FINAL REPORT

Healthy Communities Grant Program

Annual harvest of the invasive reed, *Phragmites australis*: a potential nitrogen mitigation strategy with widespread application

Martha's Vineyard Shellfish Group, Inc.

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Abstract

The purpose of this study was to investigate the potential to remove excess nitrogen from coastal salt ponds and embayments that suffer from nitrogen eutrophication by harvesting the invasive reed, *Phragmites australis* (referred to as Phragmites from here on out). Phragmites was identified as an ideal tool for bioextraction due to its well-known role as a component in alternative wastewater treatment plants, storm drains and agricultural buffer zones. In addition to its superior abilities to sequester nutrients, as an invasive plant, Phragmites is undesired in the landscape and lends itself well to being cut on an annual, or semi-annual, basis. While conducting any intensive activity in the marsh zone is often frowned upon, this concept is justified by both the removal of nitrogen, which threatens the biodiversity of many estuaries in the world; and by the presumed support of riparian residents whose views are obstructed by the tall, dense reeds.

This study identified mid to late July as the optimal harvesting time for Phragmites for the removal of nitrogen from the estuary. This summer harvest will contain an average of 65 – 100 pounds of nitrogen per acre. In most cases the reeds will regrow to a height of 24-36 inches by October, on Martha's Vineyard, MA. A second fall cutting may be ideal for use as livestock feed, and will promote increased biomass in the following season. Continued harvest may allow for the germination of native seedlings, however, the cutting itself may prevent said natives from reproducing. As usual, much more research is warranted.

Project Purpose/ Introduction

Degradation of marine habitats caused by nitrogen (N) overloads is a global problem (Castro et al. 2003). High nutrient levels, or eutrophication, often leads to excessive primary production, increased biological oxygen demand, low oxygen and decreased biodiversity. In recent years, studies by the Massachusetts Estuaries Program (MEP) have confirmed that high N loading, especially from onsite septic systems, is the primary driver of the degraded environmental quality observed in many of the state's estuaries (Howes et al., http://www.oceanscience.net/estuaries). The MEP investigations confirm that most of the water bodies studied are impaired to some degree with many experiencing severe losses in eelgrass habitat, reduced species diversity and increasing periods of hypoxia/anoxia. The MEP studies have developed nitrogen budgets, stating target nitrogen reductions required to reverse eutrophic conditions and restore water quality. Local municipalities have been tasked with developing plans to meet the target nitrogen reductions. Conventional tertiary sewage treatment systems are the most likely means to that end. However, because of the high costs for construction and operation of these systems, municipalities are seeking more affordable alternatives. Further, because much of the problematic N enters the embayments though slow moving groundwater plumes, the impacts of N will continue for years after the installation of wastewater treatment systems. This delayed delivery of N-rich ground water makes *in situ* mitigation an added necessity.

In recent years, coastal municipal departments and environmental NGOs have initiated shellfish (most often oyster) propagation programs in response to N reduction targets. Such projects are supported by research touting the N reduction potential of aquaculture through direct harvest of protein-rich soft tissue as well as bacterially-driven sediment denitrification. Unfortunately, many ponds that need a drastic reduction of N inputs also exhibit high levels of coliform bacteria, thus classifying them as closed to shellfish harvest for all or part of the year. In Massachusetts, shellfish culture in closed waters is limited by regulations set forth by the Division of Marine Fisheries, warranting yet more creative, non-shellfish solutions to the nitrogen problem. An inevitable drawback to increased oyster propagation is the reduction in value to private oyster farmers, as the oyster supply increases via municipal propagation.

Phragmites australis (referred to as Phragmites, here forward) is a cosmopolitan species that is highly invasive in North America. Using dense leave litter, a tall thick canopy and efficient root systems, Phragmites outcompete native vegetation, alters nutrient and water cycles (Windham and Meyers 2003, Zhao et al 2012), and excludes native animals, especially specialist species (Kiviat 2012). For these reasons, Phragmites is generally detested by conservationists, land managers and riparian residents who are unable to see the water because of the tall, thick reeds. Treatment with systemic herbicides such as glyphosate (the active ingredient in Roundup®) is generally considered the most effective method of control, although multiple applications are often required to completely irradiate Phragmites from a habitat. Controversy over the safety and carcinogenic effects of glyphosate has escalated in recent years.

Despite its invasive nature, there is scientific evidence that Phragmites provides important ecological services, especially sequestration of N, carbon and phosphorus (Meuleman et al. 2002, Toet et al. 2002, Lawniczak 2010, Ruiz and Velasco 2010). This strong affinity for uptake has been exploited for nutrient management in eutrophied estuaries and lakes in other parts of the world (Gonza´lez-Alcaraz et al. 2012, Zhao et al. 2012) and in storm water ditches and wastewater treatment applications (Meuleman et al. 2002).

In addition to removing N from the adjacent body of water, managed harvests may slow the spread of the invasive reed by exhausting its energy (nutrient) reserves (MA DCR 2002, Asaeda et al. 2005). Harvesting the reeds when the biomass is near its peak could potentially improve habitat for native flora and fauna by reducing the depth of leaf litter which is deposited every fall, and acts as an insulated weed-mat against native plants (Kiviat 2002, Holdgedge and Bertness 2011). Harvests of Phragmites could also provide useful byproducts and/or employment opportunities in coastal communities. Harvesting existing stands of Phragmites offers an especially favorable means for bioextraction for these reasons:

1) Phragmites are known for their ability to assimilate nutrients. They thrive in areas of high nutrients and are often indicators of enriched environments (Ruiz and Valasco 2010). Their roots penetrate up to 6 feet deep (King County BMP 2010) and thus intercept nitrogen rich groundwater in addition to surface runoff. Nitrogen is stored in the plant tissues at concentrations commonly around 20 g N m^{-2} and as high as 100 g N m^{-2} (Meyerson et al. 2000, references therein) and the harvest of the above ground plant tissues has been recommended for N mitigation in similar studies (Toet et al. 2005, Zhao et al. 2012). When used as a filter for agricultural runoff, the reeds were documented to remove between 66 and 100% of the inflowing DIN (Comin 1997).

2) Phragmites are abundant in the riparian zone of some ponds. Shellfish and macroalgae offer excellent N extraction opportunities, but they must be propagated in order to achieve significant biomass and N bioextraction. Taking advantage of already existing standing stocks of Phragmites means there is no cost to plant and culture the bioremediating organisms.

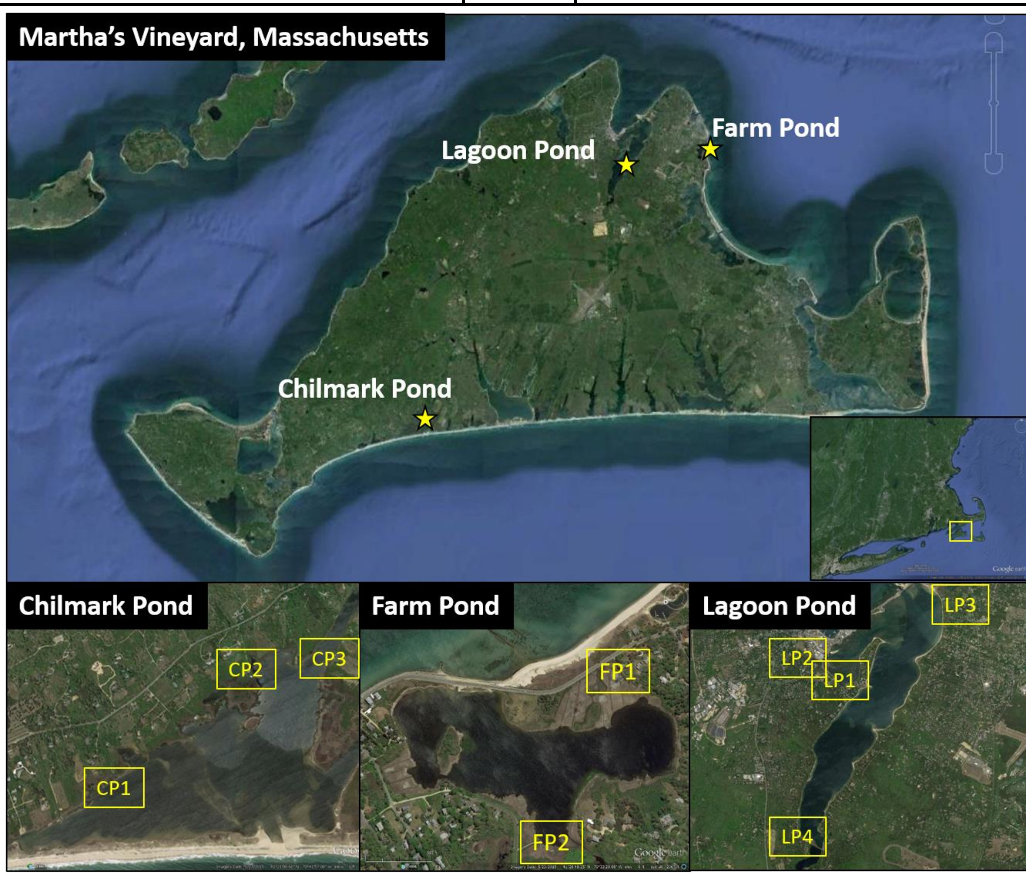
3) Phragmites are an invasive species, and as such, harvest of the above ground biomass should require minimal permits compared to native vegetation. Further, the maximum N content in the tissues occurs prior to seed set, so optimal harvest times may also prevent the formation of seeds reducing spread via seed germination.

4) Harvested Phragmites could be utilized as a high N component in compost, or a raw material for the production of burnable pellets for biochar; a stable, high carbon soil amendment being promoted as a means of carbon sequestration. Grazing livestock are capable of consuming Phragmites (Silliman et al. 2014) and so it may be a potential local, sustainable feed source for local livestock.

The objectives of this study are to 1) calculate an average value of N sequestered in above ground Phragmites on Martha's Vineyard; and determine what impact the harvest of the reeds might have on reducing N loads to the estuaries; 2) evaluate the response of reed stands and native plants to annual or semiannual cutting; 3) identify the logistical and regulatory issues involved in a harvest; 4) investigate uses of harvested reeds as a means to offset harvest costs, including potential for small business to capitalize on the harvest activity and cut byproduct.

The study focused on three estuaries on Martha's Vineyard, Massachusetts, USA, however, is widely applicable in brackish or estuarine habitats. We involved as much of the Island as possible. MV Shellfish Group is a non-profit that was designed to directly service all 6 Island towns in the form of commercially valuable shellfish seed as well as consultation with regards to shellfish, aquaculture and water quality, where appropriate. With these lines of communication already existing, we are able to share news and events and ask for feedback from a broad base of stakeholders. This includes leaders of every environmental group on the Island, Boards of Health, Conservation Commissions, Shellfish Departments, Selectmen, and half-a-dozen 'Friends of' pond groups.

Project Objective	Done	Accomplishment
#1: Investigate N sequestration		
a) Conduct Literature Review	YES	Literature Review
b) Collect bi-weekly plant samples	YES	Seasonal N concentration, biomass, density
c) Impact on groundwater N	YES	Report on capacity of Phragmites to sequester groundwater N
d) Use loggers to assess water quality	YES	Water quality data for Chilmark Pond
e) Map and calculate reed area	YES	Maps, calculation of reed area
#2: Monitor impacts of experimental harvest		
a) Monitor reed regrowth	YES	Report of impact of cutting on Phragmites regrowth
b) Monitor native vegetation	YES	Report of impact of cutting on native vegetation
#3: Disscuss regulatory aspects of harvest	YES	Regulatory guide to implementation
#4: Evaluate potential products		
a) Produce biofuel pellets	NO	Biomass pellets, demonstrate capacity to heat aquaponics greenhouse
b) Appraise use as livestock feed	YES	Report on viability and value of Phragmites in livestock farm application



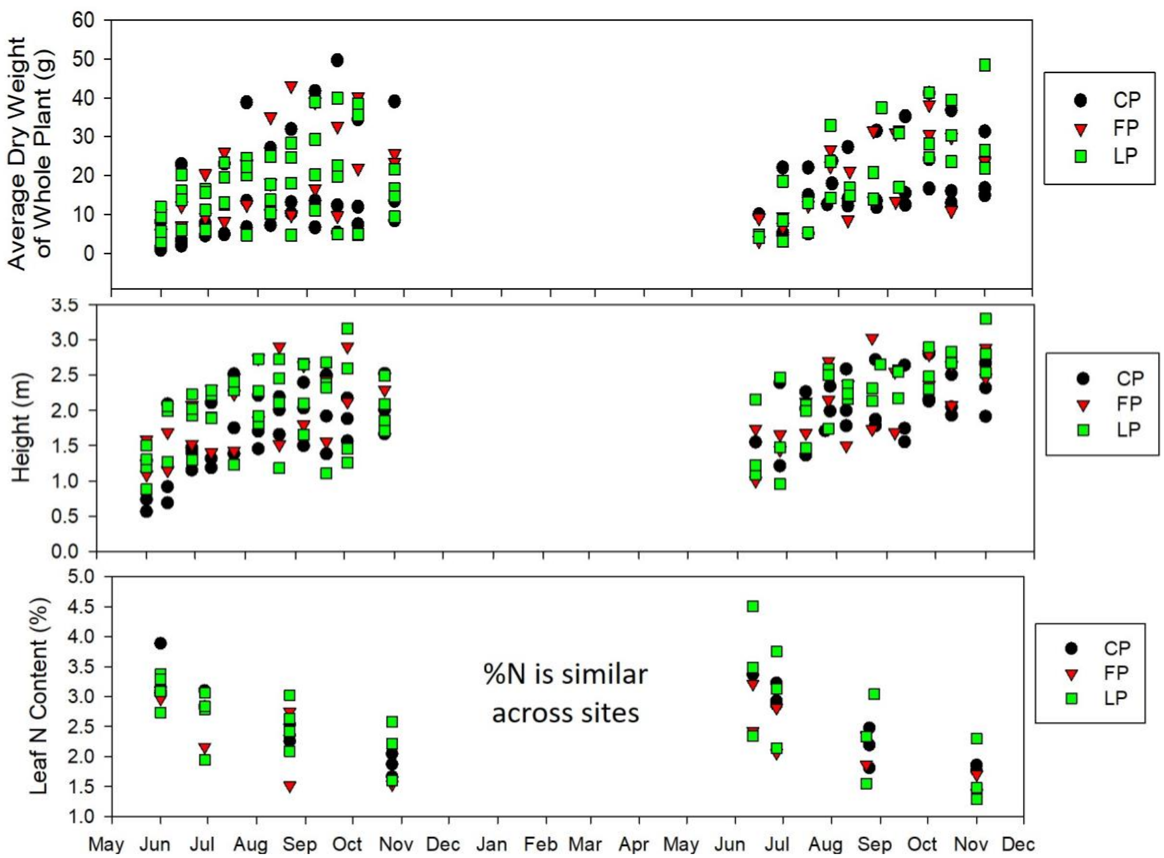
Objective #1: To investigate N cycling and sequestration of Phragmites

Task 1.a

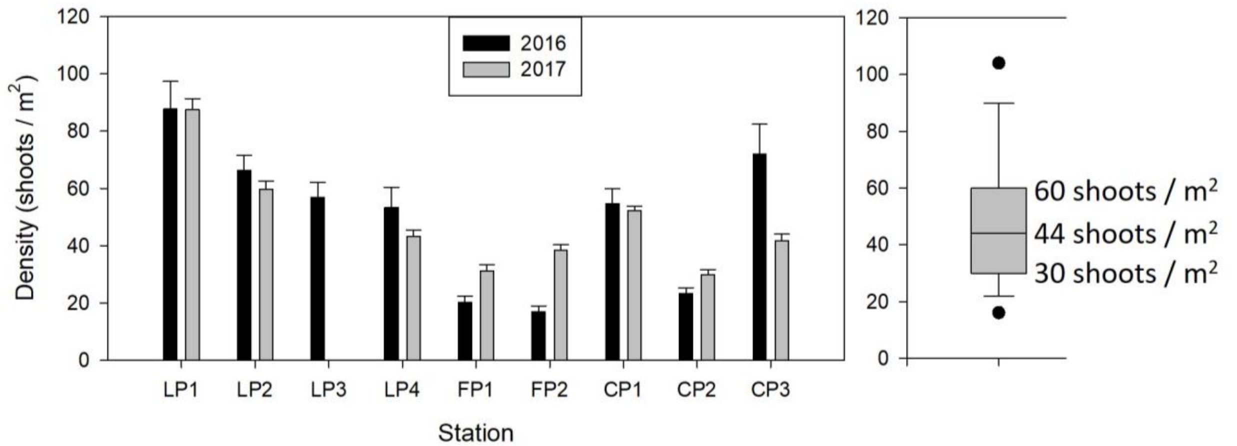
The first task was to construct a literature review of the nitrogen sequestration abilities of Phragmites. This document helps us communicate with peers, colleagues and the public, the stimulus and rational for this project. The review consolidates over 70 pieces of current literature (circa 2016) and presents powerful findings such as, *A study performed in Spain where a wetland populated by* Phragmites *was affected by agricultural run-off resulted in a 60-100% nitrogen retention (Comín et al. 1997; Romero et al. 1999).*

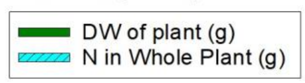
Task 1.b

The vast majority of our efforts were spent establishing average characteristic of the Phragmites on Martha's Vineyard. To do this, we sampled nine stands of Phragmites from 3 estuaries on the island of Martha's Vineyard twice per month from June through November in 2016 and 2017. Two of these stations were lost in the second year of the study because they were cut down without our knowledge, and were therefor excluded from analysis. Three plants were cut from each station at every sampling date; they were measured, broken down into its components (leaves, stem and flower if present), weighed, dried and weighed again. Samples from several dates were analyzed for nitrogen tissue content. These samples provided information on the variability of tissue nitrogen concentration at different sites and also at different times in the growing season.



In combination with GIS mapping of the Phragmites stands and stalk density surveys, we are able to estimate the nitrogen content of aerial Phragmites tissues per unit area and thus how much could be removed from the system by harvesting at different times of the growing season. While statistically significant differences do exist among the stations and sites for the biweekly sampling, the ranges overlap well among all three sites. Combining all data to be representative of Martha's Vineyard is appropriate. While stations are statistically different with regard to stalk density, the point of sampling multiple locations across the Island was to get an estimate of the range of density values in order to estimate potential harvest yields for nitrogen. Using the median value and 25th and 75th percentiles of 44 shoots m^{-2} and 30-60 shoots m^{-2} is the appropriate estimate for shoot density and was used to estimate nitrogen per unit area.

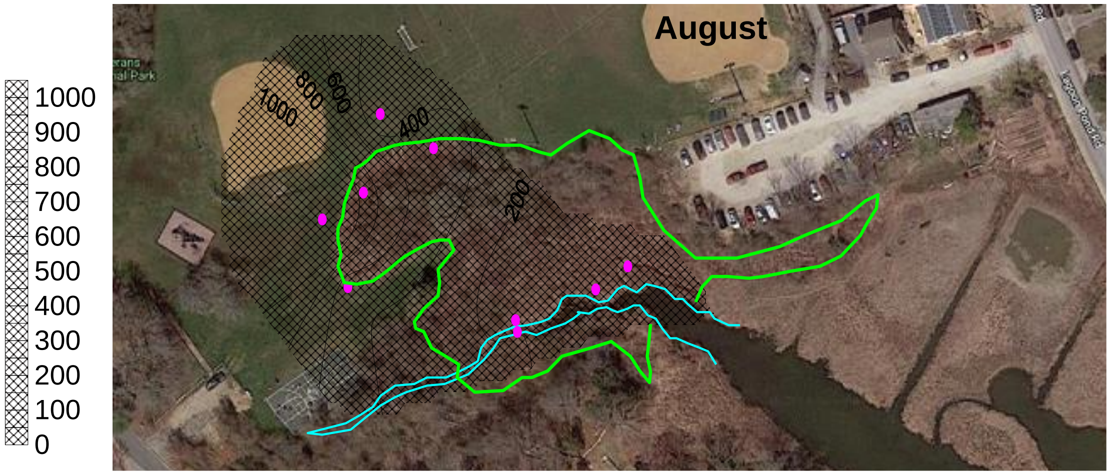




Our data reveal that a harvest of Phragmites in the month of July would yield approximately 65 to 102 lbs of nitrogen per acre of reeds. The greatest concentration of nitrogen per area can be found in late August/early September, but, we do not recommend harvesting at that time for two reasons. The first is that the plants are blooming by mid-August and due to the highly invasive nature of Phragmites it is not recommended that plants be handled, cut and transported during that time. The second reason is that the proportion of wet weight to nitrogen content is much higher in September than in July, so that more physical work would be done to remove equal amounts of nitrogen. In fact, one would do more "work" in July to remove equal nitrogen that could be harvested in June. However, when Phragmites are cut in late July they are less likely to regrow and flower in the same season as they are if cut in June. This only matters if one of the objectives of harvesting is to manage the spread of the invasive reeds through seed dispersal.

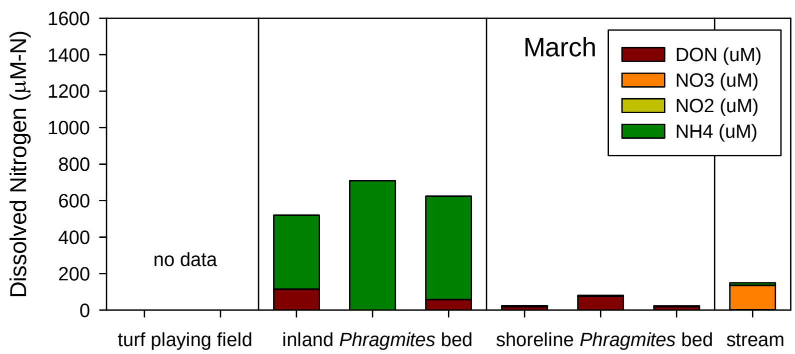
	N per square meter ($g N / m^2$)	harvest as pounds of nitrogen per acre
June 1, plant est.	**6.0 (1.4 – 13.5)**	**53 (12 – 120)**
July 1, plant est.	**7.3 (2.3 – 15.4)**	**65 (20 – 137)**
July 27, harvest est.	**11.5 (6.8 – 17.2)**	**102 (61 – 153)**

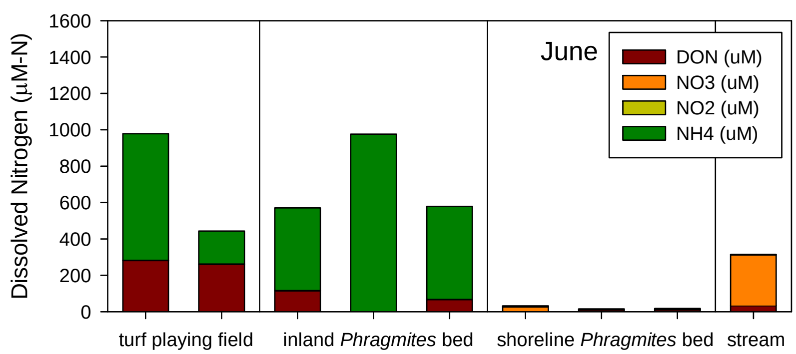
Task 1.c

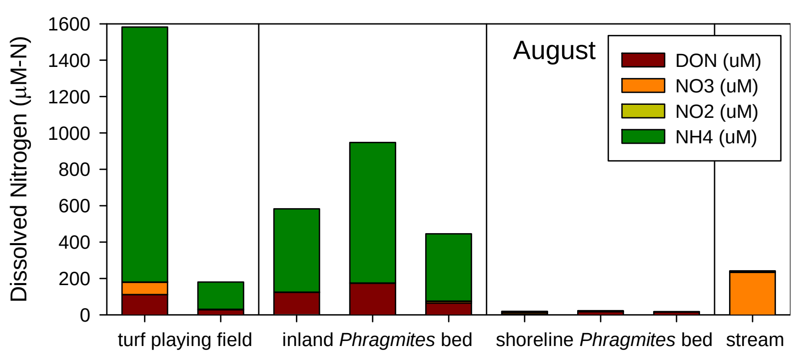


We felt that it was important to demonstrate that Phragmites does indeed intercept groundwater and assimilate the nitrogen into its tissues, so we performed groundwater sampling on 3/10/17, 6/15/17 and 8/15/17. Six wells were installed in a *Phragmites* bed on Lagoon Pond; three wells at the upland side (up-gradient) and three wells at the stream side of the bed (down-gradient). Depth to water in all six wells was typically 30 cm below the sediment surface. The three up-gradient wells were one-inch diameter PVC wells, with a five-foot section of 10 slot PVC screen and one to three feet of riser. They were housed in an uncemented flush well housing. The down-gradient wells near the stream consisted of 3-foot stainless steel drive points (1.25 inch diameter) and two to three feet of galvanized pipe riser. Groundwater level fluctuates with the tides, especially moon tides, and the area can partially flood after a significant rain event.

A sample was also taken from the stream nearest the most inland coastal well. And an ASTM Type I blank was taken each sampling trip. In June, two stations further inland, in the grassy area outside of the *Phragmites* bed were added, sampled with a







piezometer. Because of dry conditions, one of these stations did not yield water during the August sampling trip.

The near surface groundwater was anoxic; ammonium was the main species of dissolved inorganic nitrogen found in all groundwater samples. Nitrate was the main species of total dissolved nitrogen found in the stream water. In the grass playing field and the upland edges of the Phragmites bed, ammonium typically accounted for >75% of the total dissolved nitrogen, with dissolved organic nitrogen constituting the remaining portion.

The shoreline stations showed the lowest dissolved nitrogen, illustrating the capacity for Phragmites to assimilate nitrogen into biomass and eventually into solid forms. Some portion of the nitrogen is also removed to gaseous form through denitrification, though that was not measured as part of this project. A large part of the removed nitrogen remains in solid form as plant matter which dies, decays, and contributes to the peat layer of the marsh, some of which may be transported into the adjacent water bodies as detritus during a storm event. In the March sample, all of the dissolved inorganic nitrogen was removed and a small amount of dissolved organic nitrogen remained in the groundwater, likely representing the refractory portion of the dissolved organic nitrogen pool. June and August both showed lower levels of total dissolved nitrogen remaining in the groundwater, likely reflecting greater plant and bacterial activity during these warmer months coupled with slower groundwater transport time in these drier seasons, allowing for more complete assimilation of the nitrogen.

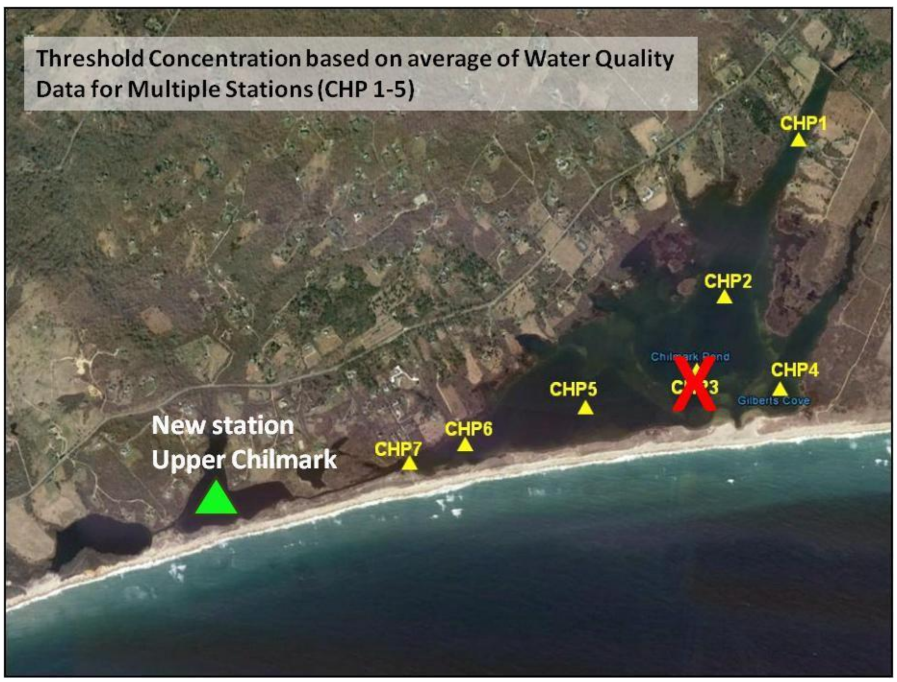
The key finding of the groundwater study was that, *yes,* Phragmites (and other vegetation) do in fact access the groundwater and remove nitrogen from it. A very notable trend in the data is that the stream samples were much higher in total nitrogen (150-310 uM) than the samples taken from within the Phragmites bed at the shoreline of the stream (15-80uM). This indicated that groundwater that flows through the Phragmites bed enters the stream cleaner than the water that does not.

Task1.d

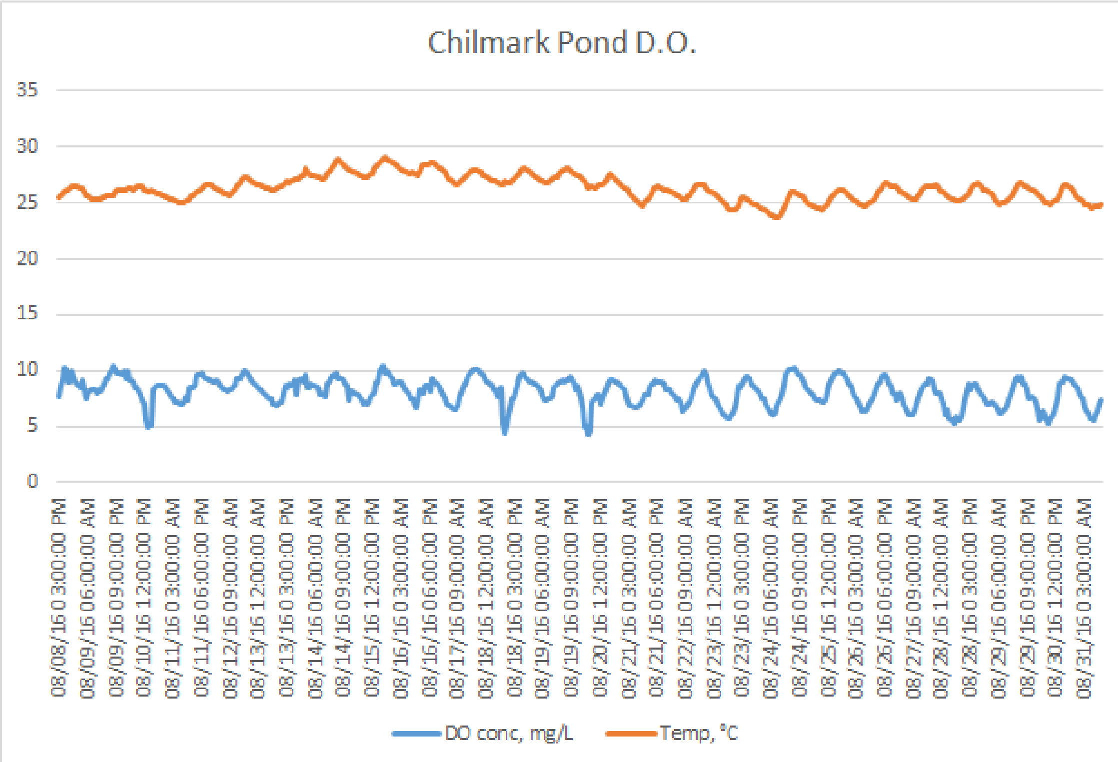
Partially as a means to involve our regional planning body in this project, several continuous temperature and dissolved oxygen (DO) loggers were deployed into Chilmark Pond by the Water Resource Planner of the Martha's Vineyard Commission. Chilmark Pond was chosen for this part of the study because it has A) an enormous amount of Phragmites; B) a completed Massachusetts Estuaries Project report that states that the salt pond is impaired by nitrogen; and C) currently receives less management than other Great Ponds on the island, in part, because shellfish harvest is not permitted due to high bacteria levels. Data from the loggers was used, along with other water quality data collected by the MVC, to assess the current health of the pond, and add to the long-term data set. Below is a summary of some of the findings.

> The MVC Island-Wide Water Quality Monitoring Program supported a status assessment of Chilmark Pond based on the 2016 and 2017 results. The integrated Health Index indicates that nutrient related water quality throughout Chilmark Pond (including the western most tributary basin) is impaired based on its moderate to poor summertime water quality. Key parameters (water clarity, nitrogen levels, oxygen depletion and phytoplankton biomass) are all consistent with a nutrient enriched basin, with poor clarity, periodic oxygen depletions and high phytoplankton biomass. Chilmark Pond has relatively uniform water quality due to its only periodic tidal exchange.
>
> Although the general *moderate-poor* Health Status of Chilmark Pond basins has not changed significantly based on the metrics, the Total Nitrogen

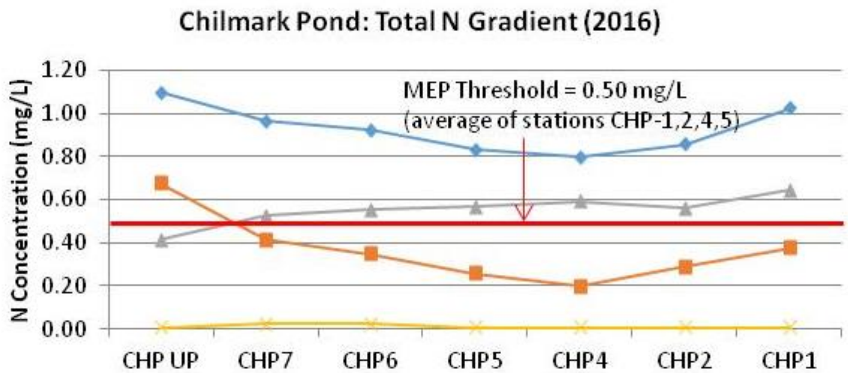
(TN) levels varied significantly from 2016 to 2017, showing much higher summertime TN levels throughout the pond in 2016. The 2017 TN concentrations ranged from 0.533 mg/L - 0.642 mg/L. The 2016 TN concentrations ranged from 0.797 mg/L - 1.096 mg/L, higher than the 0.704-0.808 mg/L range found in the historic data (circa MVC, 2004). Both data sets are significantly higher than the MEP TN threshold of 0.50 mg/L average of stations CHP-1,2,4,5, needed for restoration of pond habitats. This can be seen more clearly in the average TN concentration for those same stations historically (0.744 mg/L, 2004), in 2016 (0.877 mg/L) and in 2017 (0.588 mg/L). While it is not possible to confirm a trend with only the 2016 and 2017 data, this difference is almost certainly the result of the success of the pond opening in the 2 years, as watershed loading has not declined. Given that the levels in TN and associated water quality metrics have indicated impairment to key habitats within the pond in the historic surveys, 2016 and 2017, it appears that nitrogen management remains necessary to restore this salt pond. However, since 2017 supported the highest water quality on record, it is likely that continued efforts to improve the quality of the openings should yield significant improvements should a refined and focused opening protocol coupled to estuarine response in Chilmark Pond be implemented.

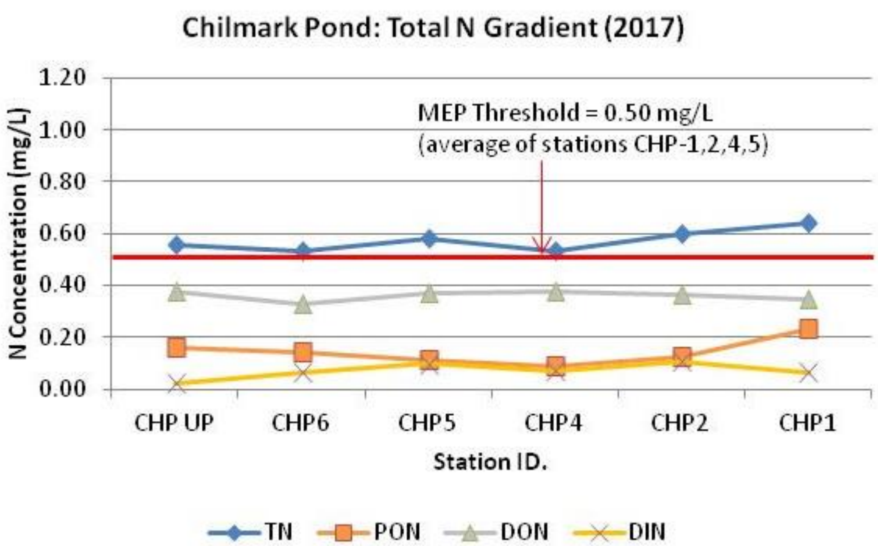


Historic Sampling Points (yellow symbols) in Chilmark Pond including MEP established "sentinel station" (average of CHP 1-5). Stations re-visited for 2016 and 2017 sampling seasons. Stations denoted by a red X are historic stations that are not being sampled under the unified Island-wide Monitoring Program.



Temperature and DO from logger data are helpful to the long-term data set. The blue line shows the moderate "breathing" pattern of an impaired estuary, shows that the pond is often hypoxic in the late summer.





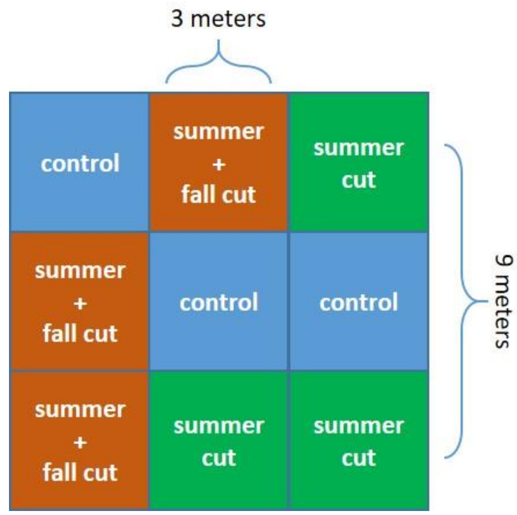
Task 1.e

Using GIS images and ground-truthing, we mapped the Phragmites in Chilmark Pond and Lagoon Pond on Martha's Vineyard. There are several stands that were excluded from these maps because they either had too much native vegetation or because they were very small. Analysis of these maps gives us estimates of the area inhabited by Phragmites and therefor how much nitrogen could be removed if we harvested these areas. According to our maps, there are about 2 acres of Phragmites in the West Arm of Lagoon Pond and about 12 acres in Chilmark Pond.

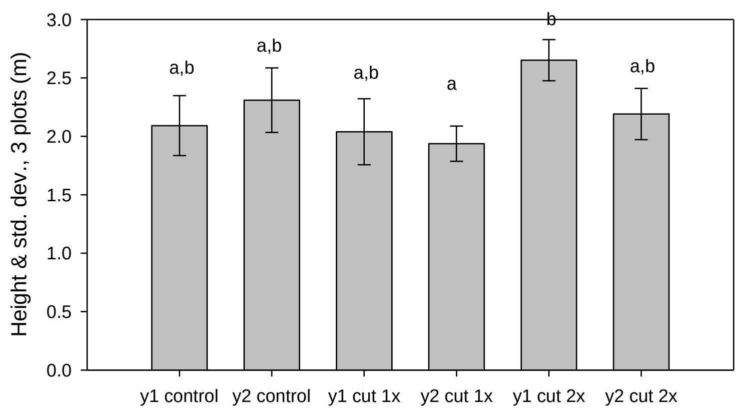

Vineyard Sound
North Rd
West Tisbury
Chilmark
Middle Rd
South Rd
Tisbury Great Pond
Chilmark Pond
Atlantic Ocean
South Rd
Cottle Cove Rd
Chilmark Pond
Atlantic Ocean
Phragmites Mapping - Chilmark Pond
Chilmark, MA
Phragmites
12 acres surrounding pond
Mapping:
The MVSG (Martha's Vineyard Shellfish Group) and the MVC (Martha's Vineyard Commission) on-screen digitized the phragmites locations based on field reconnaissance performed in Nov. 2017.
Imagery © Google
0 250 500
Feet
N
DISCLAIMER:
Data provided are for planning purposes only. The data are not adequate for boundary determination or regulatory interpretation. The MVC cannot be responsible for how these data are used or interpreted by the end user.
Compiled By: Martha's Vineyard Commission, CL Seidel, 3/12/18, ph. 508-693-3453, www.mvcommission.org
Data: Phragmites - MVC & MVSG 2017;
Aerial Photo - Google 2017
Projection: Stateplane, MA Mainland, NAD83, m
File: cls_requests; chi_pond_phragmites_2017.mxd

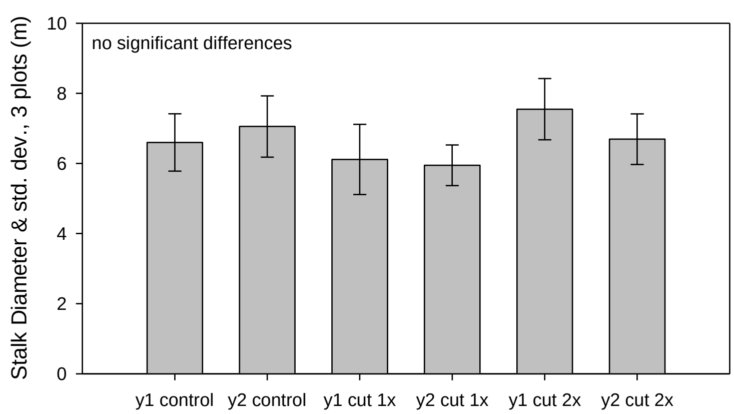
Objective #2: Monitor impacts of experimental harvest

In order to have a glimpse into what may happen when Phragmites are harvested we established a site where we would perform small experimental harvests. Images of the site and experimental layout are below. The harvest area was a checkerboard grid of 9 blocks, each with side of 3 m long, thus each plot was 9 m^2. Three plots were unharvested controls. Three were harvested once each year, in late July. Three were harvested in July each year and again in late September / early October of each year.



Task 2.a

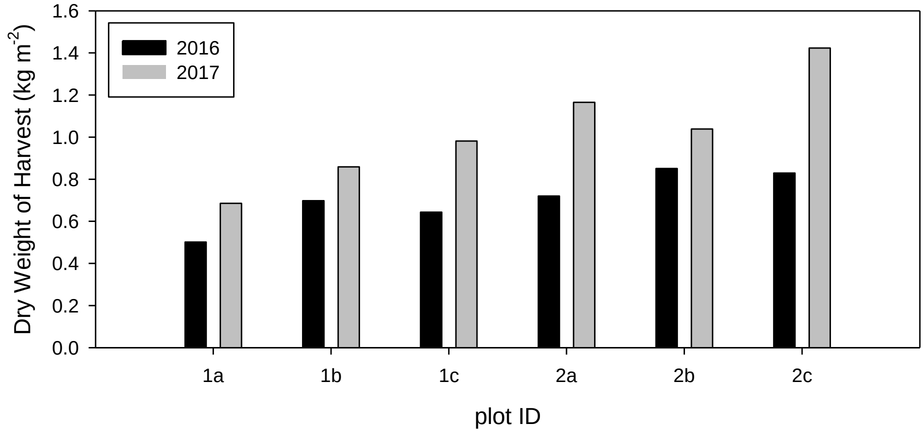




At each harvest event, height, stalk width and stem density of the Phragmites in each plot was measured. The biomass harvested from each plot was also weighed. **Harvesting did affect the characteristic of the reeds after just one year.**

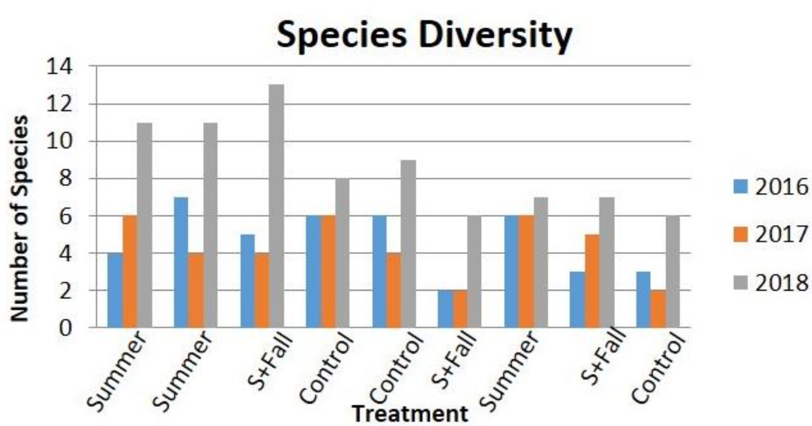
While the height of the control plots stayed the same from year 1 to year 2, both harvest treatments experienced a significant decrease in plant height. Stalk diameter revealed no significant changes. Regarding biomass (and thus total nitrogen) in the single-harvest plots (green in above diagram), the biomass was similar (no significant difference) both years. For the plots harvested twice a year in year 1 (in orange), the first harvest in year 2 was significantly larger 1.2 ± 0.2 kg m^{-2} versus 0.8 ± 0.2 kg m^{-2}. **This indicates that a small harvest in September following a large harvest in July may stimulate growth and increase harvest the following July by up to 50%. However, this was a limited pilot study and more wide scale testing of this effect is warranted in order to make decisions on**

how to manage a Phragmites harvest plan for nitrogen removal. Another aspect that deserves attention is the effect of harvest on the lateral spread of a Phragmites patch. This study did not address that question.



Task 2.b

Before each harvest event a vegetation survey was also done. The goal was to monitor the presence and frequency of native plant species in each plot as the plots were altered by harvesting. A few general trends emerged, but cannot be stated with substantial conviction with only a few seasons worth of data. Native diversity was up in 2018 in our experimental plots but also all around Chilmark Pond, perhaps due to extreme high water levels and storms which may have moved seeds around. **There is no clear increase or decrease in diversity between 2016 and 2017, however, in 2017 we saw seedlings of marsh mallows only in treatment plots, which we did not see in 2016 and did not observe in the control plots.** The reason for this would be that in the treatment plots there is little to no thatch mulch laid down at the end of the year because the plants were harvested. It is this thatch/mulch of dead Phragmites that inhibits other plants from growing in Phragmites beds. The other primary mechanism by which Phragmites excludes native plants is through shading of the sediment with its thick canopy. When the reeds are harvested the light is allowed to illuminate the ground and make it possible for seeds to germinate. Starting in 2017 and increasing in 2018, many of the treatment plots showed small patches of bare ground since the thatch layer was not being replenished by dead Phragmites. These are trends that could lead to heightened species diversity despite the ever remaining presence of the Phragmites. We have not yet decided if we will continue these harvests and surveys in 2019. Long term data is needed, using larger plot sizes to help eliminate edge effect.



Objective #3: Discuss regulatory aspects of harvest

The harvesting of Phragmites for nitrogen removal would require an Order of Conditions under the MA Wetlands Protection Act and the local town wetlands bylaws. Habitats that are considered under the Wetland Protection Act include Salt Marsh, Land Containing Shellfish and Land Subject to Coastal Storm Flowage. If the harvesting of Phragmites took place above mean high water, it is most likely that no other federal, state or local permitting would be required. Some salt marshes may be listed as Priority and/or Estimated Habitats on the Natural Heritage and Endangered Species Program (NHESP) map; if work is to take place at sites noted on the map NHESP must be notified and their conditions incorporated into the Order of Conditions.

With regards to Salt Marshes, there are many regulations in place to protect the integrity of the marsh; to protect fishes and invertebrates and to prevent pollution. **There are many ways in which harvesting of Phragmites, especially with any larger equipment, may seem to violate these regulations. However, under further inspection and consideration, responsible and well planned harvesting of Phragmites to reduce nitrogen loads to the estuary can abide by these regulations and actually help to further the mission of the Wetland Protection Act.** An example of such a regulation is:

> "…a proposed project in a salt marsh, or on lands within 100 feet of a salt marsh, or in a body of water adjacent to a salt marsh shall not destroy any portion of the salt marsh and shall not have an adverse effect on the productivity of the salt marsh. Alterations in growth, distribution and composition of salt marsh vegetation shall be considered in evaluating adverse effects on productivity…"

<u>Examples of Special Conditions likely to be considered for Order of Conditions:</u>

1. Weight diffusion required for machinery so as not to cause compaction and root kill
2. Testing for nitrogen levels before and after cutting at project site and, for comparison, a non-project site
3. Cut material shall be removed from coastal resource area in a timely manner
4. Roots systems to remain
5. Monitoring required; reports submitted to Commission

Benefits of harvesting Phragmites for Nitrogen removal relevant to MA WPA and Oak Bluffs Wetlands Bylaw, to be considered in permitting:

- Under the WPA and most town bylaws, the cutting of Phragmites is permitted and even encouraged if it leads to native species re-colonizing the area. Harvesting would have a net positive effect because the removal of nitrogen should benefit the pond overall.
- The lower stalk and root mass that are left behind absorb and contain floodwaters.
- Cutting of Phragmites for nitrogen removal could also address the aesthetic issue of property owners with water views obstructed by Phragmites – depending on time of year when cutting is appropriate (per Wetlands Bylaw interest – Historic and Natural Views and Vistas)
- Reduction of nitrogen levels in ponds protects the following interests under the MA WPA and OB Wetlands Bylaw: marine fisheries, wildlife habitat, land containing shellfish, prevention of pollution

Benefits of cutting Phragmites for nitrogen removal as opposed to attempting to eliminate Phragmites:

- Chemical treatment can impact ground water quality, fish and wildlife
- Phragmites takes up more carbon dioxide than some other salt marsh plants
- Phragmites litter accumulates faster than other salt marsh vegetation and is thus better able to keep pace with sea level rise
- Cutting of Phragmites is a low-tech, ongoing means of reducing nitrogen
- Reduction of nitrogen through cutting of Phragmites will help Towns meet the target nitrogen levels required per the Massachusetts Estuaries Project

Objective #4: Evaluate potential products

The goal of this section of the project was to explore some of the possible products that could be made from harvested Phragmites, or ways that the reeds could be used to achieve a goal in addition to removing nitrogen from the estuary system and in addition to improving aesthetics. In some parts of the world Phragmites are also used to make rayon fabric and for biofuel production. For this study we looked into Phragmites as livestock feed and as biomass for pellet production.

Task 4.a

The most significant shortcoming of this study was to do with producing pellets from harvested Phragmites and recycled cardboard. The hope was to produce pellets using an electric extruder and then burning them in a LuciaStove ®. This specialized stove would both heat a portion of an aquaponics greenhouse and produce biochar as a by-product instead of ash. Biochar is a carbon-stable soil amendments with many beneficial characteristics that concerve water and nutrients in an agriculture setting.

After harvesting over 700 lbs of fresh Phragmites, we hung it to dry in a tall open shed at the Island Grown Farm Hub, then shredded it in a borrowed Troy Built chipper-shredder. We were donated a bail of cardboard from a local waste hauling company and also put that through the chipper shredder. It was very quickly apparent to us that the chipper was not the best tool for the job, but we persevered. Nathaniel Mulcahy sent us a hammer mill and a pellet mill to make the pellets, came to the Island twice to work with us, and we spent an additional 40-50 hours on our own, feeding Phragmites and cardboard to the hammer and pellet mills. We did come close to producing large, solid biomass pellets, but the vast majority of the product was simply powder and soft, crumbling pellets. When a piece broke on one of the mills, we ran out of time on the project. We were heartbroken, to say the least, over the lost investment of time and money into this aspect of the project. **If I could change one thing about this project at the on-set, I would have arranged to send our harvested Phragmites to a biochar or biofuel company instead of trying to make our own.**

The following is part of a report written by Nathaniel Mulcahy of WorldStove:

> *Structure:* While structural integrity of both the pellets and resultant char was less than optimal the energy content in the case of the pellets lacked the typical surface sheen which results from adequate pressure, friction, and feed rate. This results in pellets that have a short storage life and are prone to increased fines during combustion and pyrolization. The resultant emissions are, as verified with in house emissions tests inferior to wood pellets having greater soot and fine particle content. These results are little reason for concern in that they are common results for initial pellet runs and given our experience with Phragmites in other countries with sufficient practice and better mills structurally sound pellets are certain.

Gas Production: The MV pellets with the mixture of cardboard and Phragmites exhibited superior off-gassing for energy production when compared to with cardboard only or Phragmites only pellets. Energy content of the gas produced with the MV pellets was comparable to propane. While the total calorific value measurement of MV mx pellets was 10% lower than that of pellets made exclusively with cardboard the more consistent gas flow signifies that more complete gas combustion is possible which will eventually result in lower emissions and could result in equal or greater actual energy output vs potential as calculated following the calorimeter tests.

Agricultural quality of resultant char: Resultant char from the LP pyrolization has a pH of 7.5. Minerals were fully soluble and therefore accessible to plants if used in soils. PAH (polycyclic aromatic hydrocarbons) content was lower than i was able to consistently measure with my existing set up and so well within safety parameters for use in agricultural soils. Mineral content was what our group has come to expect from Phragmites based pellets but what came as an unexpected result was the absorptivity. Moisture retention was 50% higher than that which we've been able to achieve in any of the past ten years of pellet studies. This increased absorptivity combined with low to moderate hydrophilic ratio means that when the resultant char is mixed with soil, it would not only increase water-retention in soils but the water retained would still be accessible to plants. If this quality can be made reproducible it would classify MV biochar as one of the closest equivalents we've so far found for sphagnum in greenhouse settings. Initial studies. **This exciting result clearly warrants further studies and has real potential for eliminating/replacing the use of sphagnum from greenhouse work and potentially reducing water needs in field cultivation for food crops such as corn and tomatoes.**

Conclusions and recommendations: The most significant results of this study has been the resultant char. Given the relatively small sample size and the fact that the definitive mix has not yet been determined there clearly is more work that could be done but the initial results are so significant that it would be well worth doing. Reducing of the harvesting of peat has significant environmental benefits in that is it a significant carbon sink. Many initiatives in the EU and UK have been working on a reduction of the use of peat in growing mediums and the possible total ban of it by 2030. Add to this the fact that the char itself is a certified carbon sequestration method means that the potential environment al and economic benefits that could come the MV study are significant at both a local and global scale.

<u>Task 4.b</u>

The other aspect that did not work out the way we hoped, was the assessment of Phragmites as a livestock feed. We had several samples tested for nutritive value and also for heavy metals – or priority pollutants – but when it came down to interpreting the results, we had a tough time. We are shellfish biologists by training, and the leaders at Mermaid Farm have a farm to run! If we had thought to employ a student associated with one of the teaching or non-profit run farms on the Island, the conclusions may have been more satisfying. We did feed harvested Phragmites to the cows at Mermaid Farm on several occasions. We offered them leaves and whole plants in June, when the reeds are still very great but are large and tough. The cow's pastures were lush a green with clover and grasses, and they were not interested in the Phragmites. We tried again at the end of September, by offering them the reeds that had regrown after a late-July harvest. **The reeds we offered in September were small, more palatable and more nutritious than the June sample, and the cows' pasture had been grazed down to dust. The cows ate all that we offered them at the end of September.**

The results of the several nutrition tests showed, at the very least, that the leaves are more nutritious than the stems and the younger plants are more nutritious than the older plants. This is what anyone would expect. Phragmites leaves and/or young plants could conceivably be incorporated into a maintenance diet, meaning one that is not for growing juveniles or pregnant/lactating females. Phragmites are fed to livestock in Europe and there are many studies looking at this exact topic. One study showed no increase in nutrition as a result of fermentation into Phragmites silage, but we are still interested in the possibility of saving this sustainably harvested, wild reed for cold season forage when grasses are hard to find.

Heavy metals and other contaminants do need to be considered when weighing the option of Phragmites for livestock feed. Phragmites concentrate some contaminants, so we sampled the bottom leaves in the fall, since Weis and Weis determined that these tissue will have the highest concentrations of unfavorable contaminants. While we compared our results to literature values, they were similar or much lower than samples from New Jersey, for example. If one wanted to feed a substantial amount of wild Phragmites to livestock or pets testing should be done and accounted for in order to optimize health and benefits.

Added Community Outreach, Education and Discussion

Instead of completing the tasks discussed above, we put more emphasis on outreach and general community involvement. Whatever shortfalls occurred in the product evaluation tasks were more than compensated by our outreach efforts in enlighten the community at large about our findings and to identify and encourage the people most likely to put our conclusions into practical applications to solve our water quality problems. Emma Green-Beach spoke to the Blacksmith Valley Association of Squibnocket Pond, Tisbury Waterways, Inc., and Chilmark Pond Foundation on the premise of this Phragmites project and was received very well because these groups have copious, unwanted Phragmites in their viewsheds as well as issues stemming from nitrogen eutrophication.

We hosted a community workshop in March 2018 – *A Phragmites Phor*um – which was announced in both local newspapers and on the SEMCO (Southeastern Massachusetts Coastal Outreach) listserve. We receive several emails from members of the listserve who just wanted to express their support and interest. As evidence of the support we have, a few people came to the Island from their winter homes in New England – despite the coming storm – and others planned on attending had it not been for the storm on its way. Over 40 people attended the event, and no standing room was left to be had.

In addition to our local audience, we presented parts of this project at the International Conference on Shellfish Restoration, the National Shellfisheries Association, Milford Aquaculture Seminar, Northeast Regional Aquaculture Conference and Expo, the Massachusetts Shellfish Officers Association, New England Estuarine Research Society and the Martha's Vineyard Coastal Conference. Although these sound very shellfish-centric, which they are, nearly all the attendants also participate in water quality issues, since they are so central to shellfish habitat quality and restoration.

Nathaniel Mulcahy of World Stove gave a presentation to the Martha's Vineyard Regional High School's environmental club in January 2017, on using Phragmites to make biofuel pellets. Afterwhich, Emma Green-Beach spoke to the same group about problems of excess nitrogen in our estuaries and the ability of Phragmites to absorb nitrogen.

The MVironmental Club formulated a project auxiliary to ours and received a few awards for their project, *Phragmites Pellets: Engineering Biomass*. They were named Massachusetts Senior School of the Year (for the third year in a row) and chosen (for the first time) at the National Level as the top Outstanding Energy Engineering and Design Project by the National Energy Education Development Project's Youth Leadership Awards program in Washington, DC. The group was also chosen for a Secretary's Award for Excellence in Energy and Environmental Education presented by the Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs and EEA Secretary Matthew Beaton.

I was continuously amazing by the enthusiasm and support we received from the community. **Several partnerships and collaborations were formed during the course of this project that I did not anticipate**. For example, I brought a few flower heads to Tim Boland, the Director of Polly Hill Arboretum (PHA), because they were different shades of purple and green, and I was curious what that could mean. In response, he offered to plant some seeds for us, to look at their germination rates. Because of his interest in the project, we invited him and his staff to attend a short presentation that Nathaniel Mulcahy, our partner from World Stove, gave to the Regional High School's MVironment Club. In response to Nathaniel's presentation on the wonders of biochar, the greenhouse staff from PHA went back to work and constructed their own biochar-producing stove.

Another example is the partnership we formed with staff from the Island Grown Initiative's Farm Hub at Thimble Farm (IGI). It began when we asked Keith Wilda, who was then manager of the Farm Hub, how he would suggest drying the Phragmites that was harvested, before we chopped it to form into pellets. He volunteered space and resources at the Farm Hub that proved to be invaluable. Keith, Rick and Nathaniel made a plan to continue this project well past the end of this grant.

Success of a project that involves a potentially controversial component such as an invasive species, is highly dependent on community involvement. We definitely experienced some push back from people who have spent a lot of their time, effort or funding (both personal and organizational) trying to irradiate *Phragmites australis* especially with herbicides. These people are doing what they think is right, and what is necessary to achieve restoration goals that are entirely inhibited by the dominant nature of Phragmites.

While many initially felt that our project threatened to undo the hard work they put in over the years, most eventually understood our objectives and grew to admire the ability of Phragmites to sequester nitrogen. Said one such neighbor, after our *Phragmites Phorum*:

> "Emma: Thanks so much for the information. Phragmites is quite an amazing plant. Your conference and the follow-up materials have given me a new respect(?!?) for it. Your harvesting sure looks like the best approach to the current tough situation. Congratulations on finding a silver lining."

The individual who sent this note via email has always been a friend and supporter of the Shellfish Group, and is also an avid botanist and conservationist. If and when a public hearing were to take place to grant the permits for Phragmites harvest on a commercial (or nearly) scale, this person's support could prove to be key. We made an effort to include the potentially-resistant parties from the onset, and I definitely think it strengthened the project.

Project Continuation

Since the official conclusion of this project we have continued to refine the concept of harvesting Phragmites to remove excess nitrogen from estuaries, with regard to several different aspects.

- We received permission from one of the local Conservation Commissions to do a few small harvests, with the intention of simply keeping the conversation going.
- This winter we reached out to the Martha's Vineyard Land Bank, who routinely cuts Phragmites to enhance views at a few of their properties. Arrangements have not yet been finalized, but we are hoping to be able to simply collect the cut Phragmites and thus meet our goal as well as theirs.
- More recently, an individual from Island Grown Initiative (IGI, another local 501(c)3) contacted us looking for Phragmites to use as mulch on fields that are being managed under a new regenerative agriculture plan. We are hoping that MV Land Bank, IGI and MVSG can collaborate to fulfil all of our objectives.
- We continued the experimental harvests and vegetation surveys with Sheriff's Meadow Foundation, in Chilmark in 2018. The plant material was composted at IGI's composting facility.
- Since the inception of this study we have received interest from a pair of ecological engineers who want to design and implement a large, amphibious Phragmites harvester. They have plans to visit a manufacturer of related machinery, in Ontario this summer.