully bottom plant due primarily to soft substrate and predation by oyster drills. Since oysters must be kept in gear until they reach harvestable size, commercial growing densities in Orleans are by necessity lower than densities where bottom planting is possible.

Commercial densities may also vary from those planted solely for nutrient removal because growers must focus on producing an oyster with a size and shape that is optimally marketable. Cup shape is a key factor in the wholesale price offered for a crop of oysters. To grow an oyster that develops a deep cup, two approaches are used: low stocking density of oysters within gear, and tumbling to remove edges. For nutrient removal, shape is not as important as overall growth in total biomass. However, during the Lonnie's Pond Oyster Aquaculture Demonstration, approximately 200,000 oysters were grown in 800 floating bags in an area of approximately 9,600 square feet. The end-of-season mass of oysters grown in this area was approximately 10 metric tons, with about half of the oysters at harvestable size. It should be noted that upon inspection by commercial growers and others, these oysters were found to be well-shaped with an acceptably deep cup.

Figure 3 conceptualizes an installation of 400 floating bags in approximately 3,800 square feet, which scales to 2,100 bags per 20,000 square feet. This configuration is based on the format used in the Lonnie's Pond demonstration. The Lonnie's Pond configuration used slightly more area than shown in Figure 2 because more space was needed between rows to accommodate boat access and due to the requirement of a square field to facilitate monitoring. Because this was a demonstration project that was also measuring oyster-enhanced benthic denitrification, disturbing the sediment by walking in the field was not allowed during the project period. This configuration works where the available food is high, and with the understanding that oysters growing in the center of the field are likely to grow more slowly than those along the edges. In Pleasant Bay, the floating bags can be installed in longer strings, which are more space-efficient.

The goals of growing premium grade oysters should be harmonized with the need to maximize oyster biomass density when finalizing gear configurations for the purposes of this Program. Section 5 describes the implementation details related to providing additional space on the water.

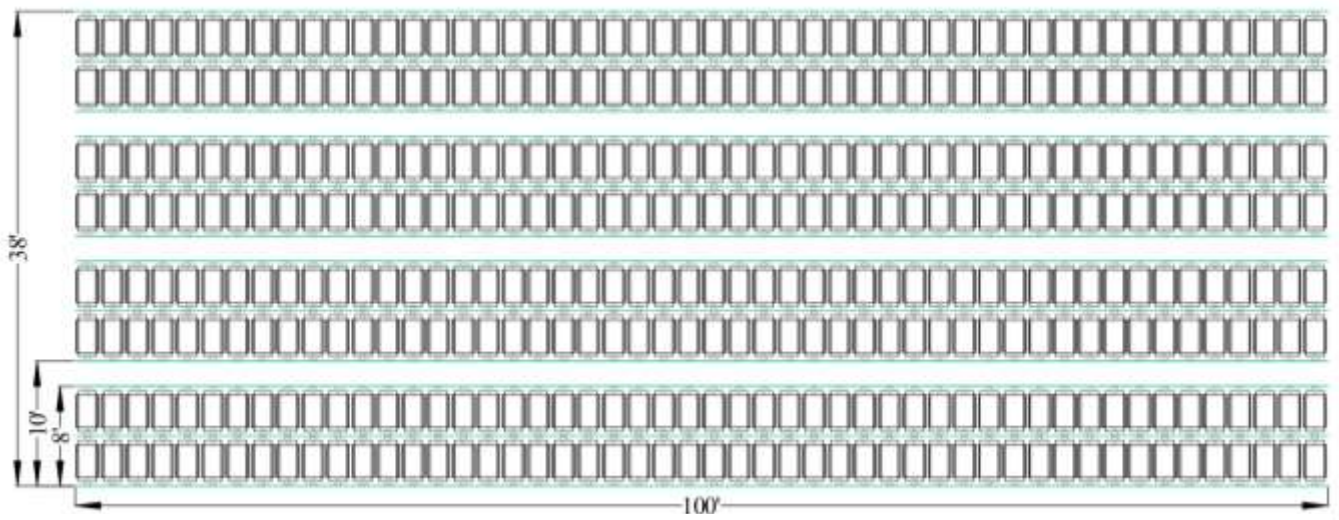

Figure 3 - Example of a Floating Bag Layout that Scales 400 bags (above) to 2,100 Floating Bags in just under half an acre (20,000 Square Feet)

4. Detailed Program Options for Enhanced Aquaculture in Pleasant Bay

A. Program Summary

The proposed Program includes incentives to current growers as well as other features to increase the number of oysters being farmed to aid in nitrogen-removal in Pleasant Bay. The incentives include a specific size and amount of oyster seed as well as the materials for the gear that is required to grow the specified quantity of seed. A process for providing additional growing area is also discussed. Growers provide the labor to build the gear and to grow and harvest the oysters. The proposed number of oysters produced would be above and beyond what is currently harvested from existing aquaculture grants.

These incentives address the financial and other constraints to increased oyster production that were expressed by growers, and summarized in Section 4. The seed, gear and area will allow growers to substantially add to the number of oysters they produce within a one or two-year timeframe. Without some form of stimulus, it is unlikely that most existing growers will expand oyster production appreciably.

Table 1 presents the cost calculations, expected nitrogen-removal and cost per kilogram of nitrogen removed for the Program. The costs to the Town include a one-time investment in the materials for gear, and an investment in seed over the six-year Program period. Growers contribute the labor needed to build the gear and grow and market the oysters. Table 1 also shows costs if growers provide a thirty or fifty percent cost share, and the issues related to this approach are discussed in Section 6. By showing the costs for different numbers of participating growers as well as cost sharing options, the impact and scale of the Program can be compared and evaluated based on stakeholder feedback. Costs do not include a contingency, and this may want further consideration during the planning stages.

Table 1 is designed to be a tool to aid in planning discussions. When reviewing this table, it is very important to note that some lines present total Program costs over the six-year timeframe, and other lines show annual or two year costs.

Key planning aspects of the Program include:

- This is presented as a six-year Program to allow the cost of gear to be amortized over its lifetime. Costs in the sixth year are only for Program oversight of the oysters purchased during the fifth year to get most of them market-ready in the sixth year;
- Total Program costs, cost- share options, and other calculations are shown for one, six and nine growers participating;
- This is to be a one-time incentive Program that will be offered to existing growers because they have proven skills in growing oysters in Pleasant Bay;
- An option of creating project areas that can also be made available to new growers currently on the waiting list is also discussed in Section 5;
- The expected enhanced production per participating grower is an additional 150,000 oysters brought to market annually (after the first year);
- A key long-term benefit of this Program is that it validates the number of oysters that can be successfully grown and marketed in the space allocated;
- Seed as well as the materials for gear needed to grow the seed is included in the incentive;
    - Based on a forty-five percent overall mortality rate, approximately 271,500 oyster seed are estimated to be needed to achieve the 150,000 oysters-to-market target;
    - The starting size of the oyster seed is approximately 3 mm; and
    - Gear specified is a floating bag system.

- Growers contribute all labor required to assemble the gear and to cultivate and sell the oysters;
- Two options for financial cost-sharing on the part of growers are presented, a fifty percent and a thirty percent share of the costs for materials to build gear and seed;
- Growers may stage their participation over the first two years to allow operations to be scaled-up effectively. A full allocation of seed and gear in the first year is also allowed if preferred;
- To ensure equitable treatment of all growers, the additional growing areas for this Program are distinct and separate from current grants; and
- These project areas would be permitted in the same way as standard aquaculture grants, but the permits would include the terms and conditions of this Program.

These features are described in the Detailed Program Description.

B. Detailed Program Description

1) Program Timeframe and Number of Participating Growers

This Program is structured to proceed over a six-year timeframe to account for the capital cost of gear and the growth time to harvest all oysters. The estimated life of the gear is approximately six years and it takes about two seasons for approximately 3 mm oysters to reach market size. Therefore, to amortize the capital expense over the six-year timeframe, and to capture the total nitrogen benefit of the oysters that are purchased in the fifth year but sold in the sixth year, a six-year Program is needed. The sixth year allows the full nitrogen value of the oysters purchased in the fifth year to be included in the calculations of cost per kilograms of nitrogen removed. The only costs to the Town in the sixth year are for the Program oversight needed to ensure good stewardship of the gear and seed and to weigh the oysters brought to market to calculate the actual nitrogen-removal for that growing season. The budget in Table 1 shows the Program cost if all nine grant holders in Pleasant Bay participate, although only six of the growers responded to the questionnaire and participated in follow-up interviews.

2) Quantity of Oysters and Growing System

For each participating grower, the annual number of additional oysters to be grown to market-size is 150,000, after the first year.

The selection of this oyster biomass is based on several factors, including:

- Average reported harvesting on Pleasant Bay grants of approximately 130,000 oyster per acre in 2015;
- The Army Corps of Engineers (ACOE) General Permit for Massachusetts limits the amount of area that can be covered by rafts and floating gear to the greater of 10 percent of the project area or 20,000 square feet;
- With 20,000-square feet of floating gear per project area, 150,000 oysters can be grown to market size, accounting for a forty-five percent mortality rate over the growing period; and
- If six growers participate, this almost doubles the number of harvest-size oysters being grown annually in Pleasant Bay.

Table 1. Six Year Program Cost and Nitrogen-Removal Estimates

Total Program = 6 Years	Nominal 3 mm Seed		
Total Program: Number of Participating Growers	1	6	9
Market Oysters per Grower per Year	150,000	150,000	150,000
Total Program: Additional Gear on Water	1,952	11,713	17,569
Total Program: Market Oysters per Year	150,000	900,000	1,350,000
Total Program: Capital for Gear	$ 28,291	$ 169,745	$ 254,618
Total Program: Seed Cost	$ 17,308	$ 103,846	$ 155,769
Program Oversight	$ 5,040	$ 30,240	$ 45,360
Total Program Cost	$ 50,639	$ 303,831	$ 455,747
Total Program Cost less Grower Share (30% of Gear & Seed)	$ 36,959	$ 221,754	$ 332,631
Total Program Cost less Grower Share (50% of Gear & Seed)	$ 27,839	$ 167,036	$ 250,554
Town Expenditure, Year 1	$ 16,945	$ 101,672	$ 152,508
Town Expenditure, Year 2	$ 19,949	$ 119,692	$ 179,537
Town Expenditure, Year 3-5 (Seed & Oversight only)	$ 4,302	$ 25,809	$ 38,714
Town Expenditure, Year 6 (Oversight Only)	$ 840	$ 5,040	$ 7,560
Grower Expenditure, Year 1 + Year 2 @ 30% Cost Share	$ 10,564	$ 10,564	$ 10,564
Grower Expenditure, per Year 3-5 @ 30% Cost Share	$ 1,038	$ 1,038	$ 1,038
Grower Expenditure, Year 1 + Year 2 @ 50% Cost Share	$ 17,607	$ 17,607	$ 17,607
Grower Expenditure, per Year 3-5 @ 50% Cost Share	$ 1,731	$ 1,731	$ 1,731
Grower Annual Revenue, Year 2-6	$ 52,500	$ 52,500	$ 52,500
Total Program: Market Value of Oysters @$0.35	$ 262,500	$ 1,575,000	$ 2,362,500
Total Program: Market Value of Oysters @$0.55	$ 412,500	$ 2,475,000	$ 3,712,500
Annual N Removal in Market Oysters, kg	44	264	396
Annual N Removal in Other Shells (Mortality), kg	2	15	22
Annual N Removal by Denitrification, kg	44	264	396
Annual N Removal, All Pathways, kg	90	542	813
$/kg of N Removed, Market Oyster Only, No Cost Share	$ 230	$ 230	$ 230
$/kg of N Removed, All Pathways, No Cost Share	$ 112	$ 112	$ 112
Gross Revenues per kg Market Oyster N @$0.35	$ 1,194	$ 1,194	$ 1,194
Gross Revenues per kg Market Oyster N @$0.55	$ 1,877	$ 1,877	$ 1,877

A growing system using floating bags is recommended for several reasons. Floating bags are:

- Widely used by growers in Pleasant Bay and Cape Cod;
- Able to be installed in high density configurations;
- Lightweight, and therefore do not require significant strength to flip in order to control fouling throughout the growing season;
- Lower cost for materials per bag than other systems; and
- Can be rapidly secured or moved in response to a forecast of severe weather.

Floating bags are recommended because they are cost effective and use space efficiently. Oysters grow well in floating bags. Moreover, operation and maintenance effort is low requiring flipping these bags weekly to control fouling. One person can flip the bags. Costs for materials per bag are $13.30 including the long lines and augers. Larger sized floating systems have higher capital costs per unit, $32.78 for an OysterGro system and $42.89 for a LowProGro system. The materials costs for floating bags are less than half the cost of these other methods. Assuming it takes twenty minutes for assembly of a floating bag, even with an allowance for labor, they are the lowest cost gear option. And, the biomass of oysters that can be grown per unit area using floating bags is high. Because they work well in a variety of growing environments, the floating bag growing system is commonly used in Pleasant Bay and throughout Cape Cod.

In terms of implementation, growers should also be able to participate over a two-year period to allow the 2,000 floating bags to be built and operations to be scaled-up effectively.

3) Planning Values for Program Calculations

There are several numerical values that must be determined to make the calculations shown in Table 1, including seed costs, materials costs per bag, stocking densities of floating bags, starting and ending oyster biomass (weights), nitrogen content of oysters, and mortality rates. The values used are shown in Table 2, and explained in the text that follow.

Table 2 - Planning Values for Program Calculations

Cost per 1,000 Oysters (~3 mm)	$ 12.75	
Nitrogen Content (% of live weight)	0.49%	
Starting Weight (g/Oyster)	0.2	
Year 1 Ending Weight (g/Oyster)	20	
Year 2 Ending Weight (g/Oyster)	60	
	Year 1	**Year 2**
Mortality	35%	15%
Oysters/bag	350	150
Materials cost per bag	$ 13.30	
Cost of spat bag for ~3 mm seed	$ 3.00	

4) Seed and Materials Costs, Stocking Densities and Oyster Biomass

Seed costs are from the 2017 Barnstable County Bid results. Per bag materials costs are based on 2016 price quotes from regional and local vendors and include bags, floats, clips, rings, rope, zip ties, long lines and augers. These costs do not include contingencies.

The number of oysters loaded per bag will determine the number of bags that must be purchased/constructed for a given starting number of oysters. Densities for growing oysters for the higher-end restaurant market are lower than for the general-purpose market because oysters grow to a better shape and deeper cup at lower densities. Stocking densities for the purposes of planning this project are 350 oysters per bag in the first season and 150 oysters per bag in the second season. These densities are based on the low end of industry practices to account for the goal of growing an oyster that can meet premium (half shell) market standards. Oyster biomass is based on average weights for Pleasant Bay off-bottom cultured oysters (Reitsma, Murphy and Franklin 2014).

5) Nitrogen Removal Values

Nitrogen-removal rates are taken directly from the average weights and percent nitrogen content in shell and soft tissue of harvestable size Pleasant Bay cultured off-bottom oysters (Reitsma, Murphy and Franklin 2014, Appendix C, table of overall [average] shellfish nitrogen content). The total nitrogen percent reported in Appendix C is for dry weight. However, the percent nitrogen for oyster wet weight is more directly useful in field evaluations. By dividing the sum of the grams of nitrogen in the shell and soft tissue (0.22g and 0.07g respectively) by the total live weight of the oyster (59.56 grams), the percent of total nitrogen content as a percentage of live (wet) weight can be calculated. This total nitrogen value for Pleasant Bay cultured off-bottom oysters is 0.49 percent of live weight.

Denitrification rates are assumed to equal the nutrient uptake in the shell and soft tissue based on the expected soft sediment and other chemical conditions under existing grant sites (Newell et al., 2005). As shown in Table 1, if six growers participate, an additional 900,000 oysters will be harvested annually from Pleasant Bay and the nitrogen-removal from these market-size oysters will be 264 kg per year based on the oyster biomass wet weight, not including denitrification. If other nitrogen-removal pathways are included such as denitrification and the nitrogen contained in the shells of oysters that grow partially but die before they reach market size, the nitrogen-removal is increased to 542 kg. Nominal 3 mm seed is so small it is assumed to have a *de minimis* nitrogen content.

6) Mortality Values

The total number of oysters purchased is higher than the target harvest values to account for expected mortality rates. To determine the amount of seed that should be provided to growers, the target number of market oysters in each tier are increased by the expected mortality over the two-year growing season. There is a wide range of published and reported values for annual mortality rates for oysters grown in gear from 2mm seed to market size. Oyster survival rates vary from one year to another and are impacted both by husbandry practices as well as events of nature. Quality of seed, stocking densities in both nursery and grow-out, disease and weather events can all impact survival. On the low end, a 10 percent mortality rate is presented in a model business plan published by the Northeast Regional Aquaculture Center (Rhodes et al. 2005). Mortality rates at the Lonnie's Pond demonstration project were less than 10 percent. Bricker (2014) and Hudson et al. (2012) propose mortality rates of 55 and 50 percent respectively. The US Department of Agriculture (USDA) Noninsured Crop Disaster Assistance Program uses 44 to 46 percent as normal mortality rates for oyster aquaculture in their payout calculations.

The analysis proposed for enhanced aquaculture in Orleans assumes 55 percent of the oysters purchased will reach the market, or a total mortality rate of 45 percent. This mortality is based on a 65 percent survival in the first year with an 85 percent survival of the surviving first year oysters also surviving in the second year. While mortality rates can be lower or higher, this benchmark seems in keeping with local experience. To keep oyster mortality low, it is critical to provide enough gear and labor to maintain appropriate stocking densities and to control fouling. Overwintering in gear that controls drill predations could reduce locally-experienced mortality rates significantly.

7) Program Oversight Costs

Annual costs include project management associated with ongoing oversight, reporting and monitoring. After the initial implementation period, ongoing, annual reporting and compliance/enforcement is critical for two reasons: compliance monitoring for nitrogen-removal, and to ensure good stewardship of the seed and gear that has been provided through Town funding.

Tasks associated with ongoing oversight include:

- Sourcing seed;
- Validating that seed and gear were installed in the field following Best Management Practices;
- Validating that historic levels of productivity on the grants are maintained in addition to the increased production through the Program;
- Confirming weights of oysters that go to market to measure the quantity of biomass removed;
- Inspecting gear at the end of the growing season to ensure proper maintenance and storage;
- Addressing issues as they arise; and
- Preparing Program documentation and reporting.

To facilitate oversight, the following items are recommended:

- Bags are tagged with serial numbers provided by the Town but installed by the grower;
- Seed delivery is certified by the hatchery and an on-the-water inspection occurs within 24 hours of delivery;
- After the initial inspection, site visits occur once every three weeks;
- All market oysters will be weighed in batches as they are bagged for sale. This data on weight will be provided by the grower to the Town; and
- The Town will be given copies of the monthly reports that growers already are required to submit to DMF for all oysters taken to market showing the date and number sold, including those from the existing grants. This will provide the Town assurance that additional oysters are being grown over and above historical levels.

Regular site visits during the growing season are recommended. The purpose of these site visits is to evaluate oyster growth and survival. A possible approach for this site review is to randomly select four bags from the growing area. All oysters from these four bags would then be separated into live/dead categories to assess mortality. In order to help achieve nitrogen removal goals, all dead shells would be removed from the estuary. After separation, live oysters would be counted and weighed, with 25 photographed on a pad with scale grid. At the end of the season, weighing the oysters that go to market will confirm the nitrogen-removal due to this Program. Water quality monitoring is already an ongoing expense of the Town, and no additional water quality monitoring would be required during this Program. The cost of compliance monitoring to validate the weight of harvested oysters is incorporated into the ongoing Program oversight line item in the budget.

For the first year of this Program, there are one-time implementation costs that are associated with start-up that are not included in the analysis. These costs include working with growers, the Shellfish Constable, local stakeholders and DMF to finalize the growing areas, assisting with permitting of these areas, preparing a fact sheet with a listing of Program expectations both on the Town and grower side, assisting growers with the logistics of participation, addressing issues that arise, evaluating the effectiveness of the Program, confirming the nitrogen-content in shell and soft tissue as well as denitrification rates and reporting to the Town over the implementation period.

8) Long-Term Program

A long-term benefit of this Program is that is validates whether oysters can be successfully grown in the density and gear configuration proposed. If successful, it is possible that growers would want to continue the cycle of purchasing materials and assembling new gear as required to continue growing the additional 150,000 oysters annually for nitrogen removal.

The Town would need to make several decisions at the end of the Program period:

- Whether to allow the use of use of the designated half-acre project areas to continue after the demonstration period; and
- Whether to implement prescriptive standards for all aquaculture grants that are based on the site-specific facts obtained from this Program.

After the demonstration period, the Town should evaluate the Program outcomes for effectiveness at achieving the nitrogen-removal and other goals. Using an adaptive management approach, factors such as production results, water quality impacts, operational experiences, feedback from participants and other considerations would be reviewed. Management decisions made after the demonstration period may alter the Program approach or even discontinue the use of these project areas. Because these new project areas are distinct from the current grant structure, these decisions do not impact growers' current rights and expectations.

The Town's exiting shellfish regulations for grant areas do not currently require the level of market-size oyster production planned in this Program. These local shellfish regulations could be reviewed if the productivity on these new project areas is reasonably demonstrated through this Program. This could be considered as part of the overall implementation strategy for nitrogen-removal.

9) Additional Space to Grow Oysters for this Program

Growers have indicated that they require additional growing area in order to cultivate more oysters. The ACOE Massachusetts General Permit for Aquaculture limits the amount of floating gear that can be installed on an aquaculture project site. The limits are the greater of 10 percent of the project area or 20,000 square feet. Thus, if a project is located on a site that is between 20,000 square feet and almost five acres, the total area covered by gear cannot exceed 20,000 sf. According to the Shellfish Constable, nine, half-acre project areas, for a total of four and a half acres could be accommodated based on the surface area of the water available in the designated aquaculture areas shown in Figure 2.

For planning purposes, it is expected that 2100 bags can be installed in 20,000 square feet. With hypothetically no mortality, at a low stocking density of 150 oysters per bag, 2100 bags would allow 315,000 second-year oysters to be installed. The Program target is 150,000 oysters, and with an overall estimated mortality of forty-five percent the 150,000 oysters should be able to be grown in an approximately 2000 bags. These bags contain a starting quantity of approximately 271,500 oysters that should provide a post-mortality number of 150,000 market-size oysters.

There are several considerations that affect the feasibility of this layout for all areas in Pleasant Bay. The need to maintain a field by boat versus by standing changes the space requirements between bags and impacts bag density. The goals of the grower also influence gear layout. A goal of implementation is to work with growers to maximize the number of floating bags per unit area, with the requirement that 150,000 oysters are grown to marketable size in the second through sixth years of the Program.

Standard state and federal permitting requirements apply to providing additional growing area for this Program. Any additional growing areas proposed as part of this demonstration will be determined by the Shellfish Constable, working with DMF, growers and applicable stakeholders, on a site-specific basis.

C. Permitting of Additional Space to Grow Oysters for this Program

1) Overview

The history of small-scale private aquaculture in the Orleans section of Pleasant Bay dates to the 1920's (Pleasant Bay Resource Management Plan 1998). By 1998, Orleans had designated forty acres as suitable for private aquaculture grants. The entire forty acres of current and potential Aquaculture Grant Areas is shown in Figure 2. The Pleasant Bay Resource Management Plan (2013) also includes recommendations for allowing the expansion of an existing grant when the following are met:

- Compliance with all applicable local, state and regional regulations, policies and best management practices;
- No negative impact on other marine invertebrates, shorebirds, migratory birds, or other rare or endangered species; and
- Based on historical harvest data and an objective site investigation there is no likelihood of a natural recurrence of a wild shellfish population.

Permitting any additional acreage for enhanced aquaculture in the Aquaculture Grant Areas of Pleasant Bay is likely subject to the same requirements as those for permitting any new grant areas, or expanding existing grants. Of critical importance is the biological assessment to ensure that productive bottom is not being taken out of the public domain. Other environmental considerations are also reviewed as part of the permitting process. This is a familiar system to growers in Orleans, who have already obtained the required permissions to grow shellfish on their current grant location.

There are several considerations related to providing additional area to accommodate this Program, including:

- Current shellfish grants are limited to two acres per grower in Orleans;
- Some growers have already expanded their grant to two acres; and
- Gear cannot cover the greater of ten percent of a project area or 20,000 square feet, pursuant to the ACOE General Permit.

Because Orleans limits aquaculture grant areas to two acres per grower, an equity issue arises if the system for providing additional area to accommodate this Program is based solely on expanding existing grants. Four grants have already expanded to the two-acre maximum, while the remaining grants are still under the two-acre limit. In discussing this issue with the Shellfish Constable, the current grants that are under two acres could be expanded to two acres without negatively impacting navigation. However, this approach of allowing some grants to expand to two acres does not address the expressed need for additional space from grant holders that have already expanded to two acres. Allowing all grant holders in Pleasant Bay to participate equally in this Program requires a different approach for providing space than simply expanding current grant areas. Another issue is that ACOE regulations effectively allow up to 20,000 square feet of

gear coverage for project areas that are up to approximately five acres. Current grants in Pleasant Bay all have this allowance. By requiring that 20,000 areas within existing grants be used for the Program, it effectively removes all useable area on existing grants for their current aquaculture operations.

One solution to these issues is to designate new project areas that are specifically tied to this Program.

There are several benefits of this approach:

- The current status of the Town's existing aquaculture grant system is maintained;
- All grant holders are treated equally; and
- The maximum allowable coverage by gear is 20,000 square feet per project area, thus accommodating the space required for the gear to grow the Program's additional quantities of shellfish for nitrogen-reduction goals.

Because this is a demonstration project, it may be important to differentiate this Program from current aquaculture operations. After the six-year project period, the current status-quo remains intact, thus minimizing the risks to growers and the Town.

Creating new project areas also allows all the growers in Pleasant Bay to participate equally, regardless of the size of their current commercial operations. Estimates for this Program have shown that approximately 2,000 floating bags will be needed to grow 150,000 oysters to market size. It is possible to locate 2,100 floating bags on 20,000 square feet. These half-acre aquaculture project areas are designed to maximize the quantity of oyster biomass that is grown on as small a footprint as is practical.

For this approach to be permitted, local shellfish regulations might need to be amended to allow existing grant holders in Pleasant Bay to hold more than one grant while they are participating in this Program and beyond if it is determined to be an effective means of reducing nitrogen.

Another possible mechanism was reviewed for offering this incentive to growers equitably. This approach involves increasing the maximum allowable grant area to three acres. There are several issues with this approach. Expanding the grants of the nine active growers' sites to three acres would use a total of twenty-seven of the forty acres currently mapped for aquaculture, and require a change in local shellfish regulation. Moreover, to accommodate appropriate passage for navigation, expanding all grants to three acres could not be done by simply expanding grants where they are presently located Pleasant Bay. A three-acre maximum would require reconfiguring grant sites to use the available area in Pleasant Bay more efficiently, and ensure boating access is maintained through the grant areas. The current configuration of grants has developed over many years with sites initially chosen by growers based on suitability for quahogs. These grants are now primarily used to grow oysters, so the specific locations of grant sites may be more flexible. However, this is a significant change over current conditions and may not be warranted to accommodate a six-year demonstration project. Moreover, expanding existing grants to three acres would not address the issue of ACOE regulations on gear coverage or the needs of new growers currently on the waiting list for grant areas in Pleasant Bay.

2) Details of the Permitting Process

The existing growers in Pleasant Bay have regulatory approvals for their operations, including local approvals for grant sites through the Orleans Board of Selectmen as well as state propagation permits to grow shellfish. The project areas for this Program would be permitted in the same way as standard aquaculture grants. In addition, these permits would include the specific terms and conditions of this Program.

This standard permitting process includes:

- Applicant that is participating in the Program applies to Board of Selectmen (BOS) for approval of a "municipal aquaculture license site", referred to in Orleans as a shellfish grant, and a Public Hearing is held. If approved, this local decision would be conditioned based on the specific requirements of the Program;
- If the shellfish grant is approved by BOS, they request certification from DMF for this specific location;
- Once DMF has certified the location, the applicant may be required to apply for an ACOE permit and Conservation Commission determination to place structures on the site; and
- Once all permits are in hand, DMF issues a propagation permit to the growers. This propagation permit gives the applicant permission to grow shellfish and could also be conditioned based on the specific requirements of the Program.

The local permitting step gives permission for a grower to utilize a specific area for aquaculture. These locations are technically called municipal aquaculture license sites. In Orleans, these sites are called shellfish grants, and can also be referred to as leases. Local regulations govern these grants and in Orleans, do not allow grants of more than two acres. To permit a site in Orleans, an applicant submits a specific location to the Board of Selectmen who will then hold a public hearing on the proposed location. Input from the Shellfish Constable is an important consideration in this process. If the Selectmen approve the location of a grant, they request a DMF certification of this site, which includes a biological assessment to determine whether the bottom is considered to be productive for wild species as well as a review of other environmental considerations. Aquaculture grants cannot be sited in areas with already productive bottom so as not to remove the area from the public resource. The forty acres of Aquaculture Grant Area in Pleasant Bay were designated for shellfish aquaculture based on the expectation that the bottom is not productive. However, this must be reconfirmed on a site-by-site basis.

After local approval of a grant location and DMF certification, the grant holder may need to apply to the Conservation Commission and ACOE. Then, a propagation permit can be issued by DMF. These permits allow the growing of shellfish in the state of Massachusetts. Propagation permits are associated with specific grant areas and are only issued by DMF after certification and all other permitting. These propagation permits may also have conditions regarding species grown, gear type, minimum production standards, individuals allowed on the site and actions to take in the event of closures. These propagation permits are renewed annually.

The permitting process for the project areas proposed as part of this Program is the same as the process used for approving any new aquaculture grant in the Town. From a regulatory perspective, these project areas are aquaculture grants. These grants are referred to as project areas to clarify and highlight that they have specific terms and conditions that are different from Town's standard aquaculture grants.

3) Crop Insurance

The USDA offers insurance for farmed oyster crops. This program, entitled the Noninsured Crop Disaster Assistance Program offers basic coverage for catastrophic loss as well as several enhanced options. The basic insurance costs are considered a service fee and are the lesser of $250 per crop or $750 per producer per county and includes:

- Lost Inventory above 50 percent of expected production at 55 percent of average market price[and
- Provides about 20 percent of expected income for a total loss.

Higher levels of coverage are also available, ranging from 50 to 65 percent of production, in 5 percent increments. Coverage is valued at 100 percent of the average market price. The cost of the insurance premiums for this level of coverage is calculated as 5.25 percent of the estimated value of the crop being insured. Coverage periods are from October 1 to September 30 and are renewed annually. For an oyster farm, the insured crop includes all the size classes growing during the annual insurance period. There are reporting requirements (seeding dates and inventory) and caps on the payments, including an overall limit of $125,000 per person and a maximum premium capped at $6,563 (the maximum payment limitation times a 5.25 percent premium fee). The Farm Service Agency (FSA) administers this insurance program through the Southeastern County office (including Plymouth, Barnstable, Dukes and Nantucket counties). The Executive Director is Steven Ward who can be contacted at 508.295.5151. If the insurance option is pursued, Mr. Ward has indicated that he would come to Orleans to meet with interested growers to present details of the noninsured crop insurance program. The above agencies also have low interest loans that may be needed by growers to participate in purchasing more seed and equipment.

4) Other Shellfish Species

Growers have indicated that they are interested in growing varieties of shellfish other than oysters as part of their operation. As part of project implementation, growers should be allowed to present specific funding requests for other shellfish systems that both offer a reliable approach for harvesting a predictable biomass of shellfish and achieve the same dollars to kilogram of nitrogen removed ratio. These proposals should then be reviewed on a case-by-case basis.

5. Working with New Growers on Waiting List

This section describes a Program modification that would include new growers that are currently on the Town's waiting list. Existing growers as well as these new growers would both participate to increase the quantity of shellfish harvested from the aquaculture areas in Pleasant Bay. Project areas would still be added within the main growing area north of Sampson Island as well as in the area west of Hog Island. Nine, half-acre sites for existing growers are planned as part of the initial Program. Project areas and the associated incentives and production requirements could also be offered to new growers on the waiting list.

If new growers were to be included in the Program, there are two ways for space to be allocated:

- The number of half-acre project areas could be held to nine and if any existing growers did not participate, these project areas and the associated incentives of seed and gear could then be offered to those on the waiting list; and
- The number of project areas could be increased and offered to those on the wait list. The oyster production targets and other aspects of Program participation would apply.

Assistance to these new growers could also include providing information on available classes and workshops for new growers or perhaps even sponsoring a local class. To recognize the fact that new growers were waiting for standard leases with a long-term potential, new growers could be explicitly allowed to maintain use of this grant area after the six-year period, provided they meet the Town's shellfish regulations. The continued use of these areas by existing growers would still be determined based on Program outcomes.

A third option is to include nine project areas to accommodate existing growers and use any other space that is available for standard aquaculture grants. With this option, if new growers were not interested in the Program, they would still be able to obtain a grant under existing shellfish regulations.

As part of the Town's technical review, extending the incentive package to new grant holders should be discussed.

A key next step is determining the actual number of project areas and additional standard grants that could be accommodated within the designated Aquaculture Grant Areas in Pleasant Bay. The following steps would be important to evaluating the total number of project areas and standard grant sites available:

- A biological survey of area to initially define appropriate areas for new grant sites; and
- Mapping and layout of all new grant locations to optimize the use of this space.

Conducting a biological survey and systematically mapping areas will establish the maximum acreage for aquaculture in general in Pleasant Bay. This area can then be allocated between the desired number of additional project areas and standard shellfish grants.

6. Analysis of Program Options

A. Dollars per Kilogram of Nitrogen Removed and Other Considerations

As shown in Table 1, the cost per kilogram of nitrogen removed by this Program is estimated to be $112/kg N with all methods combined (denitrification and the nitrogen in the shells of dead animals in addition to harvest). If the mass of nitrogen removed is only from harvest, the cost per kilogram of nitrogen removed is $230/kg N. A fifty percent cost share will reduce the cost to the Town per grower from $50,639 to $27,839. The cost per kilogram of nitrogen removed is then reduced to $62/kg N with all methods included. Counting only the nitrogen sequestered in the shell and soft tissue of the market-size oyster, the cost metric is $127/kg N. Cost share values for dollars per kilogram do not scale in a linear fashion because the cost of Program oversight is not shared by the grower. Based on measured denitrification rates in soft sediments (Newell et al. 2005), the removal via denitrification should be included in this analysis, and verified as part of Program implementation. In addition to comparative metric of dollars/kilogram of nitrogen removed, there are other considerations that are relevant to the decision to pursue this Program.

Through this Program, the Town can begin to work with growers to explore the merits of a framework for enhanced aquaculture as a long-term strategy for improving water quality in Pleasant Bay. In the near term, this Program enables the town to help growers leverage their existing capabilities by creating project areas and providing the materials for gear and seed required to produce 150,000 market oysters per year per grant area that remove up to 90 kilograms of nitrogen per grant annually. The Program will include optimal gear layout, suitable locations and monitoring for oversight and regulatory compliance. Because shellfish have substantial economic value, long-term implementation could consist of providing project areas only, with growers purchasing the seed and gear needed to grow the minimum required number of oysters to qualify for these areas.

Another noteworthy aspect of this Program is that it creates economic activity in terms of labor wages that enhance the local economy. This benefit to the local economy should not be overlooked in weighing alternative approaches for nitrogen-removal within the Town's estuaries. The economic multiplier for shellfish aquaculture has been estimated at between $1.79 to $1.90 for every dollar in wages created (Augusto, Holmes and Barnes 2015, Northern Economics 2014). For this Program, the gross revenue generated per kilogram of nitrogen removed by market oyster is $1,194. This revenue will likely be spent on wages and salaries to grow the additional seed. Based on these multipliers, the increased economic activity generated in the local economy ranges between $2,137 and $3,614 per kilogram of nitrogen removed by this approach.

Finally, local food production is a cornerstone of long-term sustainability because of the reduced energy costs required to ship this food. Local shellfish production does not use fertilizer, pesticides or feed, making shellfish a uniquely positive crop to farm from an environmental perspective. Shellfish are one of the most practical and valuable crops to grow on Cape Cod. Using them to remove nitrogen in Pleasant Bay is both advantageous economically and environmentally.

B. Cost Sharing with Growers

Funding opportunities often require a financial contribution on the part of the applicant in terms of either cash or in-kind services. These requirements are typically in the range of thirty to fifty percent. This Program includes an in-kind contribution on the part of growers with labor to:

- Build the gear
- Install the gear;
- Operate and maintain the farm;
- Market the oysters;
- Harvest and deliver the oysters; and
- Participate in Program reporting.

Growers are already mobilized to tend their farms. The value of the labor contribution is highly variable and depends on the cost of labor to the grower and the additional time required to tend the additional oysters. Growers are not recovering these costs until the sale of oysters in the second year. While these labor costs are likely covered by the annual revenue generated by the sale of oysters in the second through sixth year of the Program, this should be considered a contribution from a cash flow perspective.

In addition to the in-kind labor contribution, this Program could require growers to pay for some of the materials for gear and seed. The financial analysis of both a thirty percent and fifty percent cost share of gear and seed was presented in Table 1 to enable this option to be discussed. While this contribution reduces the cost per kilogram of nitrogen removed, it may be an insurmountable obstacle to some of the grower's participation. The problem with requiring growers to contribute financially is the amount of capital that growers would have to have available to participate. Growers would need to advance over $10,000 for gear at a thirty percent cost-share, and over $17,000 at a fifty percent cost share. This financial resource may not be readily available to growers without loans such as those available from the Farm Service Agency or private lending institutions.

7. Next Steps

The next step is for the Town to review the Draft Enhanced Aquaculture Technical Memorandum and provide specific comments for incorporation into the final. This review process will include presentation and discussion at the Shellfish Working Group meeting, and may include discussions with other relevant boards such as the Shellfish and Waterways Committee. This Program should also be discussed with local growers. Peer-review may also be requested and may include DMF, Cape Cod Cooperative Extension and other experts.

Two approaches have been described and should be discussed. The first approach involves working with existing growers and providing seed and materials for floating bags as well as supporting the permitting for an additional half acre per participant. A second approach offers the incentive both to existing growers as well as new growers on the current waiting list for grants in Pleasant Bay. Involving people on the waiting list would necessitate delineating a total number of grants in the space available and deciding how many total project areas with incentives would be offered. A final budget for this Program including contingency will be developed based on the number of incentives the Town decides to offer, and whether cost-sharing will be required.

After comments and suggestions are received, this Technical Memorandum will be finalized and a decision to proceed (or not) with funding for either approach can be made. If the Town decides to pursue this Program, funding for project implementation would be recommended for May 2017 Town Meeting.

Regardless of whether new growers are included, if the Town decides to pursue funding for the Program that incentivizes existing growers, the following tasks are recommended as part of the implementation phase:

- Conduct a biological survey to define appropriate sizes and locations for potential new grant sites, so that the Shellfish Constable has a clear sense of what might be available both for this Program as well as the waiting list;
- Create a map layout of potential additional grant sites;
- Hold stakeholder meetings to discuss the granting of additional project areas to current grant holders for the purpose of this Program;
- Decide how to address the issue of future growers on the current waiting list given the actual number of available sites;
- Create a fact sheet that explains key aspects and expectations of the Program;
- Confirm interest in participation with growers;
- Identify reasons for lack of interest (if expressed);
- Work with participants to permit additional grant sites;
- Develop a Management Plan for this area (including floating gear management plans for severe storms);
- Provide information on available classes and workshops for any new growers that may become involved; and
- Track nitrogen removal via uptake and denitrification for oysters grown in Pleasant Bay.

There are two parts to this implementation phase. Part 1 includes the necessary steps for permitting additional acreage for this Program and Part 2 includes the procurement of materials and seed and management of the Program. Part 2 would not proceed unless permits are granted in Phase 1.

If this Program is funded in May 2017, an expected timeline is as follows:

Part 1: Permitting

July, 2017

- Funding authorization and contract to proceed signed by the Town;
- Conduct field visits with Shellfish Constable and work with DMF to define potential project area and standard grant sites based on initial biological assessments and other considerations such as navigation;
- Map the available acreage and locations of potential additional grant sites; and
- Locate the number of half-acre project areas that were determined to be appropriate for this Program as well as potential standard grant sites.

August/September 2017	• Create a fact sheet for the Program that lists key details and expectations; • Review this fact sheet with the Town and growers using a robust stakeholder process; • Set a deadline for enrollment of existing growers in Pleasant Bay to confirm the maximum number of growers who may be participating; • Based on available acreage, and interest from existing growers, decide on the allocation of areas to the waiting list; and • Propose modifications to Town shellfish regulations (if necessary).
September - December, 2017	• Assist existing and perspective growers apply for all permits and approvals for a specific project area that has been identified: o Applicant that is participating in the Program applies to Board of Selectmen (BOS) for approval of a "municipal aquaculture license site", referred to in Orleans as a shellfish grant and a Public Hearing is held. This local approval would be conditioned based on the specific requirements of the Program; o If the "municipal aquaculture license site" is approved by BOS, they request certification from DMF for this specific location; o Once DMF has certified the location, applicant may be required to apply for an ACOE permit and Conservation Commission determination to place structures on the site; and o Once all permits are in hand, DMF issues a propagation permit which is permission to grow shellfish. This propagation permit could also be conditioned based on the specific requirements of the Program.

If all permits are successfully obtained, the following are the next steps in Program implementation:

Part 2: Procurement and Management

January - February, 2018	• Finalize enrollment and gear and seed requirements; and • Order materials for gear and seed.
February - March, 2018	• Provide materials for gear to growers.
May - June, 2018	• Seed delivered; • Growers install gear and seed; and • Program oversight begins.

July - November, 2018	• Program oversight; • Denitrification study in project areas conducted; • Sampling and analysis to confirm nitrogen content of shell and soft tissue.
December 2018 - February 2019	• Data analysis; and • Program reporting and evaluation of year 1.

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Appendix A

Questions for Shellfish Growers

Questions for Shellfish Growers

Background

Orleans is conducting demonstration projects to evaluate how shellfish cultivation contributes to water quality improvements, and to determine how best to increase the overall quantity of shellfish growing in Pleasant Bay and Town Cove. Based on the findings of these projects, shellfish could become an important part of the solution for reducing the nitrogen that is polluting the town's embayments.

Private aquaculture is being looked at as one way to increase the quantity of shellfish growing to take up nitrogen from the water. In Town Cove, an assessment of areas where additional shellfish leases might be located as well as a quahog population inventory are underway.

In Pleasant Bay, there are areas where significant nitrogen must be removed to restore ecological health. Local shellfish grant holders are being contacted because of your expertise and experience growing oysters in this estuary. We are hoping to learn three things:

- Are you interested in increasing the quantity of shellfish you grow to help reduce nitrogen pollution?
- Are there constraints keeping you from growing more shellfish?
- How can the Town **help you** address these constraints?

The participation of growers in this survey is important so that we can develop a plan for including private aquaculture in the overall wastewater management program that makes sense.

This survey will help the Town understand how growers feel about increasing shellfish numbers, and identify how best to accomplish this goal. Your responses to this questionnaire will also help us in planning and preparing a budget request for the May 2017 Town Meeting. Your individual responses will remain anonymous throughout the planning process, and will be incorporated into an overall plan presented to the Town.

All proposed recommendations will be reviewed by the Orleans Shellfish Working Group before submitting to the Town. It would be very helpful to the shellfish team and the Town if you participate in this review process. Restoring the water quality in Orleans's embayments is good for everyone, including those who farm in these waters.

Questions

1. Would you be willing to talk in person? If so, please tell us your name, phone number, and when to call, and Sia Karplus will contact you to arrange a meeting or to discuss over the phone:

2. To increase shellfish production within Orleans, what do you, as a grower, think are the three most important steps for the Town to take?

3. Would a suggestion box or other anonymous way to provide ongoing input help (If anonymous input requested, explain how best to accomplish)?

4. Are you willing to increase production of shellfish on your lease?

5. Do you have any concerns or reservations that need to be addressed before you would consider participating in expansion of aquaculture in Pleasant Bay?

6. What factors (if any) are currently constraining your ability to increase or expand current production? Circle all that apply:

- Availability/cost of seed
- Availability/cost of gear
- Availability of and cost of labor
- Size/productive potential of sites
- Lack of market/low price for shellfish
- Competition among growers
- Predation (drills, crabs, etc.)
- Disease (MSX, Dermo)
- Permitting issues
- Land use conflicts
- Infrastructure/gear storage issues
- Site access issues
- Lack of upweller sites and/or additional shellfish nursery sites
- Fouling and other maintenance issues
- Other (please be specific)

7. Which of the factors circled above is the biggest constraint? Why? What would you suggest doing to eliminate this factor?

8. What **solutions** do you recommend to address the factors currently constraining your ability to increase or expand current production?

9. Do you have other comments and/or suggestions?

PLEASE RETURN BY FRIDAY, DECEMBER 9, 2016 TO

NATE SEARS - 141 Portanimicut Rd., Orleans MA 02653 (phone: 508.240.3755)