Monitoring Approaches for the Treatment of Non-Native *Phragmites australis* in Rhode Island

By

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Abstract

This review explores the current state of monitoring protocols for the management of the invasive plant *Phragmites australis* in Rhode Island. Although a native strain of *Phragmites* exists in North America, a non-native lineage of *Phragmites* believed to originate from Europe is rapidly spreading throughout coastal and inland wetlands in the U.S. This assessment was performed during the summer of 2013 while working as an intern with Rhode Island's Coastal Resources Management Council (CRMC). Our goal was to recognize flaws associated with follow-up monitoring procedures among wetland restoration permits issued by CRMC to treat *Phragmites*. Out of the 43 permits reviewed from 1999-2013, 11 had no monitoring reports on file, five didn't have the proper number of reports on file required by their permit, seven didn't specify how monitoring was to be done (and thus had no monitoring reports), four had the complete number of monitoring reports on file required by the permit and the remaining 16 either had reports done by another agency (e.g., Save The Bay) or were too early in the treatment process to submit required reports. To be most effective, consistency of the monitoring process should start before the project takes place. Outlining project goals, setting monitoring protocols, and clearly stating what is expected from reports are the first and perhaps most important steps to take in order to achieve the desired results of the treatment program.

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Introduction

Invasions of non-native species are widely considered to be one of the greatest threats to native biodiversity within a region (Martin & Blossey, 2013). In the U.S., coastal areas are especially vulnerable to biological invasions due to high human populations, habitat disturbance, and typically because of their central locations for trade and commerce (Havens et al., 1997). The Common Reed, frequently referred to by its scientific name *Phragmites australis* (hereafter referred to as *Phragmites*) is an invasive plant species that has overtaken many coastal marshes in the eastern United States (Derr, 2008). Although a native strain of *Phragmites* exists in North America, a non-native lineage of *Phragmites* believed to originate from Europe is rapidly spreading throughout coastal and inland wetlands in the U.S. (Lombard et al., 2012). Such rapid spread has caused many coastal communities to take action in order to prevent this invasive from destroying native biodiversity. Efforts to eradicate any invasive specie can be extremely difficult, which is why strong policy measures must be in place to ensure treatment is conducted effectively.

Rhode Island is currently battling an extensive *Phragmites* invasion throughout many of its coastal marshes. In 2006, non-native *Phragmites* was identified to have completely outcompeted native *Phragmites* on Rhode Island's mainland, native patches only being found on the eastern side of Block Island (Lambert & Casagrande, 2006). One agency that has been tasked with controlling *Phragmites* in the state is the Rhode Island Coastal Resources Management Council (RICRMC or simply CRMC). CRMC is a management agency with regulatory functions that is responsible for the preservation, protection, development, and restoration of coastal areas in Rhode Island (CRMC.ri.gov).

This agency has been responsible for developing 'Wetland Restoration Permits' (WRP's) which outline, when necessary, how to treat, monitor and control the spread of *Phragmites* in a particular area.

There are concerns on how effective WRP's are at successfully controlling non-native *Phragmites*, specifically the follow-up monitoring protocols associated with each permit. As an intern during the summer of 2013, I worked with CRMC reviewing Wetland Restoration Permits as they pertained to *Phragmites* monitoring. This paper will identify areas where monitoring conducted in past Wetland Restoration Permits issued by CRMC can be improved upon and how identified weaknesses can help to better control *Phragmites* in RI. Methods for treating *Phragmites* will also be examined and compared to control efforts elsewhere in the U.S. In addition, this paper will review the current status of *Phragmites* control efforts around the U.S. and how other studies can be used to help CRMC improve their WRP's as intended for *Phragmites* control. Finally, I will explore alternative management approaches that view *Phragmites* as a provider of positive ecosystem services in North American marshes and wetlands.

Characteristics of *Phragmites australis*

A perennial grass, the Common Reed has the ability to spread quickly through human altered wetlands primarily through stolons, rhizomes, and seed dispersal (Rapp et al., 2012). Although the genus *Phragmites* has existed in North America for about 40,000 years, introduced Eurasian genotypes to the East Coast in the 1800s have aggressively invaded wetlands throughout the U.S. (Martin & Blossey, 2013). It is this invasive foreign strain of *Phragmites* that land managers are most concerned with and trying to eradicate. Once thought to be limited by the high salt concentrations in coastal soils and water, recent studies have shown that *Phragmites* is able to occupy saltwater marshes, resulting in extensive expansion throughout coastal New England (Silliman, 2004). The Common Reed can reach heights up to five meters tall, forming dense stands that outcompete established native vegetation (Derr, 2008). Not only do these tall, dense stands of *Phragmites* negatively impact biodiversity, but they also become aesthetically displeasing to costal residents. While working with CRMC, I learned it is common for landowners to initiate WRPs on their property in order to improve their scenic views, rather than for ecological concerns. This characteristic of *Phragmites* is important to realize because public action for an environmental issue is often not initiated over concerns to such things as loss of biodiversity, but concerns over local impacts to personal property esthetics and values.

Preferring sunny areas, *Phragmites* can grow in fresh and brackish marshes alongside riverbeds, lakeshores and coastal regions (Derr, 2008). The plant grows rapidly, with high biomass above and below ground, hindering the growth of other species by reducing nutrients, light and space availability (Lombard et al., 2012). Many studies recognize the vulnerability constructed and/or altered wetlands have to *Phragmites* invasions. The plants' ability to survive anthropogenic changes and rapidly colonize and dominate disturbed soils make the heavily populated and developed coastal regions of the East Coast particularly vulnerable (Ailstock et al., 2001). Due to disturbances resulting from the excavation and creation of a wetland site, constructed wetlands are inherently more susceptible to invasions by fast growing, and sometimes unwanted plant species (Havens et al, 1997). A study conducted by Havens et al. (1997) found that 11 out of 15 constructed wetland sites in Virginia were invaded by the non-native Common Reed. Being one of the more populated and disturbed coastal regions in the U.S., it is easy to see how *Phragmites* has spread throughout New England, especially in Rhode Island.

Not only can *Phragmites* decrease native plant biodiversity within a wetland ecosystem but it can also have detrimental effects on animal life. For instance, the Common Reed provides less food and unsustainable habitats for certain marsh-nesting bird species like the Marsh Wren (Derr, 2008). The treatment of *Phragmites* by way of herbicide application also brings into question the effects chemical controls may have on certain bird populations when trying to eradicate the invasive from an area (Lazaran et al., 2013). Treatment strategies and the risks associated with them will be discussed in more depth in the following chapters.

Working with CRMC

An evaluation of the current state of CRMC follow-up monitoring protocols associated with *Phragmites* treatment in Rhode Island was conducted during the summer of 2013. The goal of this assessment was to determine if required follow-up monitoring stipulations were conducted according to each WRP. By determining if follow-up monitoring was (or was not) properly carried out, CRMC can take proper steps to address these potential failures in successfully treating *Phragmites* in RI. Many questions can then be asked about how to improve treatment methods and permit protocols from this assessment.

The first step in this process was to organize all CRMC issued WRP's that involved the treatment of *Phragmites*. By searching through CRMC's digital database, which keeps record of all WRP issued by the agency, permits were found ranging as far back as 1999 (*Figure 1*). These permits contained information about what area was being treated, who was responsible for treatment application, when the treatment was to take place, the targeted species, methods of treatment, and follow-up monitoring protocols. While organizing the permits, information was documented for each site in Excel worksheets (*Table 1*).

Permit Number	**Permit Type**	**Methods**	**Monitoring Schedule**	**Monitoring Reports on File**
2005-11-12	*Phragmites* Treatment	Herbicide and mulching	3 years, done annualy	1
2008-13-35	*Phragmites* Treatment	Herbicide	At the end of each growing season once projects are completed	0
2002-65-00	Wetland Restoration	Mowing of *Phragmites*	Does not Specify	0

Table 1: *Shown above is an example of how WRP regarding Phragmites treatment were organized for CRMC. This table has been simplified in order to protect the identity of permit applicants. Actual spreadsheets were more detailed in permit type, location and permit duration.*

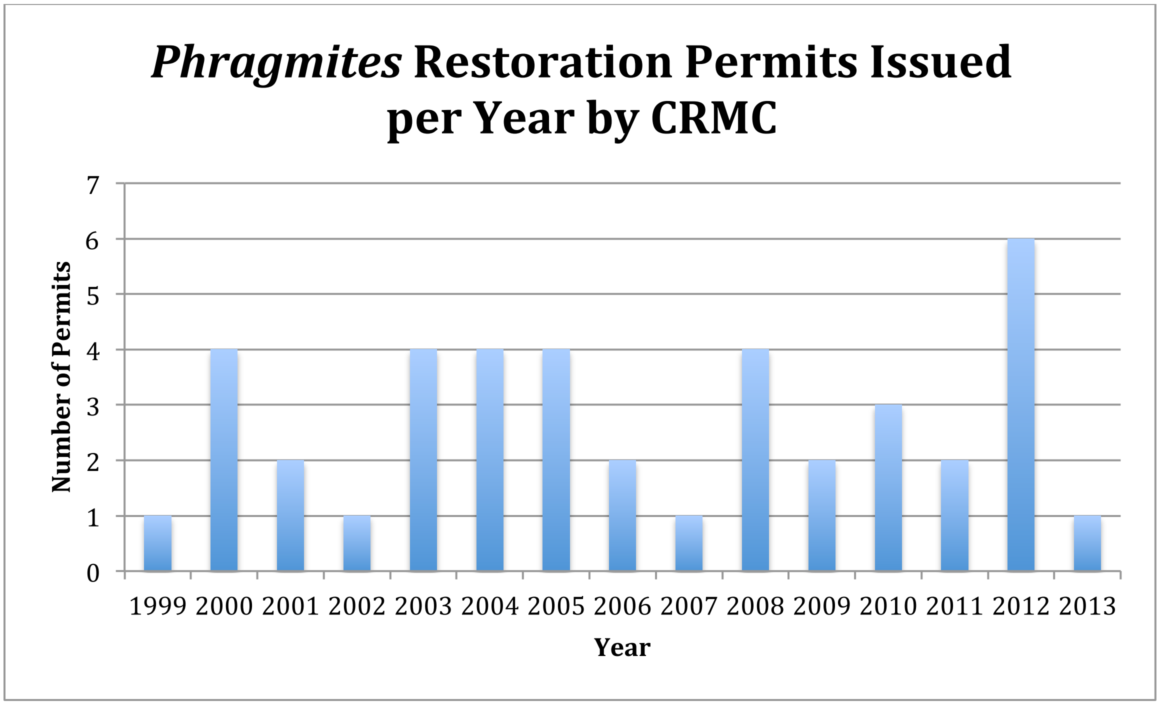


Figure 1: *The number of CRMC WRPs involving the treatment of Phragmites issued per year from 2013-1999 analyzed for my summer internship.*

CRMC's database also contained documentation of follow-up monitoring procedures to be completed by those responsible for conducting treatment methods. Theoretically, each permit would contain one file with all required monitoring reports by the entity responsible for monitoring. For instance, a consulting firm responsible for spraying herbicides to kill *Phragmites* would usually be responsible for completing the required follow-up monitoring protocols on a yearly basis and a report would then be submitted to CRMC. I looked at every permit that involved *Phragmites* treatment and took note on their follow-up monitoring procedures. Next, I indicated whether or not the proper documentation accompanied the permit. This gave me a sense of how many permits actually had monitoring protocols that had been followed according to permit stipulations.

Many of these permits varied in what they reported for monitoring; some were fairly detailed and included pictures, graphs, and maps along with a report on the goals of the project, how it has progressed and what changes should be made (if any). Others, however, lacked any visual aid and were much less descriptive in describing impacts of the restoration project and how monitoring data was gathered. Overall, the information provided within the reports varied considerably among permits. One of the most apparent things found in this review was the inconsistency in the reports. It became clear that some were much more useful in assessing how *Phragmites* treatment was progressing while others lacked meaningful results. Older permit monitoring seemed to be less informal than more recent reports and it seems CRMC has made adjustments throughout the years for what is expected in monitoring reports. Things that were found to be useful in reports were:

- Detailed pictures describing the area being treated. Also, pre and post-treatment pictures to compare the existence of *Phragmites* from year to year.

- Goals of the project outlined in the beginning of the report as well as statements on what should be done moving forward with the restoration.

- Detailed descriptions of how transects were set up and how they measured *Phragmites* cover. Areal maps provided a good visual description of the location these transects were taking place.

- Descriptions on how treatment has or has not affected the re-growth of native vegetation. Few permits reported on the condition of native flora being reintroduced as a result of *Phragmites* treatment.

- Graphs or tables showing the percent change of *Phragmites* cover from year to year as well as clear and concise methods and results sections.

- Identifying when (the time of year) and how long after initial treatment the monitoring took place. This may be important information for accurately assessing the re-growth of *Phragmites* in treated areas.

I was surprised to find many reports lacking this basic information on the results of *Phragmites* control treatments. After listing my findings in spreadsheets, I was able to give CRMC a general overview of the state of required follow-up monitoring for *Phragmites* treatment for WRP's. This information was not completely new to CRMC; it was already thought monitoring protocols needed to be improved. However, now that a good portion of more recent permits has been reviewed, progress for improving monitoring policies was initiated.

Results and Discussion

In addition to organizing permits according to their monitoring content, I visited sites where *Phragmites* had been treated under CRMC permits. Many of the areas treated were small, private lands along the Rhode Island coast (*Figure 2*). The goal of these visits was to assess the state of *Phragmites* occurrence on previously treated properties. Transects or measuring plots were not conducted in our visits to estimate the total amount of *Phragmites* on a property, rather a judgment value of high (*Phragmites* covered the majority of the treated areas), medium (about 50% *Phragmites* cover) or low (little to no standing *Phragmites*) was used to generalize the presence of *Phragmites*. This resulted in a quick assessment and gave us a sense of how much (if any) *Phragmites* had repopulated an area. The total number of sites visited was very small compared to the number of permits examined for the monitoring report summary. We targeted properties that had been treated for *Phragmites* by herbicide application, and had been recently treated or were going through a secondary treatment. The site visits gave insight on how restoration projects had progressed during different phases of the treatment process. A total of eight different sites were visited, descriptions of each are organized in *Table 2*.

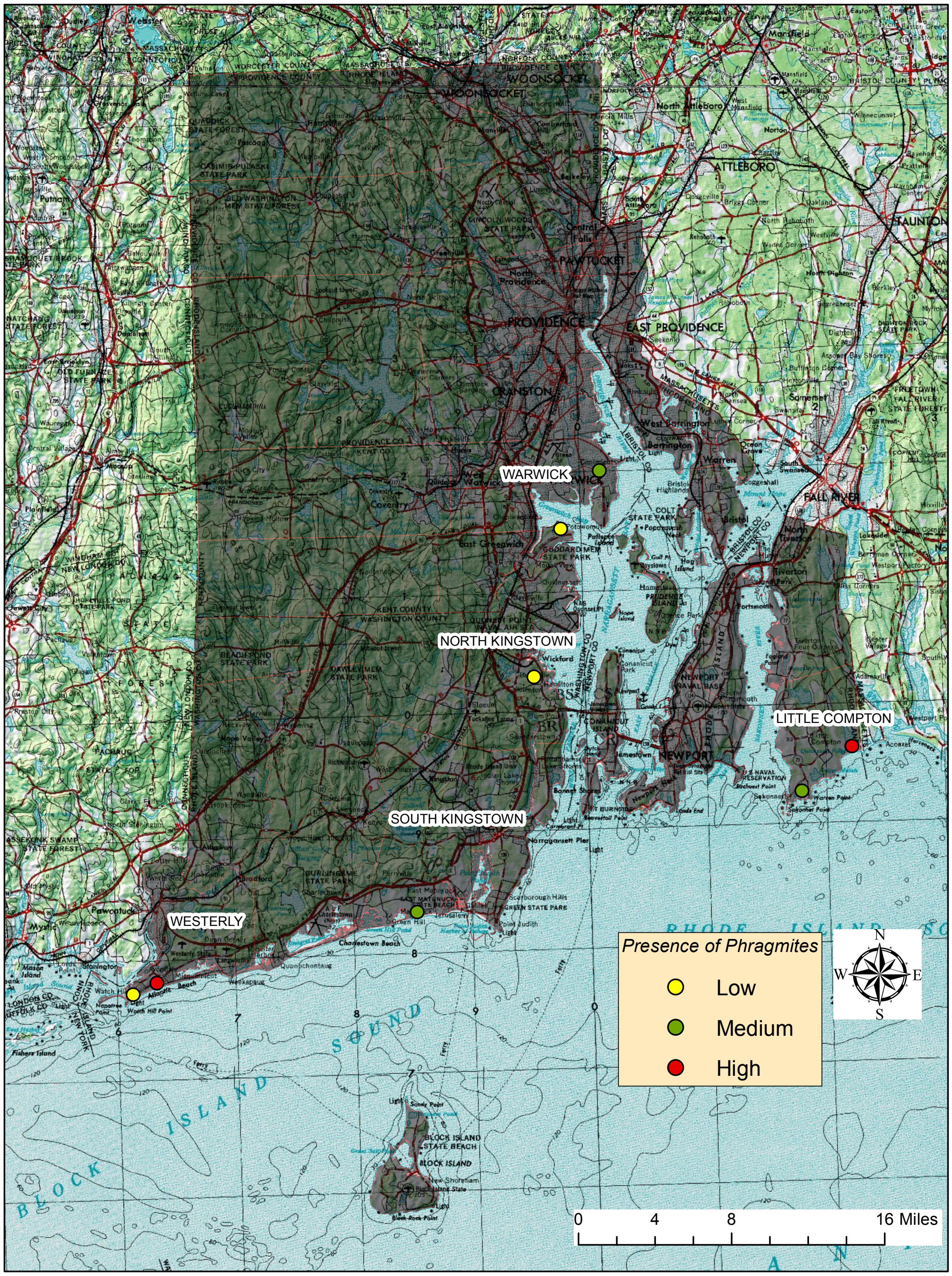


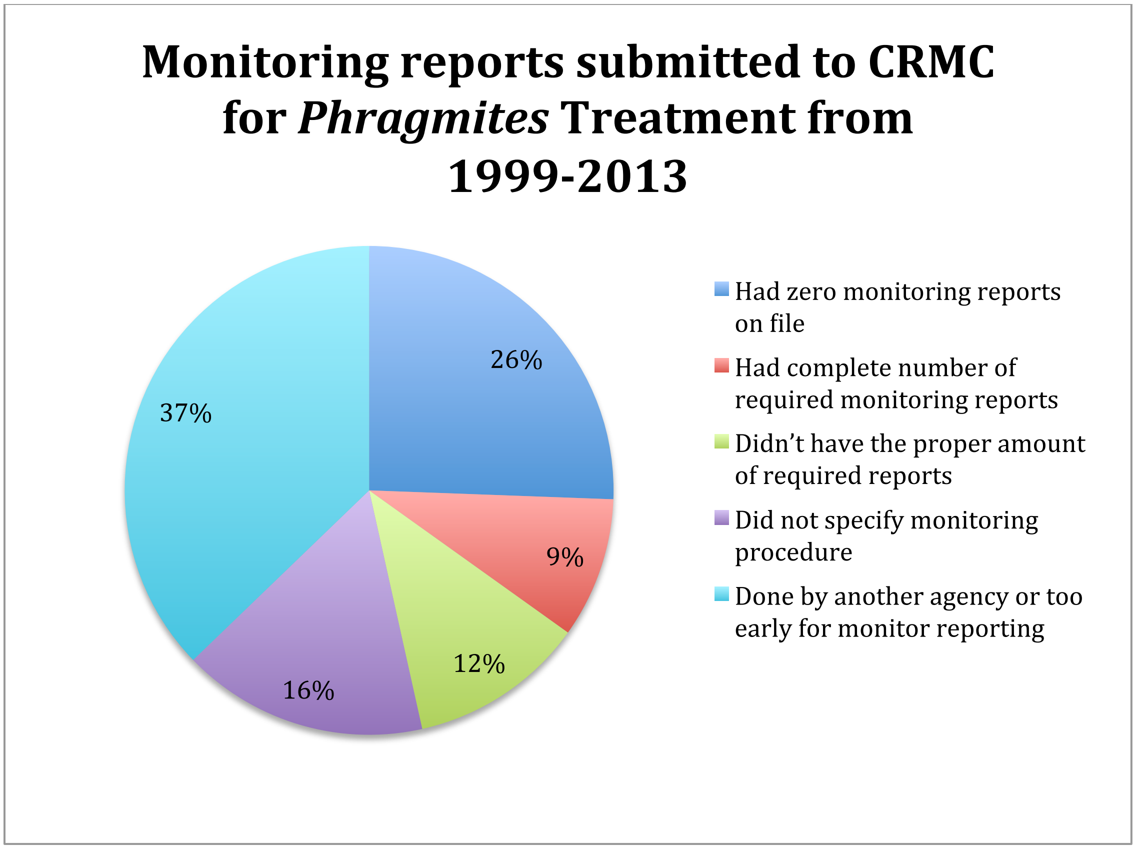
Figure 2: *This map shows the location of field visits to 8 Phragmites restoration projects conducted by CRMC. All sites were given a ranking of high (red), medium (green) or low (yellow) based on the amount of Phragmites observed.*

Site	Location	Date Re-visited	Treatment	*Phragmites* Cover
Quicksand Pond	Little Compton	10/5/13	Herbicide	High
Round Pond	Little Compton	8/6/13	Herbicide	Medium
N.K. land conservancy	N. Kingstown	8/8/13	Herbicide	Low
Permit Holder A	Warwick	8/8/13	Herbicide	Low
Permit Holder B	Westerly	7/18/13	Herbicide	Low
Permit Holder C	Westerly	7/18/13	Herbicide	High
Buckeye Brook	Warwick	8/26/13	Herbicide	Medium
Cards Pond	South Kingstown	8/27/13	Herbicide	Medium

Table 2*: Site visits were conducted to assess Phragmites occurrence on previously treated areas. Eight locations were visited, each given a ranking value of high, medium, or low based on the amount of Phragmites cover that was observed.*

There was a presence of *Phragmites* in all eight sites visited. The amount of *Phragmites* seen resulted in two locations having a value of "high," three were "medium," and three were valued as "low." Essentially, these visits helped confirm the thought already held that despite treatment efforts, managed properties still contained significant amounts of *Phragmites*. This procedure could be carried out with more quantitative rigor to find out more about the effects treatment methods are having on individual properties. My assessment simply indicated that no previously treated area was completely void of *Phragmites.*

Reviewing WRPs brought to light questions about what should be expected from monitoring reports regarding *Phragmites* treatment. Inconsistency with both documenting reports and what was outlined for the monitoring procedure were most noticeable while organizing permits. Out of the 43 permits reviewed from 1999-2013, 11 had no monitoring reports on file, five didn't have the proper number of reports on file required by their permit, seven didn't specify how monitoring was to be done (and thus had no monitoring reports), four had the complete number of monitoring reports on file required by the permit and the remaining 16 either had reports done by another agency (e.g., Save The Bay) or were too early in the treatment process to submit required reports (*Figure 3*).



***<u>Figure 3</u>**: 37% of the permits I reviewed from 1999-2013 had no follow-up monitoring reports on file with CRMC. An additional 28% of the permits either did not have the required number of monitoring reports submitted to CRMC or did not specify how monitoring would take place.*

Identifying methods for initial and follow-up treatment is important in evaluating the success of restoration projects. After examining permits issued by CRMC, the most common way to treat *Phragmites* was using herbicides in combination with cutting and mowing. Treatment by tidal inundation and mowing and cutting were only used in a few circumstances. It was also important to note the time of year follow-up treatment was to take place. It is generally believed that applying herbicides at the end of each yearly growing season, later summer to early fall, produces the most effective results. Twenty five out of the 43 CRMC permits I researched used herbicides as the primary method to treat an area infested with *Phragmites*. Eighteen of these 25 permits specified herbicide application in the fall months, three in the fall and spring months, three in summer months and one did not specify when follow-up application was going to take place. The most common type of herbicide used was a brand of glyphosate solution (Rodeo, Roundup, Aqua Pro), however imazapyr and triclopyr herbicides were applied in some cases. All three are non-selective herbicides that are commonly used to treat aquatic or semi-aquatic weeds, grasses and woody plants. All but three of these follow-up treatment protocols involved some combination of spraying and cutting *Phragmites* (*Table 3*). Only five of the 43 permits reviewed involved cutting and mowing only, while four permits specified that saltwater intrusion was the main treatment method.

Permit number	**Year**	**Type of herbicide used**	**Time of application**	**Mowing/cutting**
1999-07-030	99-'00	Rodeo	Fall	Yes
2000-01-049	00-'03	Rodeo	Fall	Yes
2000-03-105	00-'03	Rodeo	Fall	Yes
2001-09-080	01-'04	Rodeo	Fall	No
2003-03-092	03-'07	Rodeo	Fall	Yes
2004-02-045	04-'07	Does not specify	Fall and Spring	Yes
2004-09-082	04-'08	Rodeo & AquaPro	Fall	No
2005-01-099	05-'08	Roundup & Renovate	Fall	Yes
2005-07-010	05-'08	Rodeo	Fall	No
2006-07-054	06-'09	Rodeo & Renovate	Fall and Spring	Yes
2006-08-039	06-'09	Glyphosate solution	Fall	Yes
2007-08-021	07-'17	Habitat	Fall	Yes
2008-08-071	08-'14	Glyphosate solution	Summer or Fall	Yes
2008-11-081	08-'15	Imazapyr	Summer or Fall	Yes
2009-01-041	09-'13	AquaPro	Fall and Spring	Yes
2009-04-012	09-'13	Does not specify	Does not specify	Yes
2010-05-009	10-'14	Rodeo OR Habitat	Fall	Yes
2010-06-082	10-'14	Glyphosate solution	Fall	Yes

2010-08-050	10-'14	AquaPro & Agri-dex	Fall	Yes
2011-07-029	11-'16	Rodeo	Fall	Yes
2011-08-045	11-'16	Imazapyr & glyphosate	Fall	Yes
2011-12-062	12-'16	Does not specify	Summer	Yes
2012-02-076	12-'16	Rodeo & Habitat	Summer	Yes
2012-02-77	12'-16'	Rodeo	Fall	Yes
2013-01-069	13-'16	Renovate 3	Summer	Yes

Table 3*: This table lists WRP that applied herbicides to treat Phragmites. A glyphosate solution was the most common herbicide used to spray for Phragmites. All but three permits combined cutting/mowing Phragmites with herbicide application.*

Working with Consultants

As a result of inconsistent monitoring reports, CRMC questioned the effectiveness existing monitoring was having on restoration success. Financial and personnel restraints had been quoted as the reasons for such inconsistencies to exist. During my time at CRMC, I had the opportunity to meet with consultants from a prominent New England environmental consulting firm responsible for treating *Phragmites* through CRMC WRPs. Consulting firms are often hired to assist with restoration projects and are involved in just about all stages of the monitoring process. Thus, it would seem logical that collaboration between a regulating agency (CRMC) and consulting firms was necessary to determine how to effectively carry out monitoring of *Phragmites* treatment.

While collaborating with consultants, the majority of discussions focused on ways in which monitoring could be improved to ensure a successful restoration. In order to establish consistency among monitoring reports, the first step should be to set goals for the treatments. Some of the recommendations that were offered to achieve this goal were:

- The regulating agency and the persons responsible for monitoring must set clear and concise goals for the project. This could mean establishing what is expected through the restoration and what is the ultimate end result.

- Monitoring should be done every year before and after follow-up treatment is applied. Treatment, especially herbicide treatment, should be done at the end of the *Phragmites* growing season (August-November).

- Access to monitoring the same site is essential. On larger, more remote locations consultants noted that there are sometimes difficulties being able to return to exactly the same areas where initial treatment took place. Access can also be affected if the property changes ownership.

- Follow-up monitoring should be simplified. A "check-list" type of report was suggested in order for consultants to quickly evaluate the progress of a project and make sure the initial goals are still on track.

- Money for monitoring should be set-aside during the onset of the project. It was noted that financial resources were the main limiting factor for consistent monitoring. Five-plus years of follow up monitoring should be anticipated for most restoration projects to ensure the long-term success of the project.

- Baseline transects should be performed every 2-3 years during treatment. Transect areas should change as the project goes on in order to better profile the treated area. In addition, habitat maps, photo stations and plant identification should be a part of all monitoring during and after the projects completion.

In summary, consistency in monitoring should start before the project takes place. Outlining project goals, setting monitoring protocols, and clearly stating what is expected from reports are the first and perhaps most important steps to take in order to ensure project success and promote clear lines of communication among the various participants in a project. Simplification of reporting duties would allow consultants to effectively monitor projects based on their financial and personnel resources. Although every project is different, CRMC should (and now currently has) draw up a standard set of guidelines for consulting firms to follow when WRP are initiated. Questions that emerged about what these guidelines should entail following discussions with consultants included: How long should the follow-up monitoring plan be? How often should monitoring take place? How often should transects or measuring plots be conducted? How detailed should habitat maps and pictures be in order to accomplish a sense of how the project has progressed?

Current *Phragmites australis* Management Studies

CRMC is continuing to improve on their *Phragmites* control efforts in Rhode Island and their approach to pre and post-treatment monitoring. Not only is CRMC concerned with monitoring protocols but also how treatment is being performed. Monitoring is only part of the overall process to successfully eradicate *Phragmites* in a region. Because of its' expansive range along the East Coast, *Phragmites* invasions have caused ecological problems for many state environmental agencies. For this reason, many studies have evaluated the most effective ways to control the continued spread of this invasive. It is important to learn from these studies and apply their findings to Rhode Island's current *Phragmites* outbreak. The literature presented here reflects the current state of *Phragmites* control and monitoring in the U.S.

Lombard et al. (2012) reported on the effectiveness of herbicide application and long-term monitoring on *Phragmites* stands located on Sandy Neck beach on Cape Cod, MA from 2002-2009. They theorized that although herbicide application reduces *Phragmites* cover greatly in the short term, reapplication of herbicide is required for long-term effectiveness, and control is generally most successful when herbicide application is combined with other techniques such as burning, flooding, or cutting (Lombard, et al. 2012). Their suggested protocol included mapping the distribution of *Phragmites* within the study area using a GPS and to categorize locations according to patch densities.

Seasonal staff were trained to hand cut *Phragmites* stems, then drip herbicide directly onto the cut stems for maximum effectiveness. The herbicide used for treatment was either "Rodeo" or "Aquamaster," both common herbicides used in the treatment of *Phragmites*. Finally, *Phragmites* density and percent cover was tracked from 2002-2009 in order to examine the impact of herbicide application. Over the seven-year control period, *Phragmites* was steadily reduced in density and abundance (Lombard et al., 2012). These results indicate that successful control efforts for *Phragmites* can be accomplished when implemented over a long period of time. This study, however, raises questions about how practical their methods would be if implemented as control efforts for state and local governments. The process of hand cutting and dripping herbicide directly onto each *Phragmites* stalk is extremely time consuming and labor costs would likely be very high when done by a contractor. Although effective, control methods must be feasible for state agencies to implement on a large scale.

Another study done by Derr (2008) examined the effectiveness of combining herbicide application and mowing and cutting to successfully control *Phragmites* distribution near Norfolk, VA (Derr, 2008). The author presents differences in treatment methods under different growing conditions and how they work to control *Phragmites*. In addition, the study compared the effectiveness of chemical treatment vs. mechanical treatment (mowing and cutting) over concerns that herbicides may be detrimental to other aspects of wetland ecosystems. This experiment was constructed using three different methods: Response to Post-emergence Grass Herbicide, Impact of Mowing on Common Reed in Container Trials, and Impact of Mowing on Common Reed in the Field. To test its response to postemergence grass herbicide, *Phragmites* was grown in 4 L containers until fully matured. They authors applied different herbicides on each set of containers and recorded which herbicide altered *Phragmites* growth the best. The process was evaluated for five weeks while keeping random plots untreated to act as a control. The impact of mowing on common reed in containers was tested by growing *Phragmites* the same way they did for the previous experiment, cutting stems at different time intervals (one pot every 4 weeks, 6 weeks, and 8 weeks), then applying herbicides to the cut stems. They also tested pots by applying herbicides before cutting. Each *Phragmites* pot was sprayed with the herbicide glyphosate (Rodeo). The final experiment, impact of mowing on Common Reed in the field, was conducted on a dense stand of common reed adjacent to an Interstate highway in Norfolk, VA. The trial was conducted in a similar fashion as in the previous experiment with regard to cutting scheme and herbicide application. *Phragmites* were cut using a weed-whacker and monitored before and after applying Rodeo. The results indicated that only the glyphosate herbicide was seen to have any impact on controlling *Phragmites* growth (Derr, 2008). Mowing too far in advance of the growing season for *Phragmites* had little impact on controlling growth, as well as mowing two weeks after herbicide treatment. Mowing during the growing season, however, did have significant impacts on controlling new growth. Derr concluded that mowing at the correct time of year (during the growing season) can produce positive results in limiting *Phragmites* growth. However, any protocol that involves mowing will need to be done consistently and repeatedly over a long period of time. Such detailed requirements bring about concerns with monetary resources and labor constrains. Application of the glyphosate herbicide will show positive results, however the effects on surrounding ecology are unknown based off this study.

Many studies have researched ways in which to control the spread of non-native *Phragmites* on a small local or regional scale. Costs would be higher when implemented on a larger scale, and after working for an agency like CRMC, it is apparent that funds can be very tight and must be issued for maximum efficiency. Martin and Blossey (2013) constructed an economic survey that targeted organizations involved in *Phragmites* control in order to evaluate invasive species management across a variety of institutions in the U.S. The goal of this survey was to quantify the relationship between management expenditures and success of controlling *Phragmites.*

The survey asked organizations to explain their management objectives, expenditures, control methods, and management outcomes when addressing *Phragmites* eradication (Martin & Blossey, 2013). The final survey list consisted of 520 state, federal, municipal and private conservation organizations. The survey was distributed via email and asked participants to evaluate their management plans. Each question pertaining to *Phragmites* management asked the participant to rank their response on a 0-5 Likert scale, 5 being that they strongly agree and 0 being that they strongly disagree (Martin & Blossey, 2013).

Responses were received from 285 managers from 40 different states. The authors believe this was an informative representation of management approaches across the U.S. because non-native *Phragmites* is known to exist in at least 45 different states (Martin & Blossey, 2013). They received the greatest number of responses from managers working for private organizations (39 %), followed by federal (24 %), state (23 %), municipal (8 %), and finally land trusts (6%). They found that control efforts for *Phragmites* have delivered few long-term ecological benefits despite their high yearly cost. Combined expenditures for the participating organizations totaled roughly $4.6 million per year on non-native *Phragmites* treatment. State agencies were found to spend much less time per year in conducting *Phragmites* treatment compared to time spent by private organizations (an average of 10.6 hours/hectare/year vs. 12.3 hour/hectares/year). Lack of personnel and monetary resources was cited as the most common restriction for carrying out effective *Phragmites* control efforts (Martin & Blossey, 2013). This survey raises questions about how land managers should rethink their approaches to *Phragmites* control. This is a question that should be confronted by agencies such as CRMC when evaluating their *Phragmites* monitoring protocol.

Finally, to underline the importance of follow-up monitoring and treatment for successful *Phragmites* control we can learn from an experiment done by Alistock et al. (2001). Two control methods were studied, herbicide application only and a herbicide-burning combination to treat areas infested with *Phragmites*. Rodeo was applied to the study areas using both helicopters and hand-held sprayers. One site was then chosen as the "herbicide-burn" site and was burned 4 months after herbicide application. Both sites were surveyed before and after treatment methods were applied in order to measure vertebrate use, plant and microinvertebrate density, and soil and seed stock.

The study reported that a one-time herbicide application or a one-time herbicide-burning combination can significantly reduce the abundance of *Phragmites* in the short term (Alistock et al.,2001). However, after 2-3 growing seasons native vegetation was outcompeted by the reemergence of *Phragmites.* Thus, additional spot treatments of herbicide are needed to prevent regrowth of *Phragmites* in the long term. These results exemplify the importance for clear and concise monitoring reports that outline follow-up treatment protocols. Application of herbicides, although effective, must be done routinely for a few years in order to yield successful, permanent results.

After reviewing many studies, it is clear that herbicide application can be the most effective means of eradicating *Phragmites* if applied properly. Constant spraying can show positive results on decreasing the spread of *Phragmites* within an infested area. Although effective, herbicide application may have detrimental impacts on surrounding ecosystems. Concerns are raised whenever spraying takes place about possible negative impacts of herbicide application within a wetland. Therefore, an important question for managers involved with *Phragmites* removal projects is to ask if the potential negative impacts of herbicides are worth the risk, especially for biota indirectly impacted by the change in plant communities?

Lazaran et al. (2013) studied the impacts of herbicide treatment for *Phragmites* on Marsh Wren nesting behavior. Their main objectives were to: 1) asses if herbicide treatment impacted the density of male Marsh Wrens, 2) determine the impact of herbicide application on density of active Marsh Wren nests and 3) examine if the anticipated delay in vegetation growth impacted nest height or mean date of nest initiation of Marsh Wrens. Two marshes were selected for applying herbicides targeted to treat *Phragmites*, one using helicopter areal application and the other by backpack-delivered spot treatment. The team mapped Wren activity, located nests and monitored at 3-day intervals until nest and brood fate could be determined. Nest heights on vegetation as well as surrounding vegetation absent of nests were measured and density of vegetation patches were calculated.

Average territory density, nest density, number of days to nest initiation, and nest height between years from the two sites were calculated to examine the impact of herbicide application (Lazaran et al., 2013). They conclude that herbicide treatment used to control *Phragmites* negatively impacted Marsh Wren habitat, especially within the marsh that was sprayed by areal application. Because Marsh Wrens build their nests on tall, sturdy vegetation stalks, *Phragmites* has offered adequate nesting habitat for these birds. Thus, herbicide treatment of *Phragmites* was seen to reduce nesting habitat, which negatively affects Marsh Wrens. The authors do not make any claims that chemicals in herbicides used to treat *Pragmites* cause direct impacts to Marsh Wrens. It is the effectiveness of herbicides used to control *Phragmites* that impacts Marsh Wren habitat.

A conundrum for Lazaran et al. (2013) is although perceived as a threat to ecosystem function, caution should be used to treat *Phragmites* with herbicides because of their reduced effectiveness as a control method and they reduce the overall nesting habitat for Marsh Wrens, a declining species. This seems counterintuitive on the basis that managers shouldn't let an invasive like *Phragmites* go untreated.

Alternative Management Approaches

The *Phragmites* invasion is widely seen as a severe threat to ecosystems and natural wetland habitats across the U.S. Much of the literature written about *Phragmites* is how to effectively treat or eradicate the plant from an area. There is however some literature that explores the alternative uses of *Phragmites,* identifying ways in which this invasive can be used to benefit resource managers. Completely eradicating non-native *Phragmites* from North America seems unlikely. New ways to either control the continued spread of this plant or to identify the benefits of its existence may be a more logical approach to the situation.

Kiviat (2013) discusses multiple ways in which non-native *Phragmites* can provide important ecosystem services in wetlands across North America. This particular paper is based on a review of ecology and natural history literature, interactions with biologists and naturalists, and 40 years of quantitative field observations and field studies by the author. Kiviat separates positive *Phragmites* services into two different groups: Non-habitat ecosystem services and habitat functions or biodiversity support. Non-habitat services are defined as all services besides biodiversity support and include: soil building and carbon sequestration, commercial products, waste treatment, phytoremediation and bioenergy (Kiviat, 2013). The author makes many strong points about the non-habitat services *Phragmites* may provide. His list of habitat functions that support biodiversity is very detailed and include: *Phragmites* as a food source, source of shelter, as nest material, and as a vegetative buffer. For each proposed function he lists, Kiviat gives examples of how non-native *Phragmites* has evolved to become favored by many different organisms found in wetland habitats.

Kiviat proposes that management of *Phragmites* should be done on a site-by-site basis that takes into account the biota occupying existing *Phragmites* stands rather than complete eradication of *Phragmites* everywhere (Kiviat, 2013). Management goals should be set only after a thorough assessment of ecosystem services provided by a particular stand of *Phragmites* has been done in order to foster biodiversity in a region. Also, when located in particular regions, the non-habitat functions *Phragmites* can serve (i.e. flood control, wastewater treatment) may outweigh the ecological changes associated with this introduced species (Kiviat, 2013).

My major paper takes a pragmatic view on how we might manage non-native *Phragmites*. Some of the arguments are in need of further research and opinions shouldn't be solely based on the examples given here. However, I feel Kiviat (2013) is being realistic in his approach to managing *Phragmites*. It seems unlikely that complete eradication of this invasive in plausible, thus managers should identify the positive functions *Phragmites* may provide in particular regions and manage accordingly.

GIS and Remote Sensing Applications

One aspect of monitoring *Phragmites* CRMC may want to improve on is the implementation of geographic information systems (GIS) and remote sensing technologies. These tools can not only help track the spread of *Phragmites* in Rhode Island, but also help to monitor the progress of existing projects. GIS and remote sensing provide data that is obtained by satellite, areal or spatially referenced imagery, much of which is free to download off the Internet. This means that labor costs may decrease as *in situ* mapping and assessment will lessen whenever there is a need to estimate the density of *Phragmites*. CRMC currently does not employ a full-time GIS specialist; such a person could be extremely valuable not only to *Phragmites* monitoring but many of the other responsibilities CRMC takes on.

There have been studies documenting the use of remote-sensing technologies on *Phragmites* stands and one particular study sought to test the applicability of using the Hyperion hyperspectral satellite sensor in tracking *Phragmites* stands in the Great Lakes

(Pengra et al., 2007). The Hyperion sensor is aboard the EO-1 satellite and serves to merge the spectral resolution of airborne hyperspectral technology with the availability of satellite remote sensing. The study wanted to compare this satellite imagery with already proven airborne imagery for tracking the invasive *Phragmites* (Pengra et al., 2007).

The study site was a 7.5 km area located along Green Bay, Wisconsin. Imagery was collected during the growing season of *Phragmites* (September. 1-October. 15) in order to best differentiate the invasive from other wetland plants. During this time frame *Phragmites* will have a more pronounced spectral reflectance which will make it easier to identify. After data were collected and processed, the ERDAS IMAGINE 8.7 Spectral analyst module was used for image processing. Once the images were processed, areas classified as *Phragmites* were separated and mapped. Field data collection was done in order to validate the accuracy of spatial classification, a procedure commonly done when analyzing remotely sensed imagery.

Areas mapped by this study revealed locations of *Phragmites* that were previously unknown by resource managers. Without this technology, it is likely that these unknown stands of *Phragmites* would have gone untreated until the area covered became much larger. Thus, it is seen here that Hyperion spectral data is effective in providing an early indicator of an invasive infestation (Pengra et al., 2007).

The authors state that space platforms will always be at a disadvantage compared to airborne sensors because they are further from the reflecting surface and thus receive less reflective energy (Pengra et al., 2007). However, this study has proven that satellite imagery can provide enough detail to classify relatively small patches of *Phragmites* within a wetland at a much lower cost and higher availability than airborne imagery.

This tool will be much more practical for large state and government application in tracking, monitoring and planning for the treatment of *Phragmites*

Conclusions

Working with CRMC brought to light many challenges environmental managers face when trying to control invasive species. Eradication of an established pest is a long, detailed and often times financially straining process. Many factors play into a successful eradication program; the *Phragmites* invasion in Rhode Island seems to outline many of them. Although it may be impossible to completely eliminate the presence of non-native *Phragmites* in Rhode Island, certainly the outbreak can be contained if proper monitoring protocols are followed after initial treatments. The process must first start with outlining project goals and establishing realistic timetables and funding estimates for each project. Follow-up monitoring is a vital part of the treatment process and must be strictly followed. The lack of consistent monitoring requirements outlined in CRMC WRP's has been a major setback for the agency's ability to track the *Phragmites* problem.

Since my time working at CRMC, the agency has made changes to their monitoring protocols and permit application processes. A first and very important step was to construct a generic or standard set of guidelines that can be issued to anybody applying for small WRP's. CRMC considers small wetland restoration permits to be those which are less than one acre in overall size, typically located on private residential or commercial properties (RICRMC, 2014). These guidelines outline what is expected from the permit holder and define their responsibilities. Detailed descriptions of responsibilities include: impact assessment, habitat mapping, description of wetland restoration methods, restoration design, reporting requirements and monitoring protocols, cost estimates and project oversight methods (RICRMC, 2014). CRMC has also made sure to clearly outline contract requirements and ramifications for not abiding to the stipulations initiated by these guidelines; perhaps a major reason for previously violated permit agreements. These guidelines may not apply for every single restoration project CRMC gets involved in, however it is a good starting point in assuring there are clear and concise expectations for future restoration projects.

After reviewing current studies, the most successful treatment of *Phragmites* has proven to be consistent herbicide application to infested areas. Experiments have shown that this method of control can have positive effects when implemented correctly. Many of the studies reviewed above underline the importance of consistent follow-up treatment in order to prevent *Phragmites* from reestablishing in a region. Constant herbicide application, especially when done by areal broadcast spraying, can be extremely expensive and likely isn't applicable to many of the small restoration permits under CRMC's control. This means more time must be spent in the field applying herbicides by hand, a tedious and time-consuming process. It seems a logical approach would be to focus more on larger projects where *Phragmites* management can be shared by multiple state environmental agencies. Treating *Phragmites* on areas less than one-acre likely wont have a drastic impact on controlling the overall statewide outbreak and can be a drain on financial resources. Managing multiple small-scale projects may not be the most efficient way of allocating time and funds on a tight budget.

Problems CRMC faces regarding *Phragmites* monitoring in Rhode Island are not unique; similar obstacles can be seen among many environmental agencies in the U.S.

dealing with this same problem. Working with CRMC has brought forth the realities associated with invasive species control and how management is a very involved and complicated process. In reality, there exists a major question on whether the risk is worth the reward for treating *Phragmites*? It seems this question should be asked on a local scale, treating each case as an isolated issue base off local resources and values. CRMC will continue to address *Phragmites* control in Rhode Island with monitoring protocols that more effectively and efficiently reduce the spread of this invasive.

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