FINAL REPORT

West Falmouth Harbor

Oyster Bed (Reef) Development Project

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1. **Background**

Project Overview and Goals

Over a three-year period beginning in 2014, The Town of Falmouth planned and installed an oyster bed at the location where Mashapaquit Creek enters Snug Harbor. This area in West Falmouth Harbor is shown in Figures 1 and 2. The purpose of this project was to evaluate the growth and nitrogen-removal potential of an oyster bed in this estuary. The Town began this effort in 2014 with a viability study, and continued in 2015 with a pilot-scale effort where 500 bags of oyster remote set were grown for one season and then planted on the sandy bottom in this area. Remote set is shell (typically hard clam) on which oyster seed has been made to attach in a controlled environment. The 2016 implementation phase was funded by a grant from the U.S. Environmental Protection Agency (EPA) through the Southeast New England Program (SNEP) Water Quality Management Grants, administered by the Buzzards Bay National Estuary Program. This phase involved growing 1500 bags of remote set and monitoring the water quality and ecosystem service benefits in collaboration with Woods Hole Oceanographic Institution.

The main goals of the 2016 implementation phase were to:

- Achieve material reductions in the amount of nitrogen in West Falmouth Harbor
- Evaluate whether this oyster bed could be self-sustaining
- Provide a blueprint for developing oyster beds using oyster remote set

West Falmouth Harbor fails to meet water quality standards due to nitrogen pollution. It is listed as a Category 4a water on the Final Massachusetts Year 2012 Integrated List of Waters. Originally listed as a Category 5 nitrogen impaired waterbody in 2002, a Total Maximum Daily Load, (TMDL) was approved by EPA in 2008 establishing a nitrogen concentration limit of .35 mg/L at the sentinel station. The TMDL identifies the main sources of controllable nitrogen in the West Falmouth watershed and their relative contributions as the Wastewater Treatment Facility (WWTF) (61%), septic systems (20%), fertilizer and stormwater (8%). However, a significant upgrade to the town's WWTF was completed in 2005, achieving a nitrogen effluent limit of nearly 3 mg/L and considerably reducing the nitrogen load from the WWTF to West Falmouth Harbor and making septic systems the largest controllable source. Despite these efforts, this embayment is not expected to meet the TMDL and water quality standards unless further action is taken to reduce nitrogen.

Phytoplankton and other particles of algae is food for shellfish but also an unwanted symptom of eutrophication that leads to cloudy water and eelgrass die-off. As algae dies, it also sinks to the bottom, creating undesirable organic-rich sediment that is often referred to as muck. One key ecosystems service provided by oysters is uptake of particulate organic nitrogen. This form of nitrogen is comprised of the phytoplankton and other algae in the water. Recent studies (Reitsma et al. 2017) report that a harvestable size oyster of 85 mm (3.3-inches) that is grown on the bottom contains 0.32 g of nitrogen. Some studies (Bricker et al. 2015) show that filtering of the water also removes particles containing nitrogen and improves water clarity by depositing them in sediments where some nitrogen is removed by bacteria through denitrification.

The ecological services that oyster beds provide may prove critical to catalyzing the ultimate restoration of the water quality in West Falmouth Harbor. Without clear water, eelgrass cannot grow. Highly organic sediments that are produced when algae die also inhibit the growth of eelgrass and many bottom dwelling fauna. This project seeks to establish an oyster bed in order to provide a biological filter for the water entering West Falmouth Harbor from Mashapaquit Creek, which is a significant source of nutrients. Estimates of nitrogen uptake attributable to shellfish harvest in this project are found in Section 3.

Oysters are also a significant and valuable source of local food. Once established, the oyster bed in Snug Harbor could provide both a selective relay and harvest area as well as a spawning sanctuary for oysters, which have historically grown well in West Falmouth Harbor. The oysters that are spawned will help support wild commercial and recreational oyster harvesting.

2. Project Description

The project location is shown in Figures 1 and 2.

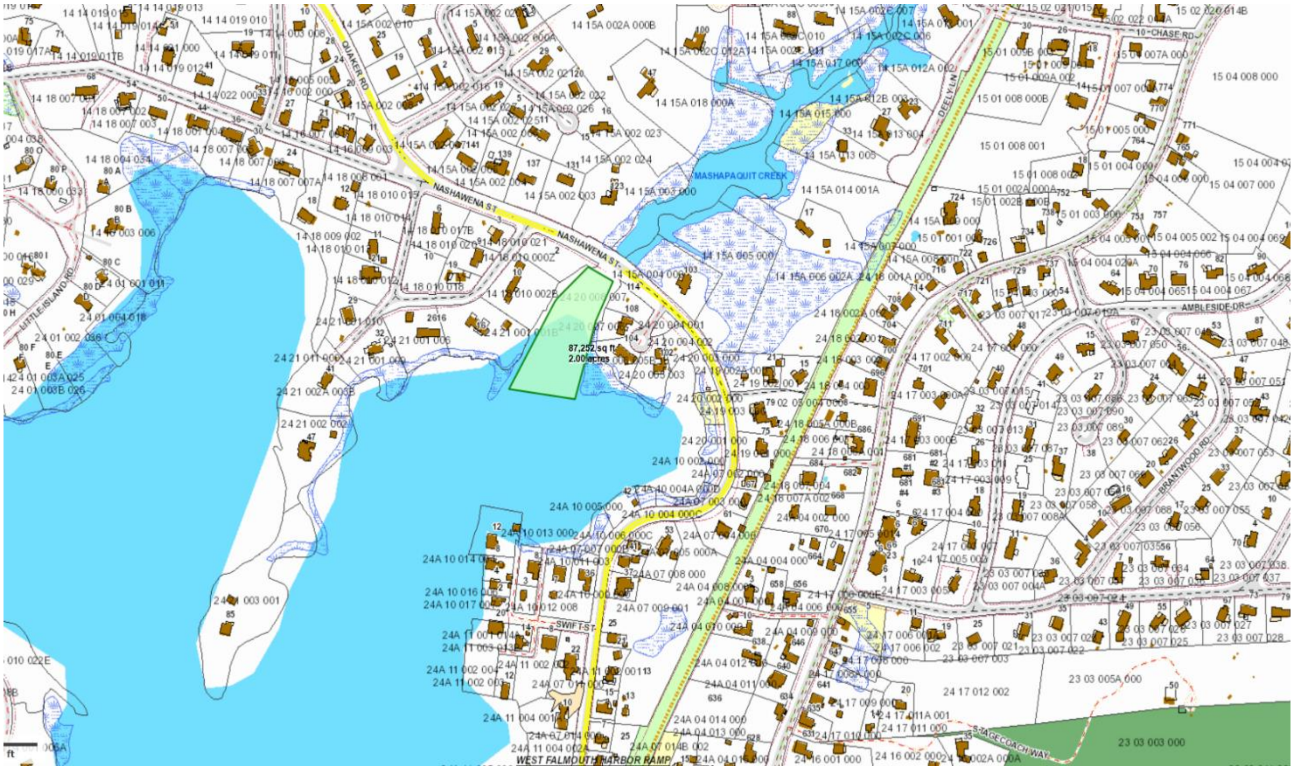

Figure 1. Locus Maps of West Falmouth Oyster Bed Location

Figure 2. Aerial View of West Falmouth Oyster Bed Location

Site Selection (2014, 2015)

Establishing an oyster bed utilizing remote set from hatcheries requires both suitable sites and an effective method for growing. The general location for the establishment of an oyster bed in Falmouth was selected for several reasons, including:

- Observed high rates of water flow and food availability
- Adequate salinity even within Mashapaquit Creek (20 ppt)
- Suitable areas of hard bottom
- Population of wild oysters in this area
- Lack of freezing even during the winter of 2014 when much of West Falmouth Harbor was solid ice

Based on these factors, a preliminary viability study was conducted in July 2014. This exploration involved installing one tray near Nashawena Bridge and 39 floating bags in different locations around the project area. Figure 3 shows the locations of the test sites. Gear was stocked with approximately 1.5 L of oyster singles at a starting size of approximately 12 mm. After approximately six weeks, a visual inspection of the oysters seemed to indicate that those located within Mashapaquit Creek were not thriving and the oysters south of the Nashawena Bridge were growing well. This relative health between oysters in the stations located within Mashapaquit Creek and stations 4A and B was assessed based on a noticeable difference in color. Measurements confirmed these visual inspections. By the end of August, measured oyster growth (starting density of 1.5 L) was as follows:

Stations 1A and 1B:	2.25 L
Stations 2A and 2B:	4 L
Stations 3A and 3B:	8 L
Stations 4A and 4B:	12.5 L

In addition, the areas within Mashapaquit Creek required a boat for access and maintenance and there is only a two-hour window around mid-tide when a work boat can get under the bridge to access this area.

Figure 3. 2014 Preliminary Study Area

Based on these results, the area south of the Nashawena Bridge was selected for continued evaluation and 500 bags of oyster remote set were purchased for the 2015 growing season to confirm the viability of this location for establishing a permanent oyster bed.

Typically, bags of remote set are purchased and directly bottom-planted. Falmouth has found that growing the remote set in floating bags and covered trays off-bottom for the first part of the growing season leads to higher survival and overall oyster density.   Keeping the remote set in floating bags and trays also protects the oysters during their early stage of growth. For these reasons, the remote set used in this demonstration was grown in floating bags and trays for one season prior to bottom planting.

During the 2015 evaluation period, oysters grew to an average of 50 mm, mortality was measured at below 5%, and the average number of live oysters per floating bag was approximately 300. Based on these favorable results, both in terms of growth as well as overwintering survival, an implementation project using 1500 oyster remote set bags was planned for 2016. Figures 4 - 6 are photodocumentation of the 2015 pilot study.

Figure 4. Oysters in the Fall of 2015, Prior to Bottom Planting

Figure 5. Oysters Bottom Planted in the Fall of 2015

Figure 6. Left: Oysters in the spring of 2016. Right: Population Counts in the spring of 2016

Project Implementation (2016)

The following steps were taken to implement the 2016 project:

- Assemble floating bags for installation of remote set
- Build cultch bags for remote setting of oysters
- Deliver cutch bags and coordinating with local hatchery to have oyster spat attached to cultch
- Retrieve remote set (oyster spat attached to cultch)
- Install remote set

In April and May, 2016, Falmouth Marine and Environmental Services (MES) staff loaded cultch into mesh bags to create the substrate on which oyster seed is attached. This process involved using a traffic cone as a funnel to efficiently load approximately 10 pounds of clam shell into 10 L mesh bags. Falmouth has been stockpiling clam shell from a local business for several years in anticipation of future projects involving oyster remote set. This shell is clean and dry. In June 2016, 1,500 cultch bags were delivered to ARC (the local hatchery in Dennis, MA). Because ARC was undergoing construction, remote set was not available for pick-up until the last week of July 2016. As soon as the remote set became available, MES staff mobilized to retrieve the 1,500 bags of remote set and began installing it in floating bags on August 3, 2016. Within five days, this remote set had been installed in trays and floating gear.

Approximately 840 floating bags and 30 trays were installed at the project location shown in Figure 1. The floating bags and trays were loaded with approximately 1.5 and 4 remote set bags (respectively). The water surface area taken up by these 840 floating bags using a cinder block anchoring systems is approximately 0.5 acres. As part of its municipal propagation efforts, MES has also developed a system for installing floating bags using helical augers and lines that enables very high density of bags. As seen in Figure 7, more than 4,000 floating bags can be installed per acre. These floating bag densities are highly dependent on flow and food availability.

The purpose of starting the remote set in floating bags was to protect the oysters from predation and fouling during the early phase in their life cycle. Floating bags are widely used across Cape Cod because oysters grow well in them. Low mortality is often measured when using floating bags. At the end of the first growing season, oysters reached an average length of approximately 31 mm. It is likely, based on standard growth rates of oysters, that had remote set been available in late June (as was expected), the oysters would have reached 40 – 50 mm in length.

Operation and maintenance of the floating bag installation included regular flipping of the bags to control fouling. The floating bags were installed so that at low tide, the field could be maintained by foot, greatly reducing the level of effort required for this vital maintenance step. As part of routine maintenance, data was collected on growth rates. Prior to bottom planting, population counts and survival rates were measured.

In October 2016, the remote set oysters were bottom-planted to establish a permanent oyster bed biofilter. The procedure used to bottom plant the oysters involved the following steps:

- Field verification of hard bottom within the Snug Harbor project site

- Marking of these hard bottom areas with buoys
- Systematically emptying strings of floating bags within the marked areas

One challenge with bottom planting is keeping track of where remote set is placed as workers walk on the bottom. A tool was created to enable staff to keep track of where strings of floating bags were emptied within the areas of hard bottom, so that strings of floating bags would be planted across the marked area. This tool included a floating line cut to the approximate width of the planting area that was secured with cinder block anchors and buoys to mark the ends. Once the first string of floating bags was planted, this tool was moved to mark where the second string of bags should be deposited. This approach avoided having staff step on the oysters that had already been put on the bottom, and helped ensure that the area was planted uniformly.

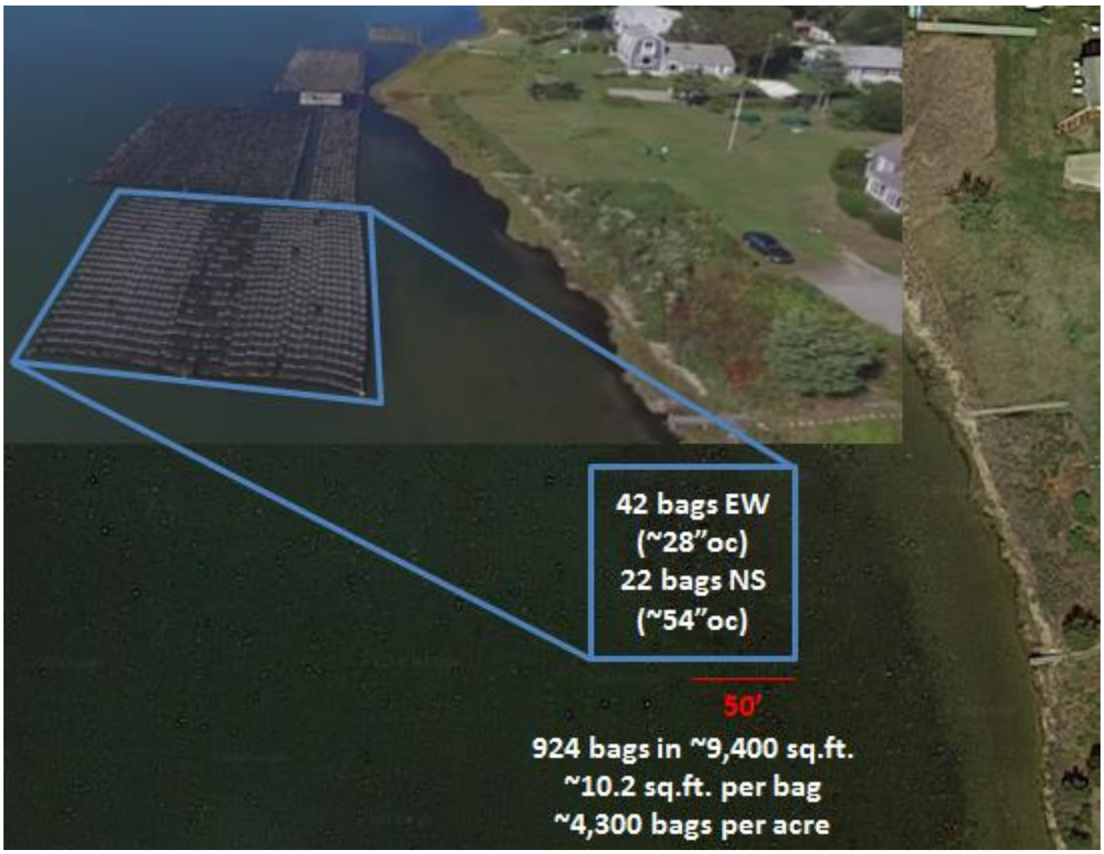

Figure 7. Floating Bag Densities Demonstrated by Municipal Oyster Propagation Operated by the Town of Falmouth in 2016.

Figures 8 - 11 are photodocumentation of the 2016 installation:

Figure 8. 1500 Bags of Remote Set Delivered by Falmouth Staff to Staging Area of Snug Harbor Installation Site

Figure 9. Use of Bobcat by Falmouth Staff to Unload Remote Set

Figure 10. 1500 Bags of Remote Set Being Installed in the Water by Falmouth Staff

Figure 11. Installation of Remote Set in Floating Bags and Trays

3. Population Data and Nitrogen Uptake Estimates

When oyster remote set is first installed, the oyster spat is not visible. As the microscopic seed begins to grow, it is evidenced by small dark spots on the cultch. After installation in 2016, the remote set was monitored weekly to determine when oysters reached a reasonable measurement size. Length measurements of a sample size of 100 oysters began on September 9, 2016. Final lengths were measured on October 21, 2016, prior to bottom planting. Table 1 shows the average measured lengths over the growing season and Figure 12 charts the growth over time.

Table 1. Oyster Remote Set Growth

Date:	**9/9/2016**	**9/23/2016**	**10/7/2016**	**10/21/2016**
Oyster Size:	mm	mm	mm	mm
Average Length:	15.63	18.73	24.07	30.92

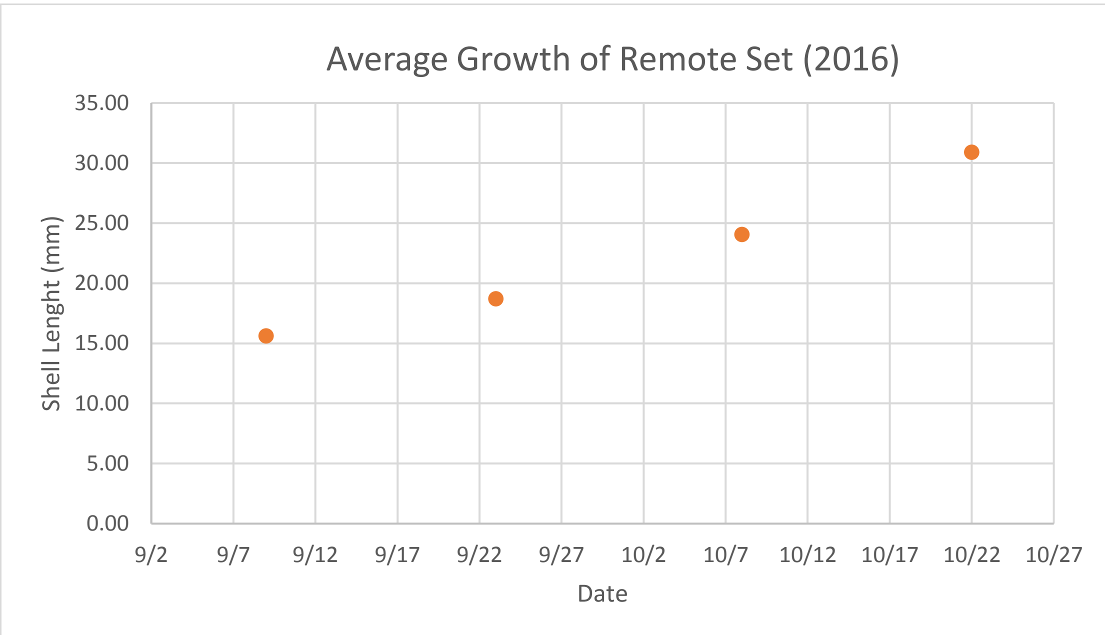

Figure 12. Oyster Remote Set Growth over the Season

Figure 13. Photograph of oysters at the end of October, 2016

A total of 840 floating bags containing 1,300 of the remote set bags and 50 trays containing 200 remote set bags were installed. At the end of the growing season (November, 2016), these oysters were bottom planted in the approximately 3,000 sq. ft. area shown in Figure 14.

Figure 14. 2016 Oyster Bed Planting Area

Prior to bottom planting, five floating bags from three rafts (total of 15 bags) were assessed for both the total oyster population as well as survival. Floating bags were taken from each of the four sides as well as the center of each raft. The entire bag was emptied and all live and dead oysters were counted. The number of live and dead oysters per floating bag was then recorded. The average number of live oysters per floating bag was then calculated to be 296 and the mortality was measured at less than 5%. Please note that this mortality only includes the survival of oysters once they had reached a size where shell was produced. This reported mortality does not include the mortality of spat that never reached the size where shell was visible. Based on these measurements, the estimated population of oysters that was bottom planted in 2016 is approximately 308,000. Mortality will likely reduce the population of planted oysters over time.

Reported mortality for oyster reefs varies widely. There is also a range of published and reported values for annual mortality rates for oysters grown in gear from 2 mm 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. Bricker (2014) and Hudson et al. (2012) propose mortality rates of 55% and 50% respectively, for gear-based aquaculture. The U.S. Department of Agriculture (USDA) Noninsured Crop Disaster Assistance Program uses 44% to 46% as normal mortality rates for oyster aquaculture in their payout calculations. The mortality for an oyster bed in the wild is likely higher than the mortality rate for gear-based aquaculture, especially with respect to predation and weather events. For planning purposes, mortality of an oyster bed is assumed to be 50%.

The value from published literature (Reitsma et al. 2017) for the nitrogen content of Cape Cod oysters that are cultured on the bottom is 0.32 grams per 85 mm oyster. Based on this value, the nitrogen uptake from 308,000 oysters that grow to adult size is 99 kg N (308,000 oysters x 0.32-grams N/oyster). Assuming constant growth over two seasons, half of this nitrogen, or approximately 50 kg would be incorporated into shell and soft tissue per season. The area in which the West Falmouth oyster bed was planted measures approximately 3,000 sq. ft. The planting density was 1.5 - 2 ft^2 per remote set bag or approximately 100 oysters per square foot. At an estimated 50% mortality, an oyster bed covering one acre could support a population of over 2 million oysters, and uptake over 350 kg N/year.

The first oyster Best Management Practice report from an expert panel in the Chesapeake Bay (Cornwell et al. 2016) indicates that there is scientific agreement regarding nitrogen uptake in oyster tissue. This report also highlights that there are still outstanding questions regarding regulatory credit for nitrogen *removal* from permanent oyster installations. This panel will be addressing the issue of nitrogen-removal from oyster beds and reefs in a future report. The oyster bed that has been initiated in Snug Harbor will be allowed to establish itself for several years, and then strategic harvest may occur to remove the nitrogen contained in the oysters.

4. Budget Estimates for Implementation

Based on updated (2017) cost for the gear and labor required to execute this project, a planning-level budget for developing an oyster bed using 1500 bags of remote set is shown in Table 2. This budget assumes volunteer labor to build the 840 floating bags needed, and that project management will be incorporated into the municipal propagation efforts of the MES department. Specialized monitoring costs are not included.

Table 2. Planning Budget for Oyster Bed Development

Item	Description	Cost
Labor - seasonal position	Installation, operation, maintenance and volunteer coordination	$ 20,000
Patrol	Enforcement	$ 2,000
Remote set purchase (1500 bags)	Cost of cultch bags and remote set (spat-on-shell)	$ 24,000
Gear purchase (includes bags, lines, anchors, etc)	System for 840 floating bags	$ 11,760
Trays	50 trays	$ 1,950
Labor to build bags	Volunteers	$ -
Project management and reporting	MES Department program	$ -
TOTAL		**$ 59,710**

Based on the removal of 50 kg of N per year for 310,000 oysters, and an amortization of the gear, remote set and labor expense over 5 years, the dollars per kilogram of nitrogen removed is $280/kg N removed.

The initial budget for this grant was amended to allow reallocation of $2400 to cover a portion of the costs to produce a video (total cost $3,500) to help meet the outreach goals of the project.

5. Monitoring

Critical water quality parameters were monitored near the oyster grow-out location. Leveraging ongoing collaborations between the Woods Hole Oceanographic Institution and the Buzzards Bay Coalition, monthly water samples were collected for nutrient concentrations, including nitrate, nitrite, ammonium, total dissolved nitrogen and particulate organic nitrogen. Samples were also analyzed for chlorophyll-*a* and phaeopigment concentrations. Total nitrogen at the study site exceeded 1.2 mg/L during both summer 2015 and summer 2016 (Figure 15 left) with chlorophyll-*a* pigment concentrations exceeding 30 μg/L during both summers (Figure 15 right). Discrete measurements of dissolved oxygen concentration reached minimums of ~4 mg/L during both summers monitored.

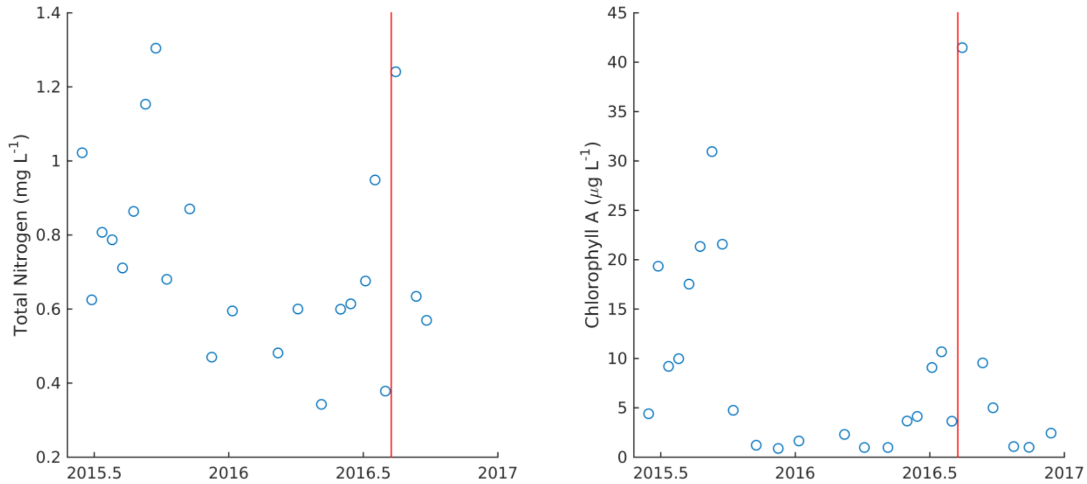

Figure 15. Total nitrogen and chlorophyll A concentration from monthly grab samples near the grow-out location. The vertical red line indicates when the oyster bags were installed.

During summer 2016, a multiparameter datasonde was also installed at the monitoring site that was downloaded, cleaned, and recalibrated every two weeks throughout the summer. The datasonde monitored temperature, salinity, dissolved oxygen, pH, turbidity, and water depth every 30 minutes for the study period. There was a brief hiatus in measurements from late August through early September when the instrument was not collecting data. Daily variations in dissolved oxygen were large and often greater than 10 mg/L (Figure 16). Both extremely low (~1 mg/L) and high (>20 mg/L) dissolved oxygen concentrations were observed (Figure 16).

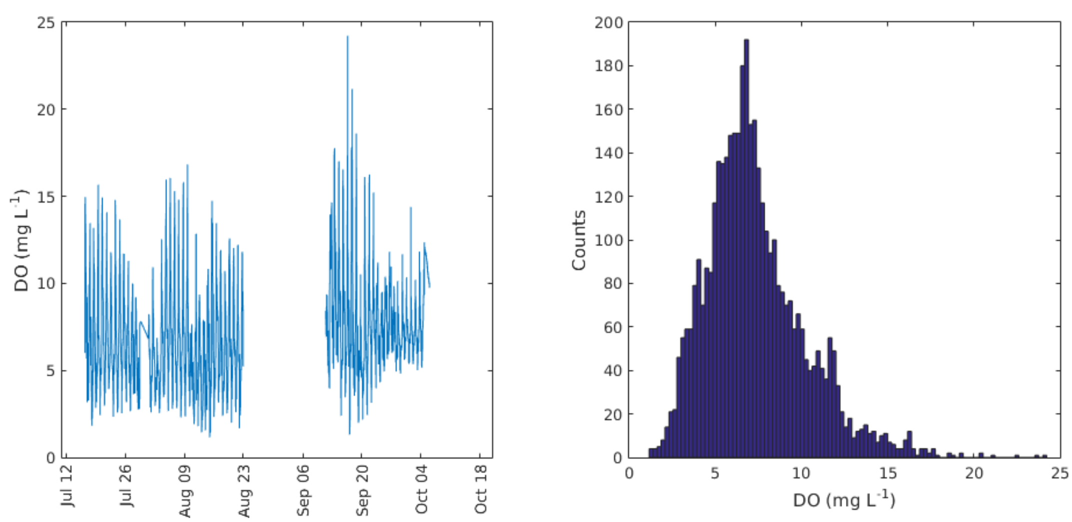

Figure 16. Dissolved oxygen concentration time series and histogram.

From the existing monitoring data, the new oyster bed does not show a measurable impact on nutrient and chlorophyll-*a* concentrations. The oysters were not installed at the study site until early August. This means that while the impact of adult oysters may be measurable, likely the small-sized oysters installed late in the season would not yet have had an impact on water column nutrients. These data do provide important baseline information from before and after the installation to assess the future impacts of the new oyster bed on West Falmouth Harbor.

6. Summary and Recommendations

Key findings of this project include:

- Survival of remote set is high is floating bags. Of the oysters that grew on the cultch to a size where shell was visible, mortality was less than 5%. The survival of spat was not measured.

- Oysters grew from spat to over 30 mm from August to October. This growth over a three-month, warm-weather period is similar to the amount of growth of oyster singles that were grown by the MES Department for municipal propagation.

- The estimated nitrogen uptake in shell and soft tissue for this installation is almost 50 kg per year for 308,000 oysters. Some additional nitrogen may be filtered out of the water column and deposited in sediments (not quantified in this study).

- Costs in terms of dollars per kilogram of nitrogen harvested: $272

- The program's outcomes also highlight the importance of site selection and viability testing as critical first steps in planning.

- Due to the visibility of this location, many people stop and ask questions when staff is working on this project. This provides an excellent opportunity to discuss environmental issues and the role of shellfish in water quality improvements. There is a great deal of public support for this project.

- Several public outreach presentations during the planning and implementation phases of this project have been made, including:

    - Presentations at two meetings sponsored by EPA/SNEP (August and October, 2016)
    - Presentation to West Falmouth Village Association meeting (June, 2016)
    - Periodic updates at Falmouth Water Quality Management Committee meetings
    - “From Town To Table: Falmouth Oysters” video posted on Vimeo at https://vimeo.com/210045949 and the Falmouth MES Facebook page, and has been presented at various venues, including a Massachusetts Shellfish Offices Association meeting, Trinity College, Falmouth Fisherman’s Association and Cape Cod

Cooperative Extension. Showing this video to Falmouth's Fall 2017 Town Meeting and the Cape Cod Commission's OneCape conference in June 2017 are also planned.

- Additional presentations are planned once this project report is finalized

Based on the lessons learned, it is recommended that the population and survival of this oyster bed in this area of Snug Harbor be evaluated in the fall of 2017, and scale-up to a one-acre oyster bed be considered.

7. References

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