Technical Memorandum

To: J. Jefferson Gregg, Jessica Janney – GHD, Inc.

From: Anastasia Karplus, Eric Karplus – Science Wares, Inc.

Subject: **Final Shellfish Feasibility Study for Salt Pond**

Date: October 15, 2018

I. Background

In its continuing effort to address nitrogen impacts to its coastal embayments, including Salt Pond, the Town of Eastham, MA commissioned several Technical Memorandums in 2017 that outlined a variety of approaches to be further evaluated for feasibility of use. Technical Memorandum No. 3 (by GHD Inc.), which focused on the Salt Pond watershed, identified the need for development of a feasibility study for the use of shellfish in Salt Pond to reduce its watershed nitrogen load. A 2012 MEP report[1] published a present watershed load of 1,830 kg nitrogen per year and a target watershed nitrogen load of 437 kg nitrogen per year to bring Salt Pond into Total Maximum Daily Load (TMDL) compliance. This memo evaluates the suitability of shellfish cultivation as part of the strategy for achieving a 1,390 kg/year reduction in Salt Pond's watershed nitrogen load.

II. Preliminary Site Suitability

Geographic, Current Use and Tidal Factors

As shown in Figure 1, Salt Pond is a terminal pond in Eastham, MA covering slightly under 19 acres adjacent to the Cape Cod National Seashore, and the inlet channel connecting the pond to Salt Pond Bay covers an additional estimated 3 acres[2]. The land around the perimeter of the pond is part of the Town of Eastham, and the town manages a boat landing with a small parking lot on the west side of the pond.

The Salt Pond Visitor Center of the Cape Cod National Seashore, is located at 50 Nauset Road, Eastham, MA and is essentially open year round for visitors to enjoy. The National Seashore is the primary abutter to this site and the observation areas accessible from the visitor center overlook most of Salt Pond.

[1] Howes, B., R. Samimy, D. Schlezinger, E. Eichner, Kelley, S, Ramsey, J and Detjens, P, Massachusetts Estuaries Project Linked Watershed-Embayment Approach to Determine Critical Nitrogen Loading Thresholds for the Nauset Harbor Embayment System Towns of Orleans and Eastham, Massachusetts, FINAL REPORT – December 2012, Executive Summary p.10.

[2] Approximated using online area tool at https://www.mapsonline.net/easthamma/index.html

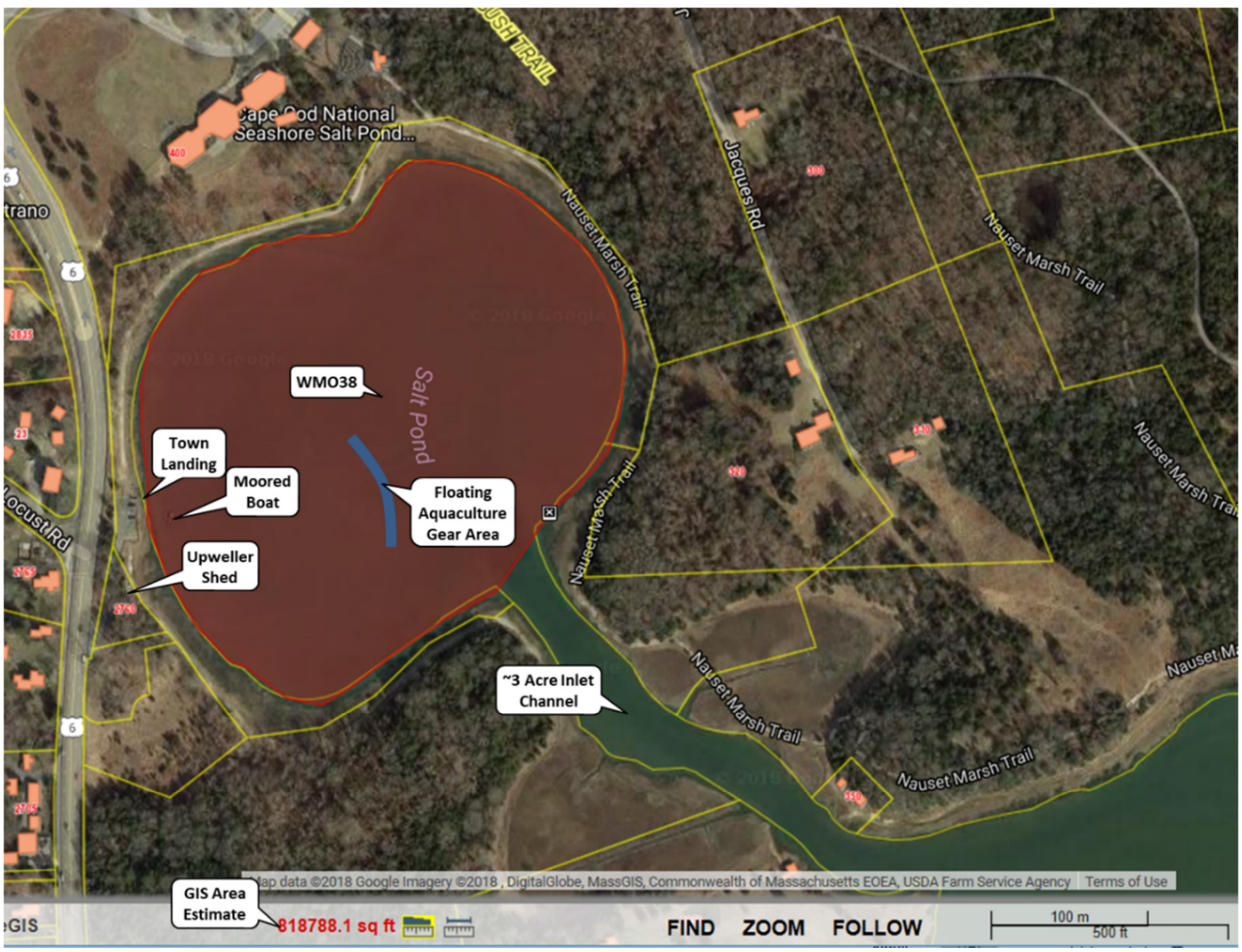
The Nauset Marsh Trail circumnavigates Salt Pond at an elevation that can be navigated by foot at or below most normal high tides. The trail passes through the Town's land as well as Cape Cod National Seashore land.

Recreational kayaking occurs on the pond throughout the year, some launching from the boat landing and some coming in from Salt Pond Bay through the inlet. Small powerboats visit infrequently, there are a few moored in the inlet channel. One boat is moored directly in front of the town parking lot.

The Town of Eastham operates a municipal propagation program that utilizes an upweller in a shed located on the southwest shore of the pond to raise a population of approximately 250,000 quahogs from 2-3mm at the beginning of the season to 12-20mm at the end of the season. A population of approximately 20,000 oysters measuring about ¾" is deployed in floating bags in the southern middle area of the pond at the beginning of the growing season. By the end of the growing season these oysters occupy up to 150 bags. There are no active aquaculture grants in Salt Pond.

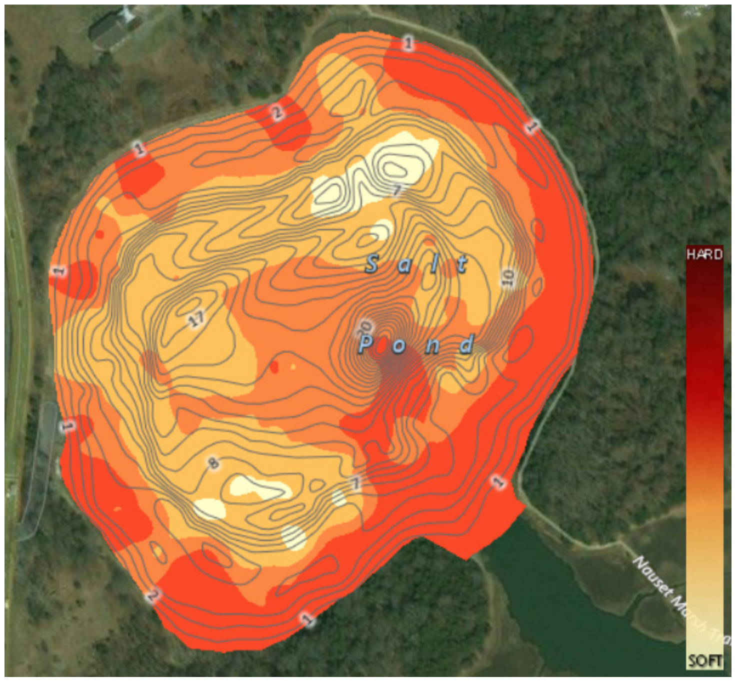
The Anderson Lab at WHOI has been conducting intensive research on Harmful Algal Blooms (HABs) in Nauset Marsh for several decades. Their research involves many measurements made throughout the year in Salt Pond.

Figure 1. Overview of Salt Pond.



The ~12 million cubic foot pond is over 20' deep in some places at high tide. Typical tide excursions are on the order of 4 feet. The perimeter of the pond has a generally hard bottom composed of a small amount of organic matter mixed with sand and small rocks adjacent to marsh grass. At low tide, most of the perimeter of the pond is walkable and has a depth of around 1 foot at a distance of about 10' from shore, with a 5-10° slope. A depth contour and hardness map of the bottom is shown in Figure 2.

Figure 2. Side-scan sonar survey of Salt Pond showing depth and bottom hardness.



Site Ecology Factors

There is presently no eelgrass in Salt Pond. Significant *ulva* blooms occur, often more than once a year. This and other macro algae often accumulates around the perimeter of the pond and can get lodged in the marsh grass at high tide. The most recent bloom prior to the writing of this report was observed in early June 2018. The interaction of this algae with aquaculture gear would need to be managed, especially during bloom episodes. If too much algae accumulates in and around the gear, it can restrict the flow of food to the animals, which can limit their growth and eventually cause them to die. Significant algae blooms can also cause the dissolved oxygen content of the water to oscillate broadly. At the end of a sunny day, the production of oxygen by the algae can cause the concentration of dissolved oxygen in the water to be more than twice the steady state level that the water can support. This oxygen rich environment enables organisms in the water to thrive and multiply, and the increased metabolism per unit volume of water often results in anoxic conditions by the early morning hours. If a period of several cloudy days occurs at a time like this, it is possible for the water to remain in an anoxic state for an extended period. The first visible sign of this condition is small dead fish along the shoreline at low tide. Shellfish can usually tolerate anoxic conditions for a few days, with larger animals being more tolerant than smaller animals. Oxygen equilibrium is eventually restored by a combination of the death of organisms that consume oxygen (both micro and macro organisms), the revival of oxygen production by photosynthesis, and the diffusion of oxygen from the air into the water. The latter process is facilitated by windy conditions that help to mechanically agitate the water surface so a larger effective area of water is exposed to the oxygen available in the air.

During high algae growth periods, an effective management strategy for floating gear is to flip bags more frequently, which typically requires about 15 seconds per bag for 6mm diamond mesh bags. If floating spat bags are being used, there are normally more shellfish per bag early in the season so there are fewer bags to maintain, however the process also involves scrubbing the bags with a large brush, which typically requires about 30 seconds per bag and sometimes needs to be done every 2-3 days until about mid-July when the shellfish can be spread out into 6mm diamond mesh bags.

The marsh grass surrounding the pond contains wild ribbed mussels. The perimeter of the pond supports recreational quahog harvesting, and the quahog population is replenished by the Town of Eastham's municipal propagation activities.

The Town of Eastham raises a population of 250,000-300,000 quahogs in the upweller each year using nutrient-bearing water from Salt Pond. These oysters reach an average of 12-20mm in size by the end of the season, and most are free planted outside Salt Pond. It is estimated that 80% of the initial population is planted, and that the ultimate harvest from this population is 750-1,000 ten-quart baskets. A population of 20,000-25,000 oysters is grown from ¾" seed to wild harvest size in ~150 floating bags. These oysters are bottom planted in the inlet channel and other areas in Nauset Marsh for recreational harvest in November/December. The town also receives 100-150 bushels of contaminated quahogs from the Taunton River that are already at legal harvest size. These shellfish are planted in closed areas for one year and are opened for recreational harvest a year later. It is estimated that most of the shellfish raised and planted by the town are ultimately removed by recreational harvesters.

While a detailed quantitative survey has not been conducted, there are known to be predators such as green crabs that occasionally appear on the oysters in Salt Pond. Tunicates (sea squirts) and have been observed on the floating bags. Conch, starfish, and oyster drills are known to be in nearby waters. None of these organisms have had an unmanageable impact on Eastham's municipal shellfish operation, and are not believed to present a risk that would be unmanageable for a larger scale operation.

Research supervised by the Anderson Lab at WHOI found paralytic shellfish poisoning (PSP) from red tide in Salt Pond in 27 of the last 30 years[3]. Anderson's lab has reported abundant vibrio cysts at the bottom of the pond[4], and red tides have appeared regularly in the pond. This phenomenon was confirmed by Eastham's shellfish constable. After a red tide closure, three 'clear' observations must be made before an area is reopened. This typically occurs within three weeks after the red tide subsides. The appearance and duration of red tides are difficult to predict. The situation has not prevented Eastham's municipal propagation program from raising quahogs oysters that are made available for wild harvest in the inlet channel in the fall of each year.

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[3] Alexis Fisher 'Explore Nature' Episode 3 published March 17, 2016 accessible through http://www.whoi.edu/page.do?pid=13418&tid=282&cid=240529

[4] Cojanu, D., Hugus, E., Setting a Watchman for Harmful Algal Blooms, originally published online September 9, 2015, accessible through http://www.whoi.edu/page.do?pid=13418&tid=282&cid=222509

A 2012 MEP report[5] stated "The computed flushing rates for Nauset Harbor show that each system generally flushes well, with flushing times on the order of a day. Of all the modeled sub-embayments, Salt Pond has the longest flushing times, with a local flushing time (which is the time it takes for a particle of water that enters Salt Pond from inlet to leave the pond) that is nearly 4 days. This deep kettle pond does not flush as well as other sub-embayments due to its large mean volume (11,933,800 ft^3). Because there is already almost no attenuation of the tide signal from Nauset Bay to inside Salt Pond, it would not be possible to make significant improvements to the flushing characteristics of this sub-embayment by dredging the tidal creek connection the pond to the Nauset system."

There is a water quality monitoring station WMO-38 near the middle of Salt Pond that has been in use since 2003. Samples are acquired by trained volunteers and Town of Eastham staff and analyzed by the Coastal Systems Analytical Facility at SMAST-UMass Dartmouth. Samples are collected approximately two weeks apart on five dates each year, with the first sample typically taken in mid-July and the last sample typically taken in mid-September. Figure 3 shows the water quality parameters dissolved oxygen (DO), salinity, temperature, and chlorophyll *a* from this monitoring station at the surface and at the bottom with a depth of approximately 4m. Figure 4 shows the same surface parameters from WMO-38 alongside the equivalent parameters from surface at station PBA-15 in Lonnie's Pond in Orleans, where the third year of a high-density oyster aquaculture project using floating gear is underway in 2018. Lonnie's Pond is a terminal pond in Orleans, Massachusetts that is similar to Salt Pond. Table 1 shows some comparable characteristics of the two ponds which suggest that shellfish aquaculture performance would be similar.

Table 1. Comparison of characteristics of Salt Pond in Eastham, MA and Lonnie's Pond in Orleans, MA.

	Salt Pond	Lonnie's Pond
Surface Area (acres)	19	15
Volume (million ft^3)	12	6.3
Maximum depth (feet, low tide)	20	18
Local Residence Time (days)	3.9	1.1
Surface Dissolved Oxygen (mg/L, 2015)	6.6 ± 0.40	5.1 ± 0.68
Surface Salinity (ppt, 2015)	31 ± 0.23	30 ± 0.54
Temperature (°C, 2015)	24 ± 1.2	25 ± 1.2
Chlorophyll *a* (µg/L, 2015)	5.5 ± 1.6	3.6 ± 1.2
Watershed N Load (kg/day)	5.0	2.4
Atmospheric N Load (kg/day)	0.30	0.23

[5] Howes, B., R. Samimy, D. Schlezinger, E. Eichner, Kelley, S, Ramsey, J and Detjens, P, Massachusetts Estuaries Project Linked Watershed-Embayment Approach to Determine Critical Nitrogen Loading Thresholds for the Nauset Harbor Embayment System Towns of Orleans and Eastham, Massachusetts, FINAL REPORT – December 2012, pp.105-106.

Figure 3. Water quality parameters from WMO-38 at the surface and bottom. The annual average is shown along with the standard deviation of all samples for each year. Note log scale for Chlorophyll *a*, where values above 10 ug/L indicate a eutrophic environment.

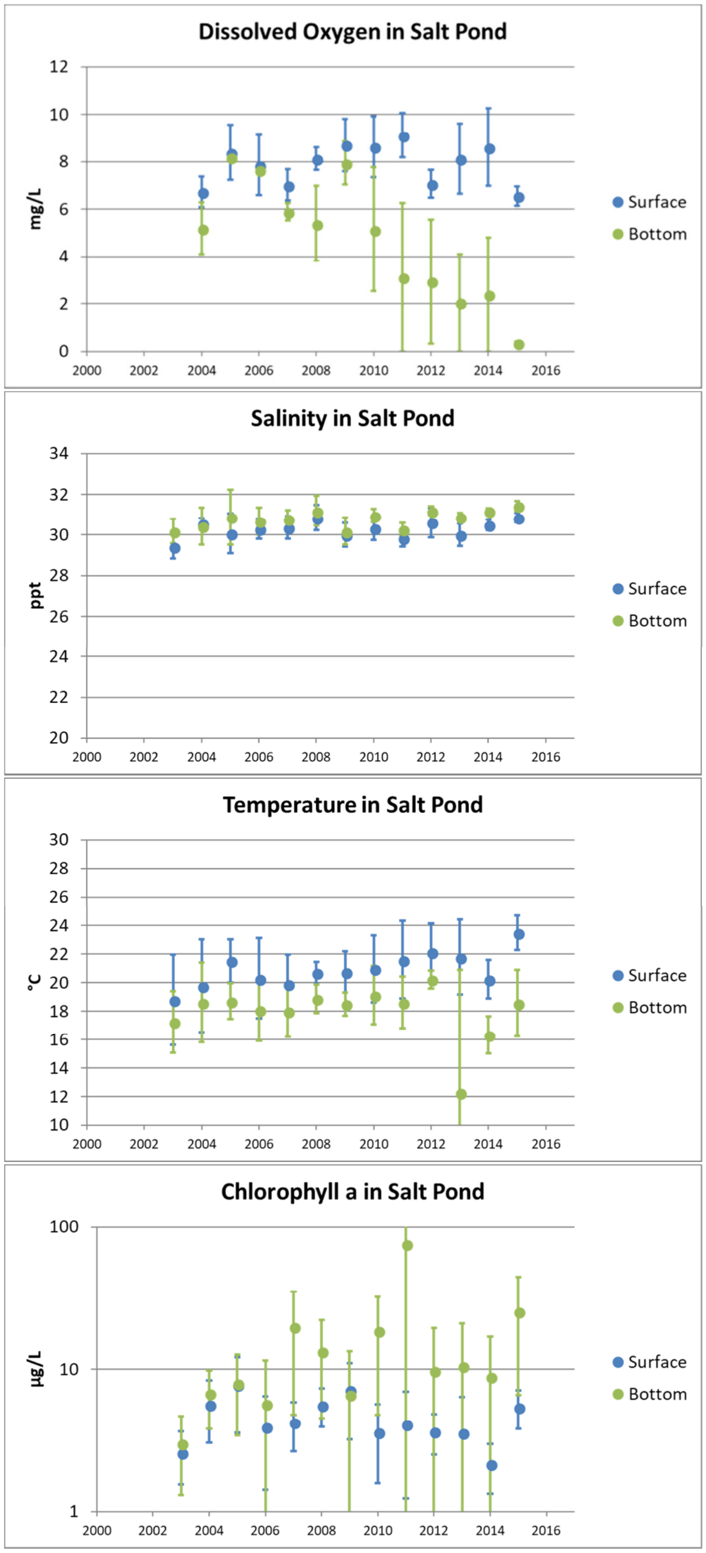
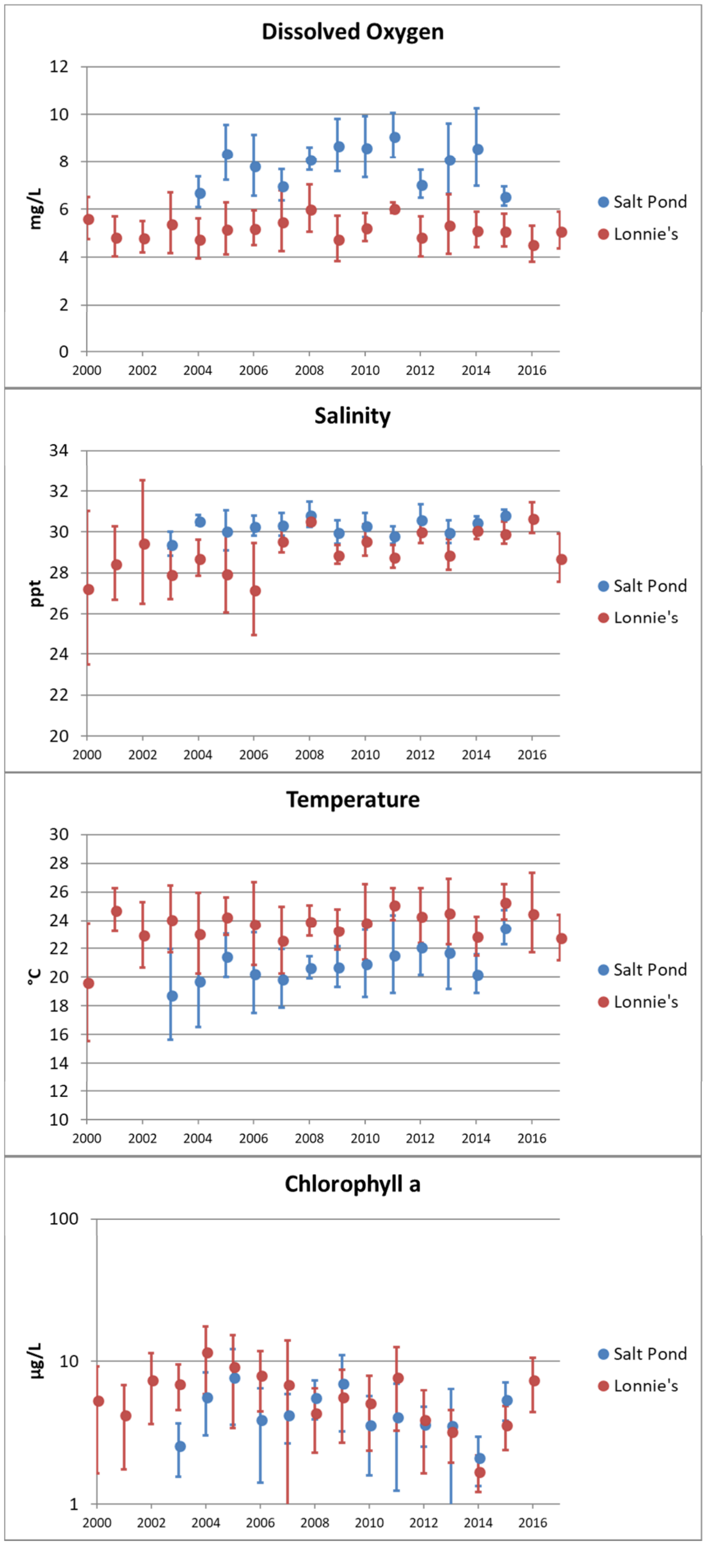


Figure 4. Water quality parameters from WMO-38 at the surface compared with equivalent parameters from PBA-15 at the surface. The annual average is shown along with the standard deviation of all samples for each year. Note log scale for Chlorophyll *a*, where values above 10 ug/L indicate a eutrophic environment.



It is notable that the surface dissolved oxygen concentration is higher in Salt Pond than it is in Lonnie's Pond, which represents a favorable condition for shellfish aquaculture. This may be due in part to the lower average temperature of the water, because oxygen solubility decreases as water temperature increases. The salinities in years 2007 and beyond are quite comparable and also suitable for shellfish aquaculture. The surface chlorophyll *a* concentration is considered a good indicator of the food resource for shellfish, and the surface concentration in Salt Pond is comparable to the surface concentration in Lonnie's Pond, where high density oyster aquaculture in floating gear performed well in 2016 and 2017.

Previous analysis has cited a low dissolved oxygen concentration at the bottom of Salt Pond as a reason to not consider bottom planting of shellfish. This consideration certainly applies in the deep central regions of the pond, but is not likely to be a factor in areas where the tidal cycle presents surface-like water within 1-2 feet of the bottom for 6-8 hours each day, which is the case for a 20-30' wide strip all the way around the perimeter of the pond.

The deep basin in Salt Pond frequently goes anoxic in the summer months. Benthic cores taken from the deeper regions confirm that the sediments are a significant net source of nitrogen to the water in Salt Pond. Two cores analyzed for the MEP report produced a sediment nitrogen flux of 73.2 +/- 0.6 mg N / m^2 / day, higher than any other sediment nitrogen fluxes measured in 32 sediment samples taken throughout the Nauset Estuarine System.[6]

[6] Howes, B., R. Samimy, D. Schlezinger, E. Eichner, Kelley, S, Ramsey, J and Detjens, P, Massachusetts Estuaries Project Linked Watershed-Embayment Approach to Determine Critical Nitrogen Loading Thresholds for the Nauset Harbor Embayment System Towns of Orleans and Eastham, Massachusetts, FINAL REPORT – December 2012, pp.74-75.

III. Proposed Shellfish Program

Nitrogen content of shellfish

Initial estimates of the nitrogen removal potential of shellfish in Salt Pond used a value of 0.5% of harvest weight associated with projects in Mashpee, MA[7]. The estimates that follow assume a nitrogen content that is 0.32% of the harvest weight of the shellfish. This value has been observed for two years in a row in oysters cultivated at high density in floating gear in Lonnie's Pond, which is a terminal pond connected to Pleasant Bay in Orleans[8]. This value is in line with other published observations for Pleasant Bay[9]. The nitrogen content of shellfish cultivated in Salt Pond should be directly measured to establish a suitable planning value.

Analysis of existing nitrogen removal from Salt Pond via shellfish

The municipal program operated by Eastham supports removal of an estimated 200,000-240,000 quahogs that grew from 1.5mm to 12mm in one season, and an estimated 20,000 oysters that grew from ¾" to more than 3" in one season. Assuming a harvest weight of 1 lb per 100 quahogs and 17 lbs per 100 oysters[10] and a nitrogen content of 0.32% of harvest weight, and that the vast majority of mass increase occurs using nutrients obtained from Salt Pond, the nitrogen removal can be estimated as shown in Table 2.

Table 2. Estimated annual nitrogen removal via Eastham's shellfish program in Salt Pond

Harvest Population	Total Harvest (kg)	Total Nitrogen (kg)
200,000 – 240,000 quahogs @ 1lb per 100	900 – 1,100	2.9 – 3.5
20,000 – 25,000 oysters @ 17lb per 100	1,500 – 1,900	4.9 – 6.2
Total	2,400 – 3,000	7.8 – 9.7

Options for increased aquaculture

The nitrogen removal target of 1,390 kg per year for Salt Pond is two orders of magnitude larger than the nitrogen removal achieved by Eastham's existing municipal propagation program. The present wild and recreation harvest needs of Eastham are well served by the scale of the Town's existing municipal propagation program, and substantial increases would not benefit the community. Additional nitrogen removal could be accomplished by allowing a commercial grower to operate in Salt Pond, if the growing activity was done in such a way that a significant number of shellfish were grown in the pond and then extracted annually. The general approach would be for the Town to contract a commercial grower who would be responsible for growing a certain amount of biomass in a specified area over a specified time period using a Town approved deployment system. The exact number of shellfish could be adjusted by the grower to optimize revenues. Higher stocking densities result in smaller shellfish, but there would be more shellfish to sell, and therefore potentially a larger total revenue per unit area of space used. The commercial grower would be able to legally sell the shellfish, and these revenues

[7] Technical Memorandum No 3 to Town of Eastham from GHD Inc, January 31, 2017.

[8] Town of Orleans, MA Water Quality and Wastewater Planning Task 10.1.B.1 - Lonnie's (Kescayo-Gansett) Pond Oyster Aquaculture Demonstration Project Year 1 Project Report - Final

[9] Reitsma J., D. Murphy and A. Franklin. 2013. Shellfish Nitrogen Content from Coastal Waters of Southeastern Massachusetts, Cape Cod Cooperative Extension and Woods Hole Sea Grant.

[10] Reitsma, J., Murphy, D.C., Archer, A.F. and York, R.H., 2017. Nitrogen extraction potential of wild and cultured bivalves harvested from nearshore waters of Cape Cod, USA. Marine Pollution Bulletin.

would pay for the equipment and labor necessary to support their operations. The grower would pay a licensing fee to the Town for the privilege of having access to the Salt Pond ecosystem resource, and this licensing fee would provide the Town with the resources it needs to oversee the program and ensure that the expected nitrogen removal target is achieved. In this way, there would be no net cost to the Town of Eastham for removing nitrogen from Salt Pond using aquaculture. In addition, there is likely to be an economic multiplier benefit to the Town for hosting a profitable business that, as described below, could be designed to bring in revenues from outside communities.

Oysters are an ideal shellfish for an aquaculture-based nitrogen removal program because they can be grown from seed to market size in a wide variety of settings, including floating gear that does not modify the bottom. In addition, oysters grow rapidly in areas such as Salt Pond and have a commercial value in local as well as off-Cape markets. The estimates that follow assume that oysters would be grown. Other shellfish could be considered, but are unlikely to have a greater market value or higher nitrogen removal capability per unit area.

Proposed options for increased aquaculture with their estimated nitrogen removal potential are summarized in Table 3. The '% of MEP Target' column assumes an annual nitrogen removal goal of 1,390 kg of nitrogen. A summary of the pros and cons of the gear and population strategies listed in Table 3 is given in Tables 4 and 5 respectively, followed by a discussion of some details on each strategy. Some visual aspects of the gear strategies in Table 4 are shown in Figures 5 and 6. Figure 7 shows the times at which bottom mounted racks might be visible from the Cape Cod National Seashore observation areas. Permitting of any approach would need to be discussed with the Massachusetts Division of Marine Fisheries.

Table 3. Preliminary aquaculture strategy estimates for Salt Pond.

Deployment / Popluation Strategy	**Deployment Area (acres)**	**Nitrogen Uptake (kg/yr)**	**% of MEP Target**	**Annual Shellfish**	**Market Value**
Bottom Plant / Y2 Only	0.69	90	6.5%	750,000	$225,000
Bottom Racks / Y1 Only	0.46	240	17%	4,400,000	$440,000
Bottom Racks / Y2 Only	0.46	140	10%	1,000,000	$350,000
Bottom Racks / Blend	0.46	170	12%	750,000	$260,000
Floating Gear / Y1 Only	1.9+	500	36%	9,100,000	$910,000
Floating Gear / Y2 Only	1.9+	290	21%	2,100,000	$720,000
Floating Gear / Blend	1.9+	440	32%	1,500,000	$540,000

Table 4. Aquaculture gear strategy pros and cons for Salt Pond.

Deployment Strategy	Pros	Cons
Bottom Plant	Low visual impact Low capital cost No bird perch	Limited to parts of perimeter Risk of predators
Bottom Racks	Intermittent visual impact Protection from predators Biodeposit options	Limited to parts of perimeter Higher capital cost Intermittent bird perch
Floating gear	Large area possible Protection from predators Biodeposit options	Visual impact Higher capital cost Uninterrupted bird perch

Table 5. Aquaculture population strategy pros and cons for Salt Pond.

Population Strategy	Pros	Cons
Y1 Only	Highest efficiency area use	Need to overwinter Lots of animals No proven market
Y2 Only	Best biodeposit output	Heavy footprint Need to protect local market
Y1&Y2 Blend	Full operation at one site	Heavy footprint Need to protect local market

Bottom Plant

This deployment configuration is shown in Figure 5a and is only suitable for oysters entering their second year of growth. Oysters entering their second year of growth would be placed directly on the bottom near the intertidal perimeter of Salt Pond. Placement could be designed in such a way that the oysters would never be visible, even at low tide. It is believed that this approach could be used in Salt Pond without introducing special gear. From a commercial perspective, this approach is typically most successful if the bottom is cultivated to remove predators prior to deploying the oysters. The approximate usable deployment area of Salt Pond for a bottom planting configuration is shown in Figure 6a.

Bottom Racks

An example of this deployment configuration is shown in Figure 5b, where oysters are placed in bags that do not float, and those bags are placed on racks in such a way that the bags get exposed to air at low tide. The exposure at low tide is necessary to limit biofouling of the gear that would eventually prevent the oysters from having good access to food. Other configurations involve using metal cages that stand off the bottom, instead of plastic bags on a metal rack. The racks can be designed to have an orderly appearance such that the top surface of the bags remains parallel to the water's surface. This approach can be used in areas with walkable bottom and could cover an area of the bottom where the water depth at low tide is zero to three feet. It is also possible to just leave the bags directly on the bottom, though this would reduce the size of the area that can be used due to the slope of the bottom. The approximate usable deployment area of Salt Pond for a bottom rack configuration is shown in Figure 6a. Figure 7 shows the times during a typical month when the gear would be exposed at low tide. Each square in the figure represents a day with time on the horizontal axis and tide level on the vertical axis. There is a red horizontal line running across the part(s) of each day when the gear would be visible at low tide.

Floating Gear

An example of this deployment configuration is shown in Figure 5c, with the usable deployment area of Salt Pond shown in Figure 6b. Bags with floats would be filled with oysters and attached to an anchoring system that could be located over any part of Salt Pond. The field shown has three sections in a L shape. Each section can hold up to 30 rows of 17 bags in a 60'x68' area. The corners of each section are held in place using telescoping augers that extend and retract vertically with the tide cycle and do not project above the water's surface. This keeps the corners of a square field from drifting as the tide goes in and out. The depth under the sections shown in the picture ranges from 1 to 12 feet at low tide, and the tide cycle is around 4 feet. This type of floating gear is maintained using a kayaks and boats, and the gear does not need to be in a location where it is possible to walk on the bottom.

Y1 Only

This strategy involves purchasing oysters from a hatchery and growing them out for the first year only. The seed is typically purchased at a small size and placed in a fine mesh bag to start, and then as it grows it is transferred into larger mesh bags. It is possible to place the early seed at high density in a smaller number of bags, and then increase the number of bags as the oysters grow. A common configuration would involve covering a third of the deployment area starting in mid-May and expanding to cover the full deployment area by the end of July. After initial deployment, the main ongoing labor activities involve cleaning gear of biofouling and transferring the animals into larger mesh bags at lower density. Most of this work occurs from early June to the end of July. The oysters would be taken out of the gear and overwintered in a climate-controlled storage container, and then sold as intermediate seed in the spring of the next year.

Y2 Only

This strategy involves purchasing intermediate size seed (~14 g per oyster) and growing it out for a second year to a harvestable size. The deployment will typically occupy the entire area during the growing season. After initial deployment, the main ongoing labor activity is harvesting oysters for sale. If gear is used, another significant activity is keeping the gear clear of biofouling. There is presently no source of intermediate seed capable of supplying the number of oysters needed for a large-scale implementation of this approach. However, a project expected to begin operating at Lonnie's Pond in Orleans, MA would be capable of supplying the required number of oysters for the 2020 growing season and beyond.

Blend

This strategy involves deploying both Y1 and Y2 oysters in the same field. Typically a quarter of the deployment area would be occupied by Y1 oysters, and the balance would be occupied by Y2 oysters. The Y1 oysters would be overwintered in a climate controlled storage container and brought in as Y2 oysters the next year.

The annual shellfish numbers in Table 3 are based on oyster stocking density and growth assumptions informed by experience with other projects on the Cape. The market values in Table 3 are based on a sale price of ~$0.10 each for one year old intermediate seed measuring 1.5-2" with an individual weight on the order of 14g, and a sale price of $0.30-0.35 each for market ready second year oysters. As discussed below, a pilot program could establish the carrying capacity of the Salt Pond ecosystem for oyster aquaculture so that a commercial grower would be able to estimate their costs and income potential more accurately.

The number of oysters produced in any scenario shown in Table 3 far exceeds what could be used locally, therefore, to support the scale of operations proposed, it would be necessary to contract a commercial grower who could sell oysters into off-cape markets. In order to protect the businesses of existing shellfishermen in the community, it may be to wise to consider placing restrictions on where the oysters from Salt Pond can be sold. For example, the terms of the permit issued to the grower could include a requirement that they provide certification of off-Cape sales.

Another important restriction underlying the assumptions in Table 3 is that the oysters would not be removed from Salt Pond during the growing season, but instead would only be sold at times when they are not growing at a substantial rate, which would typically be from late November until early May. For scenarios involving second year oysters, enforcing this assumption would have a non-trivial effect on the cash flow and market opportunities for a commercial operation. For any scenario involving first year oysters, whether they are returned to Salt Pond for a second year of growth or sold as intermediate seed, it is recommended that the first year oysters be overwintered in a land-based temperature and humidity controlled storage container. This is a proven approach used by many Cape Cod growers, and it minimizes the footprint of the operation taking place in the pond at the end of the growing season. Mortality rates are well under 5% for properly managed systems.

Floating or exposed bottom gear can make an attractive bird perch. This can introduce highly undesirable material to the water if the birds defecate while they are perched or approaching or leaving the perch. Bird deterrents that do not annoy humans and have coverage limited to the gear deployment area are currently under investigation.

There is a significant performance multiplier effect that may be available for deployments that take into consideration the biodeposit resource that oysters create. There are conflicting views about whether denitrification can be enhanced by the addition of oyster biodeposits to the sediment layer. The present consensus is that it is necessary to evaluate each system by direct observation to determine its actual performance. Measurements designed to accomplish this are being undertaken at a variety of sites on Cape Cod, and could be undertaken as part of a pilot project at Salt Pond as well. An alternative strategy that has been investigated at other locations is to simply collect and remove the biodeposits instead of letting them accumulate on the bottom. Preliminary results suggest that the nitrogen content of the biodeposits collected in this way over the course of a growing season is roughly equal to the nitrogen taken up by the oysters through growth of shell and tissue. If a biodeposit collection strategy were implemented in Salt Pond that could achieve this performance, it would essentially double the numbers in the nitrogen uptake column in Table 3. This has the potential to make an aquaculture system a significant contributor to the reduction of nitrogen levels in Salt Pond.

The nitrogen uptake projections in Table 3 are based on experience with high density oyster aquaculture projects at other locations with similar characteristics. Quahogs could be grown instead of oysters, especially if the bottom planted option is used. While it has not been done extensively, a variation on the bottom rack or floating bag system could be used in place of an upweller for large scale first year grow-out of quahogs. The nitrogen removal performance is ultimately limited by the food resource in the water. Actual performance would need to be verified with a pilot study. It is believed that quahogs would have a slightly slower growth rate than oysters, but it may be possible to compensate for this by increasing stocking density. We are not aware of a definitive study that clearly establishes whether there is a difference in the nitrogen uptake capability per unit area of available deployment space. Such a study could be undertaken as part of a pilot program designed to determine the aquaculture carrying capacity of the ecosystem in Salt Pond.

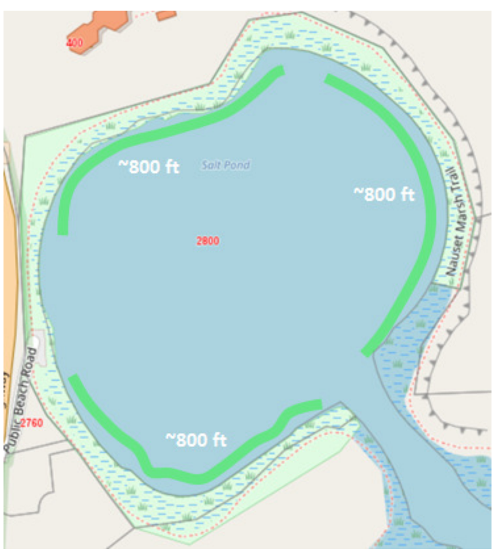
Figure 5. Proposed deployment strategies (a) bottom planted oysters partially visible only at extreme low tide (b) non-floating bags on bottom racks exposed only around low tide (c) floating bags shown with ~60% of a 0.37 acre blended installation filled with Y1 oysters in green floating spat bags and Y2 oysters in black bags.

(a) Bottom Planted

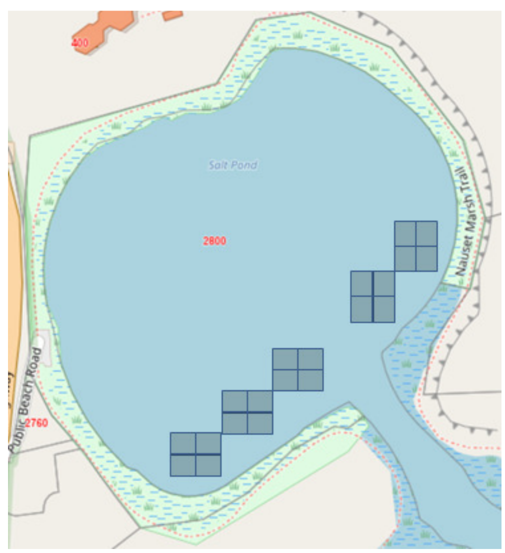
(b) Bottom Racks

(c) Floating Gear

Figure 6. Possible layouts for proposed strategies with maximum active area (a) green line showing a 12' wide strip for bottom planted oysters or 8' wide, double stacked strip of bottom racks occupying an ~2,400' long path along the perimeter of Salt Pond or (b) five units of ~0.37 acre blocks of high density floating gear, each of the five units would be similar to what is shown in Figure 5c.

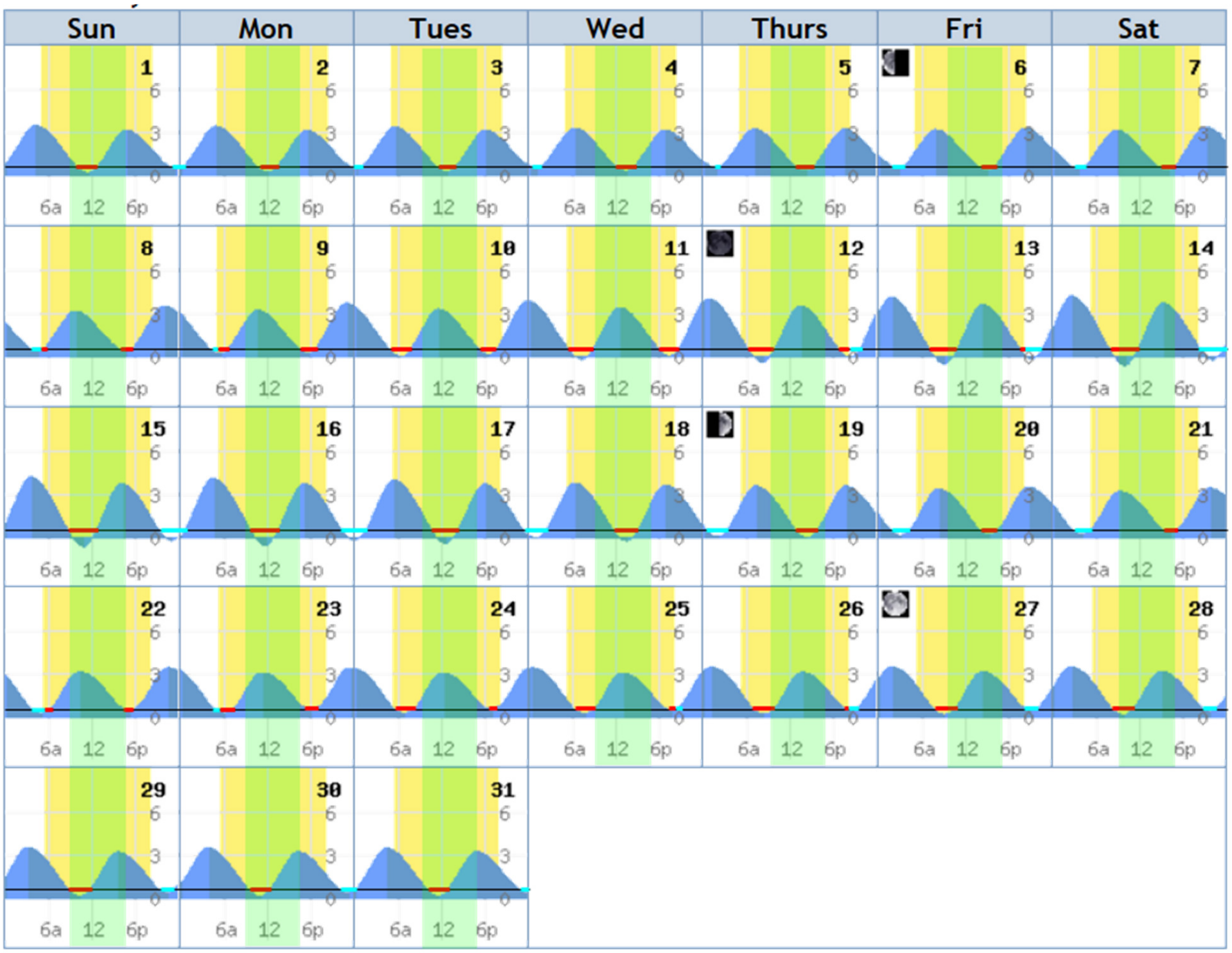


(a) Bottom planted or bottom racks



(b) Floating gear

Figure 7. Times in July 2018 between sunrise and sunset (red lines) and between sunset and sunrise (turquoise lines) when bags on bottom racks might be visible from observation areas at the Salt Pond Visitor Center facility. Hours during which the visitor center are open are overlaid in light green.



https://www.tides.net/massachusetts/2045/?year=2018&month=07

IV. Summary Conclusions and Recommendations

The Floating Gear / Y1 Only configuration shown in Table 3, combined with a strategy that extracts biodeposits to double the nitrogen removal, may be capable of accomplishing over 70% of the 1,390 kg/year reduction in Salt Pond's watershed nitrogen load needed to achieve TMDL compliance. This would be a significant scale operation. Smaller scale deployments could still make a meaningful contribution, even if biodeposit extraction is not implemented.

If the Town of Eastham is interested in exploring increased aquaculture in Salt Pond as a means of removing nitrogen, the best next step would be to discuss deployment strategies with abutters and users of Salt Pond including the Eastham Department of Natural Resources, the Salt Pond Visitors Center, and the Anderson Lab at WHOI. If there is a consensus regarding a desriable strategy to pursue, then the conversation should be extended to include the Massachusetts Division of Marine Fisheries to discuss permitting issues. If that discussion confirms that there is a feasible path forward, a demonstration project should be designed to evaluate performance of the selected deployment and guage the response of abutters and users.