Survey of *Phragmites australis* in Water Sources in Michigan’s Northern Lower Peninsula

Derek J. Walton
Acknowledgements:

Many thanks are due to my on-site advisor Thomas Yocum for incorporating me into his project for this year and for helping me to develop my own take on our research. I owe my gratitude to Tucker Hogarth and Laura Bailey for their assistance in sampling and for tolerating the unseasonably cold weather this past summer. My great appreciation goes out to Howard Yamaguchi for volunteering his expertise with the ArcGIS software as well as Heidi Lang from Tip-of-the-Mitt Watershed Council for her training in *Phragmites* identification and volunteer organization. Special thanks go out to Wayne Kladder and everyone at the Acme Township offices for their patience as I completed the Acme Township survey and their willingness to provide to me whatever resources I required. Finally, I would like to recognize Dr. Ann Fraser and the members of my literature review team: Elliott Wolfson, Paige Howell, Zachary Geiger and Zackary Smith. They have been invaluable in getting this finished product completed on schedule.
Abstract

Understanding the distribution patterns of an invasive species is a first critical step toward controlling its spread into other ecosystems. Beginning in June of 2009, grassroots environmental protection organizations in northern Lower Michigan coordinated under the supervision of the Department of Natural Resources to address the presence of a Common Reed (Phragmites australis) subspecies that was introduced via the chain of Great Lakes in the 19th century and has since spread all the way to Wisconsin (Lindorth, 1957). Two genotypes of this grass-like flora are known to exist, one of which is native to North America and is found frequently in wetland ecosystems in the Midwest. The invasive subspecies, however, has proven to spread quickly into tidal or wetland ecosystems and displace native plant species. A total of 3971 meters of shoreline were found to be affected by Phragmites along a total of 74 kilometers of shoreline on the East Grand Traverse Bay of Lake Michigan as well as on Elk and Skegemog Lakes, nearly 5.4% of the total shore. During surveying, the GPS location of each stand of reeds was recorded, along with physical data including the length, breadth, approximate stem number and stem density of each population. All of 104 stands of the Phragmites australis found on the Grand Traverse Bay shoreline were found to be of the invasive subspecies while the mere three stands on the inland lake shorelines were identified as the native genotype. This survey supplied the scientific research, with respect to Phragmites stand distribution and size, necessary for a thorough grant application to the Michigan Department of Natural Resources to be composed by community leaders in Acme Township. Such a grant would help to fund chemical treatment of invasive Phragmites with aquatic herbicides if it was deemed necessary to do so to mitigate damage to the ecosystem.
# Table of Contents

Acknowledgements........................................................................................................... iii

Abstract.......................................................................................................................... iv

List of Figures and Tables............................................................................................. vi

Introduction.................................................................................................................... 1

Materials and Methods............................................................................................... 10

Results........................................................................................................................... 16

Discussion....................................................................................................................... 23

Literature Cited.............................................................................................................. 30
List of Figures and Tables

Figure 1. Geographical and political map of survey region in Northern Lower Michigan........11

Figure 2. Invasive and native *Phragmites australis* photographed side-by-side..................14

Figure 3. GIS layer map of *Phragmites* stands in entire Acme Township..............................18

Figure 4. High resolution GIS map of southern Acme Township shoreline with parcel lines.....19

Figure 5. High resolution GIS map of central Acme Township shoreline with parcel lines.......20

Figure 6. High resolution GIS map of northern Acme Township shoreline with parcel lines.....21

Figure 7. High resolution GIS map of *Phragmites* locations in Skegemog Lake.........................22

Figure 8. Herbicide spraying for invasive *Phragmites* on Lake Charlevoix..........................27

Table I. Total *Phragmites australis* presence in areas surveyed during this study................16

Table II. Summary of *Phragmites* stand data collected from the Acme Township survey........17
Introduction:

The protection, preservation, and rehabilitation of natural ecosystems are increasingly important in the United States and around the world (Mol and Sonnefeld, 2000). To date, nearly every terrestrial or aquatic environment has been affected due to human presence. Of particular concern are environments that produce large quantities of fresh water, food, building materials and other resources necessary for human survival (Chambers et al., 1999). Unfortunately, during the continual expansion of human civilization, nature has not been a beneficiary. Through the efforts of both domestically and internationally active environmental groups, humans may, for the first time, be able to effectively mitigate the expense paid by the biological world as a result of human development. What started as grass roots organizations such as Greenpeace and The Nature Conservancy are at the heart of this difficult task; it is often through their growth and development that like-minded individuals first collaborate to consider solutions to the daunting problems we now face (Freudenberg and Steinsapir, 1991).

Introduced species represent a serious threat to biodiversity around the world. Feral goats were introduced in the Galapagos Islands in the 1920’s and have caused significant declines in tortoise habitat and populations which are only now starting to recover more than 80 years later) after the goats were forcibly removed (Milinkovitch et al., 2004). Lamprey eels, discovered in Lake Erie first in 1921 having entered via the Welland Canal, devastated the fishing industry in the Great Lakes until the development of the lampricide 3-Trifluoromethyl-4-nitrophenol (TFM) in 1958 (Boogard, 2006) In addition to invasive fauna, intrusive flora have also become problematic in parts of North
America. Mile-a-Minute Weed (*Polygonum perfoliatum*), for example, began as a curious find at a nursery in Pennsylvania but quickly got out of control. This nuisance species now re-emerges annually in nearly ten states while simultaneously out-competing native plant species (Oliver, 1996).

Non-native flora and fauna are potentially harmful to ecosystems for a variety of reasons. They may negatively impact native organisms by increasing selection pressure. Like any other organism, invasive species compete for nutrients and resources to survive. In marsh ecosystems, invasive floras utilize space and sunlight that would once have been available to native plants; they also uptake water and minerals from the soil (Callaway and Aschehoug, 2000). In addition, non-native species may have differential preferences for particular types of nutrients such as nitrogen or dissolved oxygen as a result of their biology. This disturbs the balance of the nutrient cycles and putting more strain on the organisms that suffering the presence of the invasive species (Baruch and Goldstein, 1999). Removal of nutrients is of paramount concern in any environment. Not only do invasive species extract resources from their surroundings but slow the return of these nutrients to the energy web where they are available to native species. For example, native fauna may find it difficult or impossible to ingest the invasive species and will likely not use the habitat that the flora creates due to its unfamiliarity (Lucas, Undated). As a direct result of being underutilized by native species, resources removed from the environment by invasive plants are sequestered in such a way as to reduce their contribution to the biosphere. These resources tend to remain out of nutrient cycles for most of the full lifetime of the invasive organism due to low selection pressure against
the invader (Zedler, 2004). A lack of natural predation is the primary cause of this; it is well documented that invasive species will likely encounter fewer predators in a new environment than had been present in their former ecosystem (Sanders et al., 2003). This lack of predation makes it more likely that an introduced organism will survive into later stages of development, all the while utilizing more environmental resources for growth and reproduction. In this fashion, biological molecules take longer to be returned to the nutrient web which further decreases their availability to other organisms (Ehrenfeld, 2003). Nutrient sequestration by invasive species is integral to the increase in selection pressure that they cause.

Invasive species represent a significant threat not only to other species individually, but to the food web and energy cycles as complex units. If an introduced organism successfully out-competes another species or attempts to occupy a large niche populated by multiple species, overall biodiversity and genetic diversity in the ecosystem will decrease (Gordon, 1998). The danger of this situation is akin to that of a monopoly, wherein a single entity fulfills a specific role in the environment: nitrogen fixation, for example. In a worst case scenario, the presence of the invasive species will eventually eliminate a native species responsible for performing a keystone role in that ecosystem, potentially by competition for a food source. It is possible that the invasive organism will not assume that same biological function, effectively leaving the ecosystem devoid of an organism to perform that role for a time (Zedler, 2004). After a time, natural selection will yield a replacement, but perhaps not before significant damage is done to the affected environment. This is especially threatening if the biological process was
necessary to the function of the system such as nitrogen fixation is within terrestrial environments. Currently, plants in the Fabaceae family to fix nitrogen via symbiosis with bacteria in root nodules. Increased selection pressure on plants or other organisms that perform this function will decrease the rate at which atmospheric nitrogen is converted to usable ammonium (Ehrenfeld, 2003). Thus, the presence of invasive species can inhibit nutrient cycling and simultaneously impact diversity.

Water filtration to remove dissolved solids and particulate matter is a crucial function of marshland ecosystems (Verhoeven and Meuleman, 1999). Unfortunately, they too are susceptible environments in which invasive species can take hold and ultimately inhibit water purification as a whole. One specimen that may contribute to this reduction in ecosystem function is the invasive Common Reed (*Phragmites australis*) from the Poaceae family (Vasquez *et al.*, 2005). Two subspecies of this plant are found in nature: the native form known to have existed in North America for more than 3,000 years and the invasive that is thought to have been transported to the North America from Europe in the ballast water of trading ships sometime in the late 19th century or earlier (Lindorth, 1957). The latter subspecies has shown rapid expansion in North American freshwater ecosystems for several decades and is now generally considered a nuisance species (Galatowitsch *et al.*, 1999). However, it is important to consider that the native subspecies has been a part of the Great Lakes biosphere for millennia and does promote water filtration, as well as being part of a healthy wetland ecosystem. This study dealt exclusively with the invasive subspecies for its duration. Both forms of the Common Reed are similar to other true grasses in the same family. They grow between 1.2 and 4.6
meters in height, depending on the time of season, from where it anchors to the soil by a dense mat of rhizomes. The plant itself features a thin, green stem (~1.3 cm in diameter) punctuated by tightly bound leaf sheaths attached to broad green leaves (2-3 cm wide) and a fist-sized seed head at the top of the plant. Stands of the reed are made up mostly of living plants, though in all cases numerous stems from the previous growing season remain standing, now tan in color. Expeditious growth of the invasive subspecies is linked to biological differences.

Both subspecies of *Phragmites* exhibit asexual reproduction by means of rhizomes (Alvarez et al., 2005) It was recently discovered that stems and roots of these plants may propagate by adventitious roots, or the creation of new apical meristems in living tissue though it may not be connected to the original plant (Lucas, Undated). Said differently, the plant may regenerate from root or stem fragments that are separated from the original organism. Though the mechanism by which this occurs is not well understood, it is thought to be a function of the accumulation of auxin as this hormone is known to stimulate similar processes in other species (Sachs, 2008) The ecological significance of the production of adventitious roots is that severed stem and root tissue that is carried to another area habitat may actually sprout and create a new stand of reeds. The reasons that tissue may become detached are many, but certainly include environmental conditions such as wave action or human disturbances such as mowing. Sexual reproduction results in the production of large quantities of wind-dispersed seeds; however, the viability of these is actually quite low (<10%) and is not considered to be the major contributor to increasing incidence of the invasive reed (Batty and Younger,
As with other clonal plants, the rhizomes remain the primary mode of growth and lead to some of the many harmful consequences that the Common Reed may have within an environment.

The invasive Common Reed has a handful of direct effects that damage an ecosystem. These effects are in addition to the sequestration of nutrients previously mentioned as a harmful characteristic of all invasive organisms. Increased stem density over the native growth form means that occupation of shallow waters by the invasive *Phragmites* subspecies effectively decreases the volume of water that may pass beneath or around the plants toward the shoreline. With such dense plant matter in the way, less water will travel further inland to bring water and nutrients to other shoreline vegetation. Similarly, animals that make their habitats in sheltered shoreline vegetation will have less space in which to do so (Lucas, Undated). This is significant as many fish and amphibians heavily depend on this type of environment to provide safe breeding areas for their young (Meadows and Saltonstall, 2007). Even invertebrate species are affected; shoreline habitats that develop stands of invasive *Phragmites* have been shown to have a noticeable decrease in the diversity of non-microscopic invertebrates in comparison to those with a greater diversity of native vegetation (Chambers *et al.*, 1999). In fact, vegetation feels much of the burden from the presence of this invasive species as freshwater marsh ecosystems are home to more than 100 species of aquatic plants (Odum *et al.*, 1984). Once stem density reaches a certain threshold (may be as great as 40% of soil area occupied by stems), they begin to physically inhibit the growth of other plant species by creating shade and not allowing for the native plant to growth laterally.
(Saltonstall, 2005). Not only do existing plants feel crowded growing above the soil, but below ground as well. The rhizomes of the invasive reed allow rapid lateral growth, but these roots systems have such a high density as to crowd the roots of other nearby plants thus preventing the existing plants from being able to uptake as great a volume of nutrients (Brix, 1987).

Invasive species such as the Common Reed from Europe may have economic impacts that compound the environmental damage suffered by their presence in the area where they become a problem. This is a particularly important consideration in the Great Lakes region where tourism provides a large percentage of yearly income (Ludlow, 1971). The tourist industry depends directly on the natural resources of the region to provide attractions and thus the quality of these resources will directly affect the economy in areas that depend on ecotourism (Lucas, Undated) The presence of invasive species has the potential to significantly degrade the quality of said resources and is thus a threat to the wellbeing of permanent residents (Pimentel et al., 2000). As more research is conducted, it has become apparent that the invasive reeds have the potential to cause such an upset. This causes Phragmites to be seen as a threat from multiple points of view. To prevent these repercussions from occurring, swift action is required.

Invasive plant control may be carried out via a variety of methods, each tailored to characteristics of the species that the technique is being used to eradicate. For instance hand pulling or other mechanical treatments such as tilling may be effective on plants without extensive roots systems such as Catchweed bedstraw (Galium aparine) (Lebo, 2007). Herbicides may be used successfully in many terrestrial plant species such as with
Brazilian pepper-tree (*Schinus terebinthifolius*) in Florida (Elfers, 1988). When considering methods to reduce the spread of invasive Common Reed, a number of factors must be taken into consideration, namely the rhizomatous nature of the root system, the ability of the plant to regenerate from fragments and the aquatic ecosystem into which herbicides would potentially be introduced. These properties of the plant indicate that manual eradication will likely not be effective. Worse yet is the possibility that improper disposal of fragments of destroyed plants might allow it to actually spread into new areas. Finally, application of herbicide in an aquatic environment carries inherent dangers. For this reason, special Glyphosate herbicides have been developed to handle aquatic environments such as Aquastar® and Shore Klear™, commonly mixed with a surfactant compound such as Cygnet Plus™. This mixture helps to ensure that the herbicide itself is sufficiently selective to preferentially target the species of interest and minimize the mortality of other organisms within the environment (Derr, 2008). Additionally, it is essential that the distribution of the chemical treatment is closely monitored to prevent unintended contamination of additional areas.

The project that I participated in the past summer had two major goals. The first of these focused on establishing a survey protocol for the Lake Michigan shoreline in Michigan State and carrying out the subsection of the statewide survey in Acme Township, specifically along East Grand Traverse Bay. This portion of the project closely followed the procedural guidelines established during the eradication of invasive *Phragmites* from Beaver Island that began in 2007 (Gallagher *et al.*, 2009). The second goal of the project was to bring the information gathered to the public forum and begin
educating community members and leaders on all the aspects of dealing with an aggressive invasive species. Ultimately, we sought to collect information about the distribution and density of invasive or native *Phragmites* in all survey areas and put this information into a communicable format for presentation to member of the community or to be used as a basis for a Michigan Department of Environmental Quality grant proposal for chemical treatment of the invasive flora.
Materials and Methods

Site selection

Two different types of survey sites were chosen for this project. The first was the eighteen kilometers of East Grand Traverse Bay (EGTB) shoreline that lie within Acme Township in Grand Traverse County. This area extended from the southeastern tip of East Grand Traverse Bay (EGTB) to the Ptoibego Marshland (PM) at the northernmost township boundary. I conducted this portion of the survey alone on foot in late August when the Phragmites stands were at maximum height. The function of this survey area was to assess the extent of invasive reed distribution along the shoreline as well as whether or not any native stands remained there. The second portion of the survey focused on inland bodies of water on Elk Lake, Skegemog Lake, Elk River and Torch River located in Elk Rapids, Milton, Clearwater and Whitewater Townships (Kalkaska and Antrim Counties). All of the inland lakes were surveyed by me, my on-site mentor and two high school interns from Elk Rapids, MI. We traveled along the entire shoreline of each body of water by canoe and kayak for a total distance of about fifty-six kilometers with the exception of a small portion of the west side of Elk Lake which was surveyed by motor boat. This section is heavily developed and had a low probability of being a suitable environment for the Common Reed. This study sought to determine whether or not the invasive subspecies was present in bodies of water farther removed from the EGTB shoreline to assess whether or not the invasive subspecies had been able to move up stream into the Three Lakes watershed (Elk, Skegemog and Torch Lakes).
This segment of the survey was completed between the third week of June and the last week of August, 2009.

Figure 1. Geographical and political map of survey region in Northern Lower Michigan. EGTB shoreline (from points A to B), Elk Lake shoreline (C), Skegemog Lake shoreline (D) and Torch River (E) were surveyed for stands of native and invasive subspecies of Phragmites australis.
Survey protocol

The general details of the survey conducted on the EGTB shoreline were borrowed from the survey beginning in 2007 and conducted by a support team comprised of the Beaver Island Association, township supervisors, Central Michigan University, and in cooperation with the Michigan Department of Natural Resources (Gallagher et al., 2009). The reason for our reliance on this material is that the fast action of this team was able to reduce invasive *Phragmites* abundance from a total of 27.1 acres in 2007 to 3 acres in the summer of 2008. After the 2008 growing season, only spot treatments continue to be necessary to prevent stands of the reed from re-establishing themselves. This success in controlling the invasive Common Reed was unprecedented to date regardless of treatment method, thus our protocol was constructed in the image of that used by the Beaver Island team.

Plant identification

Invasive *Phragmites australis*, especially early in the growing season around May and June, is phenotypically similar to the native subspecies. Because of this, a modest amount of training and experience was required in order to be able to quickly distinguish the two from one another reliably. Several basic characteristics were particularly useful for identification purposes. The first involved examination of the leaf sheath. Live stems of the invasive plant have a leaf sheath that adheres strongly to the stem, whereas in the native form, the sheath can be easily separated from the stem or broken with minimal effort. This characteristic is especially useful in the early part of the growing season as there is no shortage of plant matter to manipulate. Additionally, leaf sheaths on old
growth and dead plants of the native leaf plants are quickly knocked off by wave and wind action following death of the shoot, whereas they remained attached in the invasive plants even throughout the winter months. A second character became visible once the stem was exposed. The stem tissue was checked for pigmentation and a light green color indicated that the invasive subspecies was likely; native stems were distinctly crimson near the base. Characteristics of the ligule, or the small outgrowth of tissue at the junction of the leaf and leaf stem, were also analyzed. Specifically, we looked for the presence of tiny, hair-like fibers right at the junction of leaf stem and leaf tissue; in the native plants these fibers are present but as more of a waxy film. The ligule was also examined for tiny bands of brown-colored tissue. Though present in both subspecies, this band is wide (>1 mm) in invasive plants and considerably thinner for the natives. By mid-July to late August, differentiation was simplified due to stark differences in the height and density of stands. Native Phragmites populations generally reached stem heights of 2.2 to 3.0 meters and stands were interspersed with other types of vegetation (Figure 2). Invasive stems frequently reach 4.0 to 4.6 meters from the root to the seed head and caused the soil within the stand to be completely barren of vegetation other than the clonal reeds themselves.
Figure 2. Invasive Common Reed is noticeably taller during the height of growing season than is the native subspecies.

Data collection

To conduct the survey, we modeled the data that would be collected after the Beaver Island study. This meant that, in addition to recording the GPS location of each site and the date of the sampling, we also recorded measurements of width and breadth of stand by hand as well as qualitative determinations of the average stem density and total number of stems. GPS data were recorded on a GPS III Plus handheld unit from as near to the center of a stand as was possible. The mapping of GPS data was completed using the ArcView 9.3 software from ESRI. On the EGTB shoreline portion of the survey, a tape measure was used to accurately determine the dimensions of each stand, though this was done by recording two separate GPS points during the inland portion due to not being able to measure the size directly from the canoe or kayak. In all cases, the density and stem count of stands are estimates using approximate area and several counts of
stems within accessible one meter square plots and averaging these data. Some additional data was collected in the Acme Township survey.

During the survey along Acme Township I also recorded a several pieces of descriptive information about the location of each stand with relation to the surroundings. The purpose of this was to provide a resource for future parties searching for the sites to be able to find the specific stand more easily such as a contracted chemical treatment team. Being as the key goal of the survey in Elk and Skegemog Lakes was to identify whether invasive Phragmites had moved upstream to the watershed, we focused our observations on thorough identification of the plants as opposed to measurement of population and distribution because the stands were easily located without additional landmarks.

Submission of material to the affected townships was completed during late August of 2009 to make it possible for grant applications to be completed. These were sent to the Michigan Department of Environmental Quality for evaluation prior to approval of chemical treatment.
Results

A total of 104 stands of Common Reed were found while surveying shorelines in Acme Township; this amounts to a total distance of 1593 m. This distance is the sum of measurements on East Grand Traverse Bay (1382 m) as well as in the Ptobego marshland (211 m), just east of the shoreline (Table I). Given the total length of shoreline surveyed, this indicates that nearly 9% of all of the shoreline is affected by the Common Reed growing there. All of the *Phragmites* stands that were found in these wetlands and along the Acme Township shoreline were determined to be of the invasive subspecies.

**Table I.** Total distance and area occupied by *Phragmites australis* subspecies in each subsection of Acme Township (East Grand Traverse Bay and Ptobego marshland) and Skegemog Lake, as well as Acme Township as a whole.

<table>
<thead>
<tr>
<th>Location</th>
<th>Linear distance (m)</th>
<th>Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Grand Traverse Bay (EGTB)</td>
<td>1382</td>
<td>15338</td>
</tr>
<tr>
<td>Ptobego Marshland (PM)</td>
<td>211</td>
<td>2792</td>
</tr>
<tr>
<td>Total for Acme Township (EGTB + PM)</td>
<td>1593</td>
<td>18130</td>
</tr>
<tr>
<td>Skegemog Lake (Kalkaska and Clearwater Townships)</td>
<td>2378</td>
<td>56412</td>
</tr>
</tbody>
</table>

While surveying the EGTB shoreline in Acme Township, the population of Common Reed stands that were encountered varied widely. Ninety-one percent of the reed stands contained less than 1000 individual stems while two sites contained more than 10000. Fifty-two percent of these reed stands had areas of less than 100 m² with just two exceeding 1000 m². Even so, twenty-six percent of the stands were classified as having dense growth (Table II).
Table II. Summary of *Phragmites* stand data collected from the Acme Township survey in EGTB and PM.

<table>
<thead>
<tr>
<th>Population estimate</th>
<th>Percentage of reed stands</th>
<th>Area (m²)</th>
<th>Percentage of reed stands</th>
<th>Density</th>
<th>Percentage of reed stands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single or few</td>
<td>39</td>
<td>&lt;100</td>
<td>52</td>
<td>Sparse</td>
<td>46</td>
</tr>
<tr>
<td>&gt;50</td>
<td>33</td>
<td>100-249</td>
<td>18</td>
<td>Patchy</td>
<td>28</td>
</tr>
<tr>
<td>&gt;200</td>
<td>19</td>
<td>250-499</td>
<td>18</td>
<td>Dense</td>
<td>26</td>
</tr>
<tr>
<td>&gt;1000</td>
<td>7</td>
<td>500-999</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;10000</td>
<td>2</td>
<td>&gt;1000</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The survey in Acme Township on the EGTB shoreline generated a total of four maps depicting incidence of *Phragmites* found in the approximately 18 kilometers surveyed. These were provided to community leaders in order to represent the extent of the invasive species infestation in an intelligible format (Figures 3-6).
Figure 3. GIS layer of survey area in Acme Township. Each triangle marker represents one distinct *Phragmites* population of the 104 stands found there.
Figure 4. Southeastern tip of East Grand Traverse Bay where survey work for invasive Phragmites began in Acme Township. Parcel lines were added in another GIS layer to determine which landowners were affected by Phragmites. Phragmites stands are denoted by triangles and are labeled numerically in order of discovery.
Figure 5. This figure portrays the center section of Acme Township’s shoreline community overlaid with parcel lines. The triangles again denote *Phragmites* in the order of site discovery.
Figure 6. Northernmost third of survey region in Acme Township layered with invasive *Phragmites* locations and individual parcel lines.

The inland lakes survey identified only three sites of *Phragmites*, all of which were present on the shoreline of Skegemog Lake. Of these three separate populations, all were found to contain only native plants (Figure 7). Even so, the plants still occupy a considerable length of shoreline, nearly 2400 meters in total (Table I) have a substantial total area of more than 56000 m², more than the sum are of all sites along the Great Lakes shoreline in Acme Township.
Figure 7. Locations of three native *Phragmites australis* populations found on Skegemog Lake in the inland chain of lakes (Torch → Skegemog → Elk → Lake Michigan), labeled by numbered triangles. The other bodies of water in the chain contained no *Phragmites* stands and are thus not pictured.
Discussion

During the survey along the 18 kilometer East Grand Traverse Bay (EGTB) shoreline and in the Ptobeo Marsh of Acme Township, 104 stands of invasive *Phragmites australis* were located. No stands of native Common Reeds remained in either area. The linear distance of shoreline affected by these plants was 1593 m, indicating almost 9% coverage of the shoreline. Survey work on Elk and Skegemog Lakes found only three sites of *Phragmites* and these plants were of the native subspecies. However, the total shoreline affected on inland bodies of water was more than 2300 m in with an average breadth of 24 meters. The information collected from both study locations has been passed on to the individual townships and will be included in their grant applications to the state should treatment in their respective areas be deemed necessary. Ultimately, this baseline data gathered from this study will act as a guide the process of chemical suppression that is necessary to contain the spread of this aggressive plant. In the face of a tenacious, adaptable species, the development and use of more extreme measures of control such as specialized aquatic herbicides is a necessary step toward the prevention of the kind of environmental degradation that *Phragmites* is capable of producing.

The presence of aggressive invasive species within the highly diverse ecosystem of the Great Lakes is alarming. The incidence of invasive *Phragmites* distribution along the Lake Michigan shoreline is reminiscent of other exotic floral species such as purple loosestrife. On the EGTB shoreline, the infestation of *Phragmites* totals 15338 m², equivalent to 0.85 m² per meter of shoreline surveyed. The fact that this data pertains to
84 separate sites makes the potential for a rapid increase in total area highly likely, especially as newly established stands expand into nearby territory. This is compounded by the fact that more than 50% of the stands were less than 100 m², a good indicator that the stands are recently established, likely within one growing season, and already have lengthy runners generating shoots as much as 15 meters or more away from the nearest visible stem (Phillip and Field, 2005). The sites are also well-dispersed along the shoreline increasing the likelihood of seeing a considerably larger distance of affected shoreline in subsequent growing seasons if no action is taken to prevent such an expansion.

Invasive plants in the Ptobegó Marshland adjacent to EGTB serve as further evidence of the plants’ ability to spread quickly into other ecosystems with suitable soil, water and spatial characteristics. Twenty distinct sites of invasive *Phragmites* were located here, where two growing seasons prior none had existed (Figures 3, 6). By the time of this survey, nearly 2800 m² of wetland ecosystem were covered with the dense reed stands. As previously mentioned, the three modes of reproduction exhibited by *Phragmites* are vegetative growth from rhizomes, limited sexual reproduction by seeds and regeneration from root or stem fragments. Given these options, the absence of plants growing on the EGTB shoreline near the marsh make vegetative expansion unlikely. Additionally, due to the low seed viability of the subspecies, growth from seeds is also a less reasonable possibility. The most probable explanation for the presence of invasive *Phragmites* in PM then must be that some fragments of other plants were transported into the wetland environment where they took hold and expanded quickly. Indeed, the
shallow water level and high nutrient abundance in the marsh makes it an ideal place for the Common Reed after the initial introduction has taken place (Minchinton and Bertness, 2003).

Biological units such as wetland or marsh ecosystems are critical with respect to processes such as water recycling and purification (Gren et al., 1994; Verhoeven and Meuleman, 1999). Increased competition for resources may cause decreases in populations of plants responsible for water filtration thus decreasing the ability of the marshland to fulfill the this role. Though some research does indicate that *Phragmites* will not decrease the capability of a wetland to retain soil and nutrients from water, this is only true if the area floods as regularly as it would have before the reed became established there (Chambers et al., 1999). This is contradicted by information suggesting that the reeds lessen the water flow through the ecosystem, thus causing more sediment to accumulate until the area eventually becomes filled in (Weinstein and Balletto, 1999). With this information in mind, one can understand that the future of the Great Lakes ecosystem is threatened. Increased demand of food and other nutrients that should be available to native plant species will continue and the ecological advantage will belong to the invasive subspecies rather than to plants that benefit the environment by providing habitat and food sources for fish, amphibians, insects, birds and other wildlife (Mooney and Cleland, 2001).

Survey work in the Elk-Skegemog-Torch chain of lakes has thus far not located any populations of invasive Common Reed in these bodies of water or their connecting rivers. However, three large stands of native *Phragmites* were located in Skegemog
Lake. As this subspecies does occur naturally in fresh water ecosystems in Northern Michigan, this was a positive outcome of the study as a whole. A variety of theories have been put forward since this information was distributed to account for why the invasive plants had not yet made their way inland. The aforementioned low viability of seeds is one explanation, though we know that they plants do not use this as their primary mode of reproduction. The fact that the inland watershed has unidirectional flow into Lake Michigan also contributes. However, there is one factor that likely plays the greatest role in preventing the spread of this harmful flora: the mouth of the Elk Lake River on Lake Michigan is obstructed by the Elk Rapids Dam. Aside from permanently keeping Elk Lake at a higher elevation than Lake Michigan itself, the dam also prevents direct boat traffic between the two bodies of water and has since the 1920’s, long before *Phragmites* had become as ubiquitous in the Great Lakes as it is presently. With a reduced potential for boats to transport mud or water that might contain fragments of the invasive plants, this means of reproduction is also minimized. This is not the case with some other bodies of water connected to Lake Michigan such as Lake Charlevoix to the north.

Lake Charlevoix has experienced an explosive growth of the invasive subspecies in the last couple of years, now reporting nearly 60 sites (Figure 8) (Anonymous, Undated). Unlike the Elk River, there is no physical barrier that stops boat traffic from directly traveling between Lake Michigan and Lake Charlevoix. This leaves the potential open for organic material such as fragmented roots or stems to be transported into the adjacent ecosystem and establish itself easily.
Figure 8. Herbicide treatment by spraying of invasive Phragmites taking place on Lake Charlevoix. Spraying is necessary on living plants each season to minimize recurrence.

The increasing presence of invasive Phragmites in freshwater ecosystems is expected to continue, due to the increasing incidence of development and disturbance in wetland ecosystems due to human action (Chambers et al., 1999). Additionally, decreasing lake levels in the Great Lakes and the onset of global climate change that increases air and water temperatures are thought to contribute significantly to the plants rapid expansion (Wilcox et al., 2003). The invasive strain experiences little or no natural predation in the Great Lakes ecosystem making conditions ideal for further expansion of the established populations. Some species of aquatic plants may even be outcompeted altogether, forever changing the face of the Great Lakes shoreline and many aquatic ecosystems such as marshes and wetlands. In order to protect the biodiversity of these
areas and the ecological services that they provide to humanity and the biosphere, human intervention may be required in the form of herbicide application.

The grant process that is underway in Acme Township post completion of the Phragmites survey will culminate, given that the proposal is accepted, with selection of a contract through the Michigan Department of Natural Resources (MDNR). Grants are currently available for the treatment of non-native *Phragmites* via a grant application process as the state of Michigan has set aside funding for nuisance aquatic species control (Hindman, 2004). The contracting process handled by the MDNR ensures that the company chosen to handle herbicide application in such a delicate environment is composed of properly trained and certified individuals. The application process requires the submission of a publicly or privately conducted survey that can provide a sufficient amount of information to make chemical treatment a reasonable option. This includes a detailed GPS map of each affected location and some indication of the size and density of the infestation so that the best treatment method may be selected. Chemical treatment within an aquatic ecosystem is a risky endeavor and thus the MDNR, upon acceptance of the application for treatment, supplies individual local government with options for contracting the chemical application to trained individuals (Hindman, 2004). Future studies may consider the implications of this kind of treatment, the development of chemicals in order to handle this task, specifics of the application process such as technique and subsequent plant mortality rate. Additionally, it is crucial to realize that chemical treatment as described here is not the end of an invasive species, but must be completed during subsequent growing seasons to monitor the ecosystem and keep these
plants from spreading. Failure to do this would only reverse the efforts of those involved in surveying, data analysis and chemical treatment.

Formulating the specific goals for this study was accomplished, in large part, because of the work that came before it, specifically the survey completed on Beaver Island. The *Phragmites* survey in Acme Township and on Elk and Skegemog Lakes was finished in an appropriate amount of time to allow grant applications to take place with sufficient data to support a proposal for chemical treatment. The creation of high-resolution maps of the affected areas will be instrumental in helping community members to understand the threat that their neighboring ecosystems face and convince those undecided on the issue of invasive species that inaction is not an option. Additionally, this study is supported by the involvement of many different organizations within the region, indicating that awareness is growing and that through cooperation, progress can and will be made. However, this study might improve in several ways. The data presented here should be incorporated into the *Phragmites* survey data that is being collected in other townships to provide a more comprehensive view of the distribution of this invasive subspecies. Furthermore, this study needs to be completed during future growing seasons to note expansion of existing stands and the appearance of new ones. For this to happen, however, community leaders must realize that the best resources that they have are the volunteers of their own community. A great deal of manpower will lose its potency without access to adequate training and materials, such as GPS units, that are necessary to obtain accurate data.
Literature Cited:


