Appendix 3.

Tying Management Goals, Treatments, and Monitoring Protocols together for Adaptive Management

It is of critical importance to assess site specific conditions and determine explicit management goals prior to implementing management activities. These will dictate the best treatment methods and sequences for achieving success, as well as the best monitoring protocols to measure progress. Only then can adaptive management be truly implemented, where monitoring results inform subsequent management activities, and are adapted accordingly. Consistent documentation of management goals, treatments implemented and monitoring results not only will improve management at the site scale, but it also allows these data to be easily shared to inform a broader management and restoration community. Compiling site level data across many sites may also have implications at larger landscape scales. Coordinated landscape-, regional- and site-scale management and learning are needed for optimal management of *Phragmites* throughout Saginaw Bay.

A Framework for Monitoring the Success of Phragmites Management

Ideally, predefined management goals and objectives should drive the development of monitoring plans. Typical goals of *Phragmites* control include the maintenance or restoration of plant diversity, wildlife use, and ecological functioning. The monitoring plan ultimately implemented will be a function of not only management goals, but also available resources (e.g., funding, time, and expertise), characteristics of the *Phragmites* stands being treated (e.g., large vs. small area, dense vs. sparse cover), and availability, when needed, of reference sites for comparison. Although the complexity and therefore resources needed for monitoring may mean that optimal monitoring is not immediately possible at a given site, it is still important to consider upfront the optimal measures needed to assess progress towards your specified management goals. Trade-offs can then be made knowingly and wisely. It is particularly important to understand that success is not always or necessarily measured by percent *Phragmites* kill, and long-term success cannot be measured in the short time frame in which monitoring typically occurs (1-2 years). Managers should strive for the best measures for their management goals and long-term monitoring whenever possible.

Factors to Consider in Developing a Monitoring Plan

Monitoring Goals

The goals of monitoring should be framed by the overall management goals and underlying specific objectives (Table 1). For example, the simplest monitoring goal would be evaluation of management actions in reducing *Phragmites* occurrence (e.g., percent cover, frequency, density, and/or stem diameters) within a wetland where management occurred. If the management goal is to restore a functioning Great Lakes marsh ecosystem, then monitoring would require measures of plant and animal communities and ecosystem functioning as related to reference wetlands. Although evaluating the effects of management on plant/animal communities and ecosystem functioning should provide increased knowledge to inform future management, such monitoring often requires substantial resources, including money, time, and expertise (Table 1). However, the addition of at least one or more measures that go beyond % *Phragmites* kill, are highly desirable in most management scenarios to better assess progress towards specific management goals – and they are not always cost-prohibitive. For example, simple qualitative visual estimates of the total % cover of all “desirable” and “undesirable” species can be made relatively easily with limited expertise, assuming clear definitions of the categories are developed and communicated. Similarly, simply setting a threshold level of *Phragmites* cover that is believed acceptable for the persistence of particular plant and/or animal communities could also be easily measured.

Table 1. Typical monitoring goals when assessing the success of management actions targeted at invasive *Phragmites*.

Typical Monitoring Goals	
Evaluate the success of management actions in reducing *Phragmites* occurrence within the wetland	Scientific value increases, as does complexity and resources required.
Assess the effects of management actions on the overall plant community (plant diversity measures)	
Investigate the effects of management on both plant and selected animal communities (e.g., birds, amphibians, reptiles, fish, invertebrates)	
Assess the success of management actions in achieving ecosystem restoration (e.g., plant and animal communities, ecosystem functioning). See TNC work on mitigation sites: looks at ecosystem composition, structure and function. The latter requires an understanding of the fundamental ecosystem processes that drive the ecosystem and a way to determine if they are occurring.	

The best measures for some management goals and objectives may not yet be known, but implementing deliberate, consistent monitoring over time, along with on-going studies by the research community, will help improve our understanding of these measures. It is likely, for example that specific ecosystem structural measures, such as amount of plants in certain height categories, would be highly informative for some coastal wetland nesting bird species.

Wetland *restoration* is another common goal of *Phragmites* control efforts but requires monitoring beyond measuring *Phragmites* kill and plant diversity to evaluate success. Monitoring efforts rarely assess the success of restoration efforts – again, typically because of limited resources and expertise. Determining restoration success may seem simple, but in reality requires substantial planning and careful sampling that includes *ecological reference sites*. The Society for Ecological Restoration (SER) identified nine indicators of restoration success (SER 2004): 1) similar species composition as reference site; 2) native species are present; 3) appropriate functional groups are present; 4) sustains reproducing populations of species; 5) functions normally (ecosystem processes are intact); 6) site is integrated into the landscape; 7) potential threats reduced or eliminated; 8) withstands natural disturbances; and 9) site can sustain itself indefinitely. Recognizing it is unlikely that resources are available to evaluate all nine indicators, Ruiz-Jaen and Aide (2005) provided more realistic suggestions for evaluating restoration projects. The authors recommended assessments include the measurement of at least two variables within each of three ecosystem attributes (diversity, vegetation structure, and ecological processes) and comparison with at least two reference sites.

Sample Design

Based on the management and monitoring goals, the sample design should be determined before management actions are implemented. Whether you are monitoring *Phragmites* alone, various plant/animal communities, or measures of ecosystem functioning, some basis for comparison is required. For example, to assess the effects of management on *Phragmites* at a particular site, measures of *Phragmites* occurrence (e.g., percent cover, density, spatial extent) would need to be compared between separate time periods, sites, or both. Simply measuring *Phragmites* metrics at the management site after actions have occurred provides no basis for comparison and therefore, no way to evaluate success. The most statistically robust design would include both temporal (i.e., sampling before and after management) and spatial (i.e., sampling at both management and reference sites) replication (Table 2). This allows for a before-after-control-impact robust statistical analysis. Because species and ecosystems typically vary greatly over time and space, replication of sampling (e.g., years and sites sampled) should be maximized as much as possible.

Table 2. Sample design considerations when assessing the success of management actions targeted at invasive *Phragmites*.

Sample Design	Examples of Implementation	
Temporal Comparisons	Compare metrics during 1 growing season before and 1 season after management	Scientific value increases, as does complexity and resources required.
	Compare metrics during 1 growing season before and multiple seasons after management	
Spatial Comparisons	Compare metrics at management site to reference site	
	Compare metrics at multiple management sites to multiple reference sites	
Both Temporal and Spatial Comparisons	Compare metrics between the management site and a reference site during 1 growing season before and 1 season after management	
	Compare metrics between multiple management sites and multiple reference sites during 1 growing season before and multiple seasons after management	

Stand Characteristics

A Guide to the Control and Management of Invasive Phragmites (MDEQ, 2014) describes particular management strategies based on the size and density of *Phragmites* stands. Similarly, the size and density of stands, as well as other characteristics, will influence the resources required and methods to be employed for monitoring. If the same sampling methods were used across sites, monitoring costs would increase with stand size and density (Table 3). However, it is likely that limited resources will require different monitoring approaches be used at large dense stands compared to small sparse stands (Table 4).

Table 3. Influence of *Phragmites* stand size and density on monitoring costs.

Stand Size	Stand Density	
Small	Sparse	Monitoring costs and resources required increase.
Small	Dense	
Large	Sparse	
Large	Dense	

The need for better monitoring methods in large, dense infestations was demonstrated during this project, where on-the-ground monitoring of large stands (> 800 m) across the gradient from wet meadow to submergent zone in the Great Lakes coastal zone) was prohibitively time-consuming and even sometimes unsafe to implement during typical *Phragmites* treatment efforts. Fortunately, remote sensing imagery options have improved dramatically, and using World View-2 Digitial Globe imagery (60 cm resolution) during this project, even small patches of *Phragmites* dead and live stems could be detected before and after treatment. In addition, some biodiversity measures could also be detected (i.e. mixed vegetation vs monotypic *Typha, Phragmites* or *Schoenoplectus*, for example). The use of unmanned aerial vehicles is improving as well, and will almost certainly be more routinely employed for treatment monitoring. The drones used during this study were able to distinguish *Phragmites* from non-*Phragmites*, but did not allow identification of non-*Phragmites* taxa to the species level other than *Typha*, even at 5 cm resolution with a natural color camera. Further differentiation may be possible with multi-band cameras. The use of remotely sensed imagery and drones is discussed further in the main body of this report and we are highly optimistic that these evolving tools will provide more informative monitoring data, where on-the-ground monitoring in impractical. Indeed, they already did so in this project.

<u>Summary of Tier 1-3 Monitoring</u>

Appendix 2 provides an overview summary and table of some of the many studies we reviewed, as well as instructions and data forms for the Tier 1-3 protocols tested during the study. Here we highlight and briefly discuss the protocols tested, with an eye towards their practicality for routine *Phragmites* treatment monitoring.

Our Tier 1 level monitoring included the following direct observations of the treatment site:

- qualitative estimates of *Phragmites* % cover
- qualitative estimates of % cover of desirable species (determined prior to management)
- qualitative estimates of % cover undesirable species (determined prior to management
- qualitative estimates of % bare ground and % open water
- qualitative estimates of key components of the MDEQ *Phragmites* prioritization tool
    - scenic impairment – high, medium, low
    - recreation impairment – high , medium, low
    - safety impairment – high, medium, low
- ecosystem type, which can be used as a desired future condition, if appropriate

These components take little time and provide useful and relevant data (see section k of report main document). Most importantly, the percent cover of undesirable species addresses a significant concern expressed by *Phragmites* managers: the potential for secondary invasions of other undesirable species, such as European frog-bit, flowering rush or hybrid cattail. This protocol can be implemented by landowners with minimal training, and developing a photo-guide to desirable and undesirable species would facilitate this. If conducted annually, this protocol provides a consistent basis for comparison of the site condition over time and adapting management as needed.

Photomonitoring: We suggest conducting photomonitoring to coincide with this Tier 1 protocol. The Nature Conservancy (TNC) in Michigan developed a digital photo-monitoring protocol following recommendations of Rogers et al. (1984). This methodology is used by TNC to document long- and short-term changes in vegetation; the Michigan Natural Features Inventory used this methodology to document conditions at prairie fens and wet meadows with recent or planned management activities (Slaughter et al. 2010). This methodology provides guidelines on the selection and marking of points, information to be recorded, and camera lenses and settings. Interestingly, few of the studies reviewed for this project included on-the-ground photomonitoring however, it was used for the EPA GLRI study (PI Bourgeau-Chavez). Our recommendation is that photomonitoring should be a basic minimal requirement for all *Phragmites* treatment monitoring. It provides a photo log of the site over time, which is likely the best of the least expensive monitoring protocols to document change.

Phragmites Response

All of the Tier 1-3 protocols tested during this project include one or more measures of *Phragmites* response, from simple qualitative cover estimates to transect-plot based measurements of stem density, stand height, aerial cover and stem diameter. Continued use and learning from these various *Phragmites* measures will help determine which ones are the best predictors of rhizome biomass—the ultimate target of long-term control of *Phragmites.* These estimates feed into an adaptive management framework that considers site specific *Phragmites* propagule pressure, water depth, nitrogen level and landscape connectivity to inform optimal follow-up treatments, using an ecosystem MONDRIAN Model and associated Lookup Table. This is further described in the main body of the report and the Lookup Table can be found here: **https://sites.google.com/uni.edu/*Phragmites*lookuptable**

The *Phragmites* Adaptive *Management Framework (PAMF) Monitoring Protocol*

This approach requires measuring *Phragmites* stem count, abundance and diameter in 0.25m^2 quadrats within specifically delineated treatment patches at 5 locations provided by the centralized PAMF team (GLC et al. 2017). These data are then looped into a predictive State and Transition model for *Phragmites* to inform and recommend the subsequent best treatment. This is a complimentary approach to the MONDRIAN modeling used in our study, and has tremendous value for improving adaptive management of *Phragmites*. These complimentary approaches are described and compared in a document that will be hosted on the Great Lakes Commission website.

Plant Diversity

The Tier 3 protocol tested in this study, which follows the Great Lakes Coastal Wetland Monitoring protocol (Burton et al, 2008, Uzarski et al. 2017), worked well for assessing changes in plant diversity. However, it is impractical for very large routine *Phragmites* treatment sites due to required level of expertise and time required to implement it. Other methods reviewed for Tier 3 monitoring have similar constraints. Due to the time, expense, and expertise required for these more detailed, statistically rigorous protocols, it is perhaps most important to reserve their use for sites where novel treatments, research studies are undertaken or for treatments conducted to answer specific areas of controversy about management techniques. Combining on-the-ground sampling with the remote sensing imagery interpretation tested in this study provides a promising tool both for routine treatment and research monitoring.

The Tier 2 protocol tested in this study, which uses a combination of belt transects for noting dominant cover types (Live *Phragmites*, Dead *Phragmites*, Desirable species, Undesirable species, Open water, Bare/mud) interspaced with sample plots used to gather more detailed information, warrants further study. If this protocol can be refined to improve statistical analyses, it provides an alternative to more detailed all-species plot monitoring that is faster, requires far less expertise and may produce more accurate data. It is much less difficult to learn a small set of undesirable species, than to learn all wetland plant species (> 150) and recognize them at different phases of their life-cycle. The latter opens the door for substantial statistical error when highly skilled, experienced observers are unavailable or cost prohibitive.

Note that in this study we did not test protocols for assessing animal species response to *Phragmites* treatment or ecosystem restoration goals. Measuring these will require more time-intensive in-field plot-transect monitoring, unless specific vegetation measures are identified as a surrogates for success and can be interpreted through remotely sensed or drone imagery for large sites.

Table 4. Examples of possible sampling approaches based on monitoring goals and stand characteristics. These approaches could be applied using any sample design (e.g., temporal comparisons, spatial comparisons, and both temporal and spatial comparisons). Gray shaded cells indicate potential monitoring approaches for listed monitoring goals, stand size, and stand density. Green-shaded cells indicate a recommended method to use in addition to or when resources are lacking for higher level monitoring, but that is not optimal alone. The orange shaded cells indicate stand conditions where remotely sensed satellite imagery tested in this project can be helpful.

Monitoring Goal	Stand Size	Stand Density	Photograph monitoring/ Tier 1	Mapping – on-the-ground	Mapping – remote sensing	Plot/transect – Phragmites*	Plot/transect – plant community*	Animal surveys	Ecosystem functioning
Evaluate the success of management actions in reducing *Phragmites* occurrence within the wetland	Small	Sparse							
	Small	Dense							
	Large	Sparse							
	Large	Dense							
Assess the effects of management actions on the overall plant diversity	Small	Sparse							
	Small	Dense							
	Large	Sparse							
	Large	Dense							
Investigate the effects of management on both plant and selected animal communities	Small	Sparse							
	Small	Dense							
	Large	Sparse							
	Large	Dense							
Assess the success of management actions in achieving ecosystem restoration	Small	Sparse							
	Small	Dense							
	Large	Sparse							
	Large	Dense							

* The same transects and plots can be used for both *Phragmites* and plant diversity response.

** Generally small sites are those with transects spanning the water gradient that are less than 200 m in length in a large water body; large includes sites where transects are over 500 m in length in large water body.

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