Early Detection of Emerging Aquatic and Wetland Invasive Plants in Michigan




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Cover Photos:

Top left: Phragmites (*Phragmites australis* subsp. *australis*); Phyllis Higman, Photographer
Top right: Common frog-bit (*Hydrocharis morsus-ranae*); Suzan Campbell, Photographer
Bottom left: Japanese knotweed (*Polygonum cuspidatum*); Phyllis Higman, Photographer
Bottom right: Carolina fanwort (*Cabomba caroliniana*); Leslie J. Mehrhoff, Photographer

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Garlic mustard (*Alliaria petiolat*a)
Suzan Campbell, Photographer

Brazilian waterweed (*Egeria densa*)
Richard Old, Photographer

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Introduction

Invasive aquatic and wetland plants, such as purple loosestrife (*Lythrum salicaria*) and non-native phragmites (*Phragmites australis*), Eurasian water-milfoil (*Myriophyllum spicatum*) are known to cause significant and costly impacts to lakes, streams, and wetlands. Once established, they out-compete native biodiversity, alter wildlife habitat and ecological processes, limit recreational opportunities, and ultimately degrade water quality. While the threats posed by these high profile species are well known to most land managers, there are numerous additional species on Michigan's horizon that, once established, may cause similar impacts. In fact, European frog-bit (*Hydrocharis morsus-ranae*), an invasive species of significance in Ontario, Quebec, New York and Vermont, has already been documented in herbarium collections from Lake St. Clair (UM Herbarium) and noted by Michigan Natural Features Inventory staff in other locations in southeast Michigan (O'Connor, Monfils 2010). Isolated occurrences of common water hyacinth (*Echhornia crassipes*), water lettuce (*Pistia stratiotes*), Carolina fanwort (*Cabomba carolinina*), and Brazilian water-weed (*Egeria densa*) have also been reported (Eberhardt, Preisser 2010).

It is well accepted that the best approach to address invasive species impacts is first to prevent them from arriving, second to detect new occurrences early and eradicate them, and third to contain the spread of existing infestations that cannot be eradicated. Typically, by the time an invasive species has reached large-scale awareness, it is already fairly abundant and costs of eradication or control are high, while chances of success are low (Fig. 1). It is urgent that monitoring be implemented to detect new infestations while they are still scarce.

Currently there is no coordinated statewide program in place to detect and report new occurrences of invasive plants in Michigan, nor is there a trained cadre of staff to mount a rapid response. This project was undertaken to identify invasive aquatic and wetland plants of greatest concern to Michigan, field-test mapping and reporting protocols, and identify and assess the status of early detection monitoring protocols for detecting new infestations. The field component of the project was conducted in the Saginaw Bay region using sites prioritized for acquisition through a previous study (Schools 2009). Mapping and reporting protocols were explored using a field-mapping tool for hand-held computers coordinated with the Michigan Invasive Species Information Network (MISIN) mapping application (MISIN 2010). The project culminated in the production of a field guide and monitoring guidance for invasive aquatic and wetland plants posing the greatest threat to Michigan.

This report summarizes the study and provides recommendations for developing and improving early detection monitoring in Michigan.

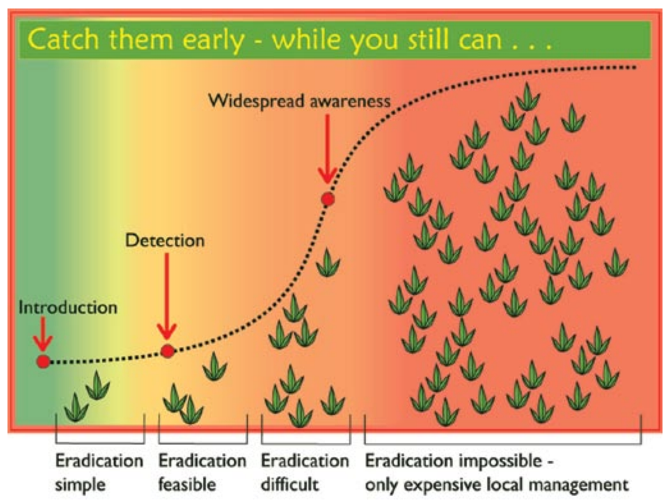

Figure 1. Colonization curve showing the relationship between early detection and cost of control.

Study Area

The study area included portions of Arenac, Bay, Saginaw, Tuscola, and Huron counties immediately surrounding Saginaw Bay (Fig. 2). Saginaw Bay is well-known for harboring many of the last remaining remnants of lakeplain prairie and associated rare species in the state (Kost et al. 2007). It is also known for its extensive infestations of non-native phragmites that span literally miles of coastal shoreline in some portions of Bay. Because of its history of disturbance and high recreational use, it is considered highly susceptible to invasion by newly emerging invasive plant species and continued invasion of non-native phragmites and other established species such as narrow-leaved cat-tail and reed canary grass. Focusing early detection efforts here was considered not only pragmatic, but also provided an opportunity to glean some sense of the impacts of invasive plants on globally significant lakeplain prairie remnants and prioritized wetlands in the region.

Methods

Target Species

To assess invasive plant species that pose a threat to Michigan's waters and wetlands, herbarium data and literature were reviewed, national, state, and local agencies, conservation organizations and web sites were consulted, and landowners, botanical experts, and professional and volunteer resource managers were queried. Pertinent legislation was also reviewed and all species listed as prohibited or restricted in Michigan's Natural Resources and Environmental Protection Act 451 of 1994, Section 324.41301 (Michigan Legislature 2010) were included as target species. Species that are currently considered problematic by natural resource managers in Michigan or in other states with similar climatic variables and ecological communities were identified and considered. Then, species from more distant regions that have had particularly significant ecological or economic impacts where they are known, were examined. Finally, the target list was reviewed by Department of Natural Resources and Environment (DNRE) staff and other natural resource professionals for refinement.

Survey Sites

Survey sites were selected from a set of 149 wetland complexes ranked as high priority for acquisition under a project conducted for the Michigan Department of Environmental Quality Saginaw Bay Coastal Initiative (Schools 2009; Fig. 2). These wetland complexes encompass 1,031 wetland polygons of three National Wetland Inventory (NWI) types: palustrine forested, palustrine shrub-scrub, and palustrine emergent (Cowardin et al. 1979). Two sub-sets of the wetland polygons were selected for potential survey. These included forty-two first-tier wetlands that contained both a known occurrence of a rare species and a high quality natural community and 287 second-tier wetlands that contained either a rare species occurrence or a high quality natural community occurrence (Kost et al. 2007, MNFI 2010). Sites were selected from these first and second tier wetlands that were most easily and efficiently accessed in the field, while assuring that surveys crossed the spectrum of wetland types and included some sites throughout the range of the study area.

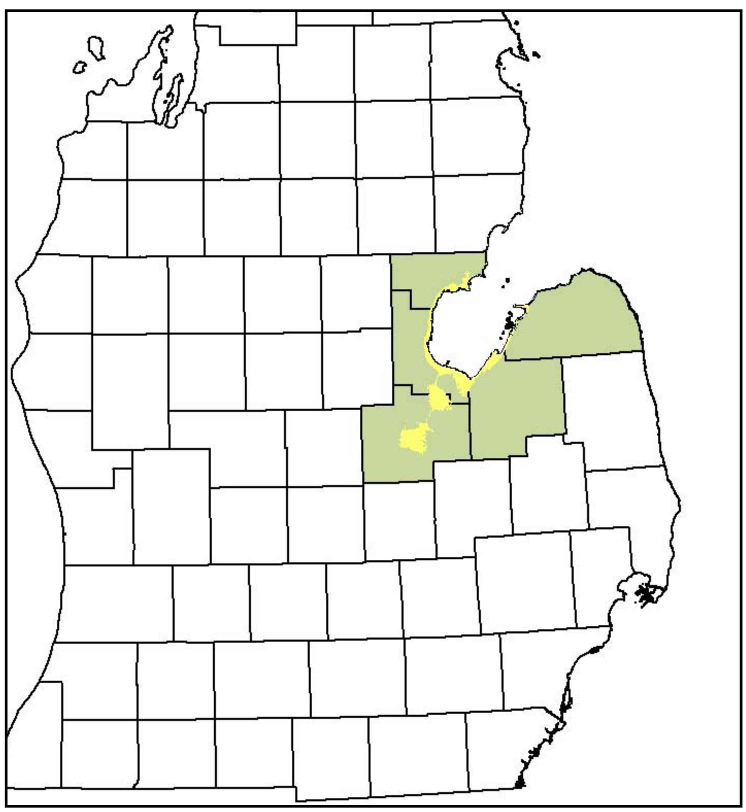

Figure 2. Map of the study area showing the location of the project and wetland complexes prioritized for acquisition (in yellow).

Surveys

Surveys were conducted during May-September, 2009 by experimenting with three techniques: random point sampling, meander surveys, and targeted entry-point surveys. Random point surveys were accomplished by sampling for target species at pre-determined random points within a site. The points were generated using the random point generation tool in Hawths tools (Beyer 2004). Surveyors navigated to each point mapping any target species along their route and any that occurred at each sampling point. Meander surveys were conducted by meandering through a site, deliberately seeking to cover its heterogeneity and mapping occurrences of any target species observed. Targeted entry-point surveys were conducted by focusing on likely sites of introduction and dispersal of invasive plants, such as boat launches, canals, streams, and ditches.

Prior to surveys, surveyors reviewed aerial photography, topographic maps, and previously collected data, where available, on wetland structure and plant species composition. Public landowners were also queried regarding any known occurrences of the target species, and, where possible, these were mapped. Some additional invasive plant data were provided as GPS points or polygons, by public or private landowners or consultants who had conducted previous work in the area.

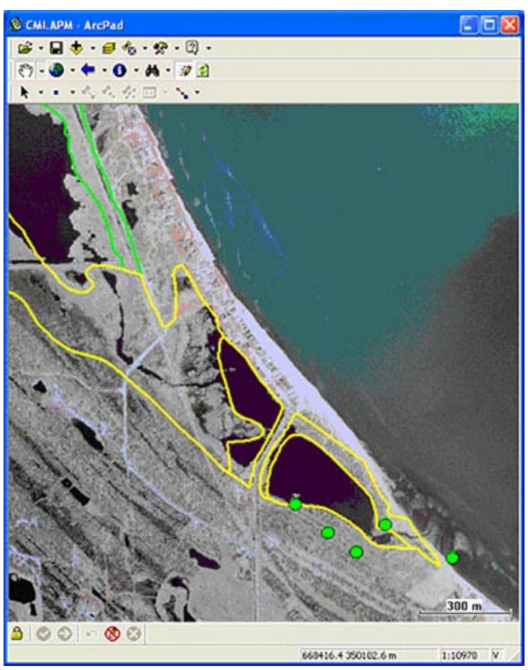

Figure 3. ArcPad screen capture showing aerial photo and wetland polygons.

Mapping

Invasive plant data were collected with a customized GIS data collection tool consisting of an ESRI ArcPad application on hand-held computers and associated GPS units. Utilizing the ArcPad application enabled in-the-field creation of GIS data with customized data collection forms. The customized forms used drop down menus to ensure that all observers collected the same standardized data. Aerial photos, topographic maps, lake contours, rare species, first and second tier wetlands, random points, and non-native phragmites distribution data (Ducks Unlimited 2007) were available on the hand-held computers. Surveyors could see their real time position in relation to any of these spatial data during field sampling (Fig. 3). Two models of GPS receivers were used with the application, either a GlobalSat or a Garmin GPS10. Both units are Wide Angle Augmentation System (WAAS) capable and have a nominal precision of plus or minus three meters when using WAAS. In some cases points were mapped with a Garmin model MAP76 GPS receiver with a nominal WAAS enabled precision of plus or minus three meters.

Mapping focused on rapid collection of distribution points of targeted invasive plants. When surveyors encountered a target species, a point was mapped and associated information was collected through dropdown menus, including: a) surveyor's initials, b) the USDA plant code for a species (2010), c) scientific and common species names, and d) density patterns within nested one, ten, and 100 acre areas (Fig. 4, 5). The density options included: a) local, b) patchy, c) dense, d) monoculture, and e) do not know, and were estimated by the surveyor. These attributes mirror those used in the MISIN online invasive species mapping application (2010). When large infestations of target species, such as non-native phragmites and narrow-leaved cat-tail, were encountered they were simply mapped as points and assigned density attributes as noted above. It was not the intent of this study to conduct fine scale polygon mapping of common invasive plants in the study area.

Early Detection Monitoring Protocols

Similar to the assessment of target invasive plants, herbarium data and literature were reviewed, pertinent national, state, and local agencies, organizations and web sites were consulted, and professional and volunteer natural resource managers were queried to assess the current status of early detection monitoring protocols and programs for newly emerging invasive aquatic and wetland plants. An annotated bibliography of key programs highlighting the scope and strengths of each was created for reference (Appendix A). This was used to guide the development of a general monitoring approach presented in this report and the accompanying field guide. Recommendations for the development of an early detection-rapid response (EDRR) program for aquatic and wetland invasive plants in Michigan were also developed and are presented in the final section of this report.

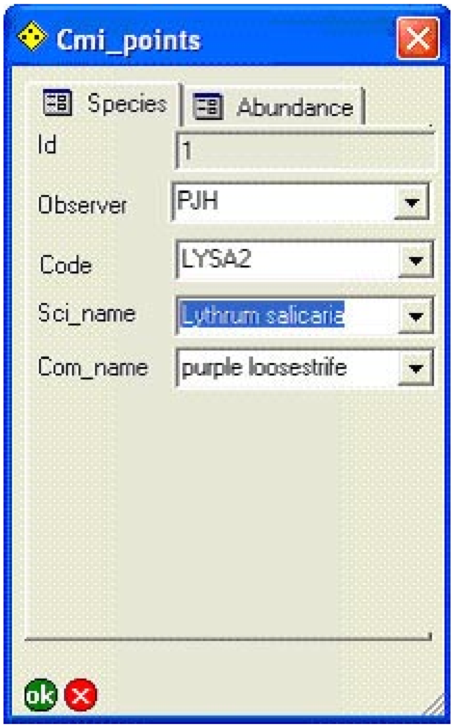

Figure. 4. ArcPad drop-down menu showing associated point data.

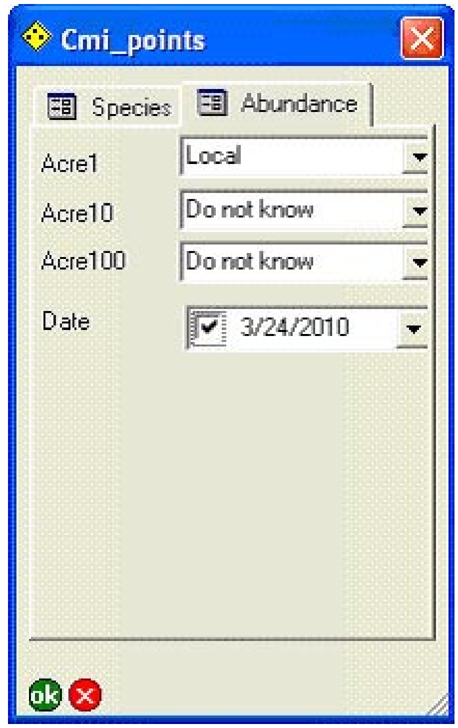

Figure. 5. ArcPad drop-down menu showing nested acreage options.

Landowner Auto-alert System

Land Conservancies and DNR offices in the study area were contacted and queried regarding their willingness to participate in an automatic alert system to be developed by the MISIN. This system is intended to alert landowners when new detections are mapped in the MISIN application. Contact information was collected for those willing to participate, and their GIS capabilities were recorded.

Development of Field Guide

Numerous field guides, web sites, and other resources were reviewed to explore alternatives for presenting species information in a way that would be most helpful to both professional general audiences. Different layouts and ways of categorizing and organizing species were explored to help users hone in on key characters, likely micro-habitats, and best survey times for target species. Feedback from DNRE staff and other interested individuals was sought to better target multiple user needs. Photos were obtained from a variety of reliable sources and each was tagged with its source and specific use agreements.

Dissemination of Findings

A final report and field guide were prepared for delivery to DNRE Water Bureau and for posting on the MNFI web site. Distribution data were prepared for uploading to the MISIN and the Great Lakes Aquatic Nonindigenous Species Information System (GLANSIS) Geographic Service Non-indigenous-Aquatic Species database. Opportunities for further dissemination of products were explored.

Results and Discussion

Target Species

Forty-eight species were identified as targets for this study (Table 1). Eighteen species are widespread and 15 locally established in southern Michigan and three have been reported but not yet confirmed with herbarium specimens prior to the completion of this report. Twenty-four of the species known in southern Michigan also occur in northern Michigan and one, marsh thistle (*Cirsium palustre*), is known only from northern Michigan. Twenty-nine species have not yet been documented or reported in the Saginaw Bay region and are considered emerging threats for the region. Eleven of these not yet been documented or reported in Michigan at all.

Some of the target species have been ranked using formal assessment tools with specified criteria in some regions of the country (Schutski et al. 2008, Morse et al. 2004), however, there is no single, widely accepted standard for determining the likelihood of establishment or potential impacts of individual species for the state. It is the intent of the Michigan Invasive Plant Council (MIPC) to provide this standard, however, it has focused primarily on terrestrial species and due to a lack of funding many species targeted in this study have not yet been assessed. Thus, the target species presented here were selected based on accounts of known occurrences and impacts in Michigan or similar places near-by, proximity of known occurrences to Michigan's borders, more distant species with particularly significant impacts where they occur, and species used in water garden and aquarium trade that have posed a threat elsewhere.

Several species included as targets may appear unlikely to survive Michigan's winters, however, repeated reliable reports of water hyacinth overwintering in mild winters in the Detroit River (Burns 2007) and in neighboring Essex County in Ontario (Groves 2006) have been received, as well as a report of both mature plants and seedlings of water lettuce in Wayne County (Campbell 2007). While neither species appears poised for rapid expansion, their presence is cause for some concern. Great Lakes coastal shores, in particular, may be vulnerable to the establishment and reproduction of species normally considered hardy well to the south of Michigan. The moderating effects of the Great Lakes on minimum low temperatures result in long growing seasons in lakeshore areas, similar to growing conditions in southern Ohio, Indiana, Illinois, and Missouri (USDA 1990, Arbor Day Foundation 2006). The most vulnerable zones are shown in light yellow in Figure 6, occurring primarily in the western Lower Peninsula, the Thumb, Lake St. Clair, and Lake Erie coastal zones. Accordingly, some southern species were included in the target list.

Species already widespread in the study area were included because better knowledge of their distribution, including locations of new isolated patches, will inform control efforts and help determine dispersal pathways. Several species were included that are more commonly found in uplands including Japanese barberry (*Berberis thunbergii*), autumn olive (*Elaeagnus umbellata*), common buckthorn (*Rhamnus cathartica*), and multiflora rose (*Rosa multiflora*). These species were included based upon reports from DNRE wetland experts and other field staff who have frequently noted these species encroaching into wetlands (Lounds 2010). Finally, the macroalga, starry stonewort was included because it has been noted in 95 lakes in southern Michigan where it is displacing native aquatic plant communities and eliminating fish spawning habitat (Preisser 2009). This emerging species could be easily detected during surveys for other lake-dwelling invasive plants.

The science of invasion biology is evolving and recent studies show that in many cases healthy diverse ecosystems, once thought to be relatively immune to invasion, are, in fact, not (Kohli et al. 2009). In some cases this is thought to be a result of increasing propagule pressure, a factor that is receiving increasing consideration as invasive species populations grow and progress across the country. These findings, in conjunction with the often cited lag-time prior to population expansion (Bryson and Carter 2004, Mack 2000) and projected climate changes due to global warming, render the target species list a critical and perpetual work in progress. It will be important to establish and implement regular review procedures to update it. Strategic monitoring of current and future target species is essential to ensure prompt action should they near Michigan's borders or move into new regions of the state. Table 2 provides a listing of the current target species and the natural communities they are likely to establish in. This information will be useful for focusing monitoring efforts.

Ultimately, it will be important for Michigan to identify and adopt a widely accepted, formal risk assessment process and secure funding to assess

Table 1. Summary of invasive plants in Michigan and the Saginaw Bay study area. Emerging invasive species for the study area and for Michigan are highlighted in red.

		Southern Michigan			Saginaw Bay Area			N. MI	Mich.
Scientific Name	**Common Name**	**Widespread**	**Local**	**Reported**	**Widespread**	**Local**	**Not Known**	**Northern Michigan**	**Not known in Michigan**
Alliaria petiolata	garlic mustard	■				■		■	
Alnus glutinosa	black alder		■				■		
Arundo donax	giant reed						■		■
Berberis thunbergii	Japanese barberry	■			■			■	
Butomus umbellatus	flowering rush		■				■	■	
Cabomba caroliniana	Carolina fanwort		■						
Callitriche stagnalis	pond water-starwort						■		■
Cirsium palustre	marsh thistle						■	■	
Crassula helmsii	swamp stonecrop						■		■
Egeria densa	Brazilian waterweed			■			■		
Eichhornia crassipes	common water hyacinth		■				■		
Elaeagnus umbellata	autumn olive	■			■				
Epilobium hirsutum	European fireweed	■			■			■	
Frangula alnus	glossy buckthorn	■			■			■	
Glyceria maxima	reed mannagrass						■		■
Hesperis matronalis	dame's rocket	■			■				
Humulus japonicus	Japanese hops		■				■		
Hydrilla verticillata	hydrilla						■		■
Hydrocharis morsus-ranae	common frog-bit		■				■		
Hygrophila polysperma	Indian swampweed						■		■
Impatiens glandulifera	ornamental jewelweed		■				■	■	
Iris pseudacorus	yellow iris		■			■		■	
Lagarosiphon major	African oxygen weed						■		■
Lysimachia nummularia	moneywort	■			■			■	
Lysimachia vulgaris	garden yellow loosestrife		■				■	■	
Lythrum salicaria	purple loosestrife	■			■			■	
Marsilea quadrifolia	European water-clover		■						
Microstegium vimineum	Japanese stiltgrass						■		■
Myriophyllum aquaticum	parrot feather water-milfoil			■			■		
Myriophyllum spicatum	Eurasian water-milfoil	■			■			■	
Najas minor	brittle water-nymph		■				■	■	
Nitellopsis obtusa	starry stonewort		■				■		
Nymphoides peltata	yellow floating heart						■		■
Pastinica sativa	wild parsnip		■				■	■	
Phalaris arundinacea	reed canarygrass	■			■			■	
Phragmites australis	phragmites	■			■			■	
Pistia stratiotes	water lettuce			■			■		
Polygonum cuspidatum	Japanese knotweed	■					■	■	
Polygonum sachalinense	giant knotweed		■				■	■	
Potamogeton crispus	curly pondweed	■					■	■	
Ranunculus ficaria	fig buttercup		■				■		
Rhamnus cathartica	common buckthorn	■			■			■	
Rosa multiflora	multiflora rose	■			■			■	
Salvinia molesta	giant salvinia						■		■
Solanum dulcamara	climbing nightshade	■			■			■	
Trapa natans	water chestnut						■		■
Typha angustifolia	narrowleaf cat-tail	■			■			■	
Typha xglauca	hybrid cat-tail	■			■			■	
		18	15	3	15	2	29	24	11

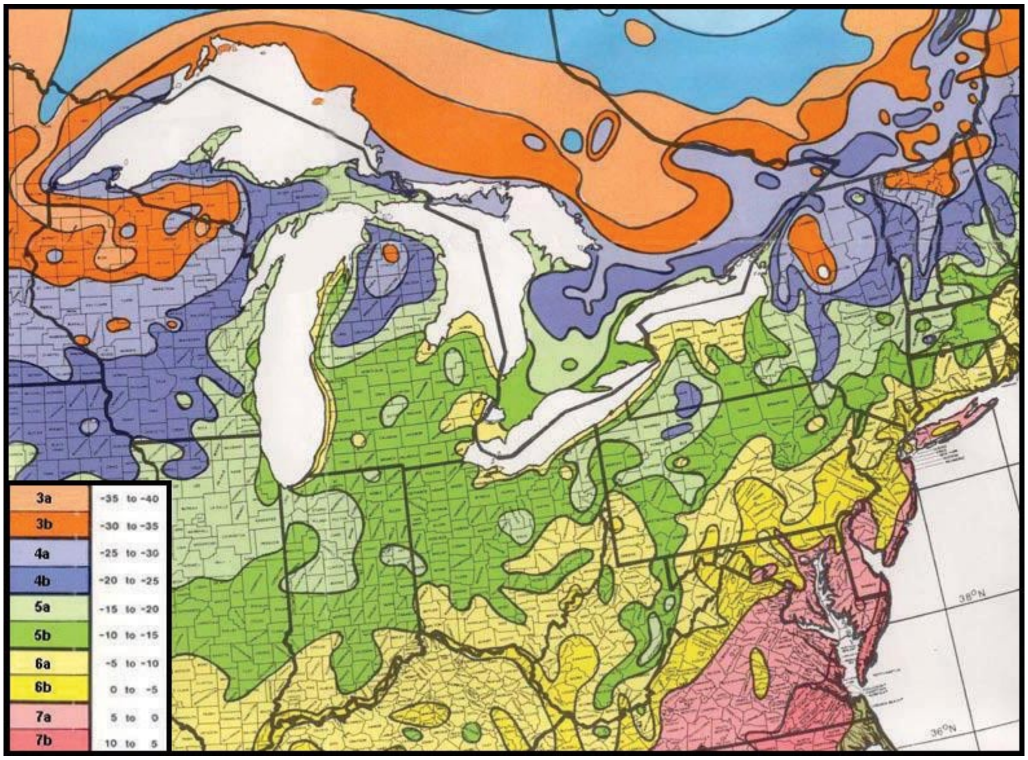

Figure 6. Map showing moderating effects of the Great lakes on minimum low temperatures of the coastal zone.

target species now and into the future. Adopting an assessment tool that considers factors such as reproduction and dispersal mechanisms and current distributions as well as predicted ecological impacts, will enable more thoughtfully considered and cost-effective allocation of resources.

Because of the time necessary to conduct exhaustive or even minimal studies to determine the specific threat of species not yet in Michigan, it is important to pay attention to and consider field experience and anecdotal information carefully. It is not cost-effective to respond to every non-native species that appears to be expanding rapidly at a particular point in time, however, experienced field staff often serve as front line messengers of change on the landscape. It will be important to establish a mechanism for ruling species out or designating watch-list categories, such as the 'caution' or 'pending' categories used by the Wisconsin Department of Natural Resources (WDNR 2010).

Survey Methods

Monitoring programs have a long history in management of agricultural pests (Carter 1989, Inglis et al. 2006), however, less consideration has been given to their design and use in natural environments. The goal of early detection monitoring is to detect infestations at a stage when management is still practical. This is a difficult task since new populations are likely to be sparse and aggregated, making them easy to miss using simple random or stratified random sampling designs (Binns et al. 2000). Typically, there is insufficient monitoring in natural areas for high probability of early detection (Mack 2000).

In a simplistic sample size estimation, adequate sample size is $n = 3/m$ where n is the number of samples required and m is the density of the rare species in the samples, based on a ß of 0.05 (Green and Young 1993). A density of 0.1 (1 observation in 10 samples) requires 30 samples for adequate detection, a density on 0.01 (1 observation in 100 samples) requires 300 samples and a density of 0.001 requires 3,000 samples. Since sample size is dependent on knowledge of the density of the rare species being sampled, a priori selection of a minimum number of samples for adequate detection probability becomes an educated guess (estimation). Pilot sampling typically conducted to determine required sample sizes for desired confidence levels, is not likely to be productive in the case of sparsely distributed species. In a recent study by The Nature Conservancy (TNC), over 500 lakes were sampled for hydrilla (*Hydrilla verticillata*) and no detections were made (Pearsall 2010).

The difficulty of access and greater habitat heterogeneity complicate detection of rare species in natural environments, particularly in aquatic habitats (Inglis et al. 2006). Goff et al. (1982) demonstrate the importance of survey experience and intuition. Success at locating rare species was greater using time-meander surveys that target the heterogeneity of the site, than systematic sampling. Surveyors use their judgment to hone in on microhabitats where these species are likely to occur. This study and others (Albert 2010, USEPA 2000) show that targeted species surveys are typically enhanced by surveyor experience. However, even with experienced surveyors, comprehensive meander or adequate simple or stratified random sampling surveys are time consuming and expensive.

Sweep surveys, conducted by forming a line of field staff, spaced some distance apart, and sweeping an entire site together are preferred by some managers (Mindell and Higman 2009, Fahlsing 2010), although this would be challenging in deep aqutatic systems. These are also costly both in manpower and time and were not feasible for this study. In addition such detailed site mapping is designed primarily for developing site-based invasive species management plans that include treatment for multiple species in terrestrial habitats. The goal of this study was to explore ways of efficiently detecting new occurrences of invasive plants throughout a large region.

<u>Random Point and Meander Surveys</u>

The random point and meander surveys conducted during this study bore the above predictions out. They were both very time intensive and no emerging invasive species were detected. Meander surveys were more efficient, allowing the surveyor to by-pass areas that were heavily infested or difficult to traverse and hone in on habitat heterogeneity. Yet the time required walk through large expanses of wetlands make the use of meander surveys impractical for the purposes of detecting newly emerging invasive species in a large region. In both cases, due to the lack of detection of any of the emerging species, statistical measures of detection probabilities were not possible.

<u>Targeted entry-point surveys</u>

Targeted entry-point surveys at boat launches, canals, road ditches, streams and disturbed areas resulted in the most frequent mapping of target species, however, as for the other surveys, only well established species were documented using this method. The cumulative results of numerous studies demonstrate that surveys of likely entry-points and dispersal pathways is cost-effective (US Congress 1993, Mack et al 2000, Higman et al. 2004, Westbrooks 2004, Bryson and Carter 2004, Silliman 2004, Saltonstall 2007, Maheu-Giroux and de Blois 2007), however, this is far from a simple task. There are dozens of boat launches alone in the Saginaw Bay study area. When combined with the hundreds of roads, canals, streams and disturbed sites in the study area, prioritizing entry points becomes yet another sampling dilemma, particularly with limited resources. Clearly, targeting likely entry-points and dispersal pathways will remain a critical component of any early detection program. However more effective means of selecting and prioritizing entry-points and dispersal pathways are needed. Further study of reproductive and dispersal mechanisms of emerging species posing the highest threat will be helpful, as will use of improved remote sensing techniques that are able to distinguish individual invasive species signatures.

<u>Recommendations</u>

The apparent absence of emerging invasive plants in the Saginaw Bay region suggests that the best approach to detecting such species early, is to identify and accurately map known populations that have already established in or near Michigan and to survey and monitor dispersal corridors in the immediate vicinity of these populations. Detection will likely be higher in the immediate vicinity of known occurrences, allowing for statistically rigorous studies of species-specific sampling methods and dispersal mechanisms. The intent of such studies would be to test whether micro-habitat features can be discerned that increase detection using meander surveys compared to systematic random sampling.

Coupling this with: a) more intensive meander surveys in “high-risk” water bodies and wetlands and b) limited surveys in “lower-risk” water bodies and wetlands, is probably the most efficient and effective way to detect new infestations. Predicting high and low risk sampling sites will be most difficult for species that are dispersed long distances by birds or other animals. Knowledge of their natural community affinities and predictive modeling of suitable habitat will be helpful (Table 2, NISC 2006, and Leung et al. 2006). Novel detection techniques, such as DNA sampling, may also be useful (Eberhardt, Pearsall 2010).

Another powerful driver for increasing the probability of early detection will be motivating

Table 2. Summary of target species and the natural communities they are likely to establish in.

Scientific Name	Common Name	Submergent Marsh	Emergent Marsh	Great Lakes Marsh	Wet Meadow	Wet Prairie	Fen	Shrub Swamp	Floodplain Forest	Deciduous Swamp	Coniferous Swamp	Bog/Muskeg	Deciduous Forest
Alliaria petiolata	garlic mustard							■	■	■			■
Alnus glutinosa	European alder (black)							■	■	■			
Arundo donax	giant reed		■	■	■	■	■						
Berberis thunbergii	Japanese barberry								■	■			■
Butomus umbellatus	flowering rush	■	■	■									
Cabomba caroliniana	Carolina fanwort	■	■	■									
Callitriche stagnalis	pond water star-wort	■	■	■									
Cirsium palustre	marsh thistle				■		■	■	■	■	■		■
Crassula helmsii	swamp stonecrop	■	■	■									
Egeria densa	Brazilian waterweed	■	■	■									
Eichhornia crassipes	common water hyacinth	■	■	■									
Elaeagnus umbellata	autumn olive						■	■	■				■
Epilobium hirsutum	European fireweed		■	■	■	■	■	■					
Frangula alnus	glossy buckthorn		■	■	■	■	■	■	■	■	■	■	■
Glyceria maxima	reed mannagrass		■	■	■			■	■				
Hesperis matronalis	dame's rocket								■	■			■
Humulus japonicus	Japanese hops		■	■				■	■				
Hydrilla verticillata	hydrilla	■	■	■									
Hydrocharis morsus-ranae	common frog-bit	■	■	■									
Hygrophila polysperma	Indian swampweed	■	■	■									
Impatiens glandulifera	ornamental jewelweed		■	■	■	■			■	■			■
Iris pseudacorus	yellow iris		■	■	■	■			■	■			■
Lagarosiphon major	African oxygen weed	■	■	■									
Lysimachia nummularia	moneywort		■	■	■			■	■	■			■
Lysimachia vulgaris	garden yellow loosestrife		■	■	■	■	■	■	■	■			■
Lythrum salicaria	purple loosestrife		■	■	■	■	■	■	■	■	■		■
Marsilea quadrifolia	European water-clover	■	■	■									
Microstegium vimineum	Japanese stiltgrass								■	■			■
Myriophyllum aquaticum	parrot feather watermilfoil	■	■	■									
Myriophyllum spicatum	Eurasian watermilfoil	■	■	■									
Najas minor	brittle waternymph	■	■	■									
Nitellopsis obtusa	starry stonewort	■	■	■									
Nymphoides peltata	yellow floating heart	■	■	■									
Pastinica sativa	wild parsnip				■	■	■						
Phalaris arundinacea	reed canarygrass		■	■	■	■	■	■	■	■	■	■	■
Phragmites australis	phragmites		■	■	■	■	■	■	■	■	■	■	■
Pistia stratiotes	water lettuce	■	■	■									
Polygonum cuspidatum	Japanese knotweed				■			■	■				■
Polygonum sachalinense	giant knotweed				■				■				■
Potamogeton crispus	curly pondweed	■	■	■					■	■			■
Ranunculus ficaria	fig buttercup				■								
Salvinia minima	water fern	■	■	■									
Salvinia molesta	giant salvinia	■	■	■									
Solanum dulcamara	climbing nightshade		■	■	■	■	■	■	■	■	■		■
Trapa natans	water chestnut	■	■	■									
Typha angustifolia	narrowleaf cattail		■	■	■	■	■	■	■	■	■	■	
Typha xlatifolia	hybrid cattail		■	■	■	■	■	■	■	■	■	■	

volunteer citizens to monitor and report new occurrences. Promoting early detection and reporting by trained citizens can vastly increase the number of eyes on the ground and water, effectively increasing sample sizes. In addition,the resultant spatial data captured can be used over time to better understand dispersal pathways. This will improve the targeting of high and low risk monitoring sites.

Regarding the spread of widespread invasive species, such as non-native phragmites, it makes sense to monitor and protect valued sites and survey for outliers at the leading edges of infestations, rather then in the midst of heavily invaded sites. Rapid, coarse scale mapping of the highest threat and fastest dispersing species throughout Michigan are recommended to help identify their leading edges of dispersal.

Strategies to mitigate impacts of widespread invasive species will also benefit from systematic assessment of high quality and valued sites in the region of interest. Efforts can then be prioritized to keep these sites as free from new invasions as possible. This will require: a) regular monitoring of valued sites to keep new infestations from establishing, b) regular monitoring of source infestations to contain them, and c) identifying and blocking dispersal pathways.

Survey Results

Twenty-eight sites were sampled (Fig. 7) and 15 target species (Table 3) were documented during this study. All species mapped have been long-established and are widespread in southern Lower Michigan. Sixteen species that are widespread or locally established in southern Michigan were not documented in the study area (Table 4), nor were any of the other 29 species posing an emerging threat for Saginaw Bay. These latter results are heartening, but do not reflect statistically robust sampling, a complex and time-consuming task as discussed in the sampling methods section.

All species documented during the study were found in one or both of the first and second tier wetlands sampled. The presence of multiple, well-

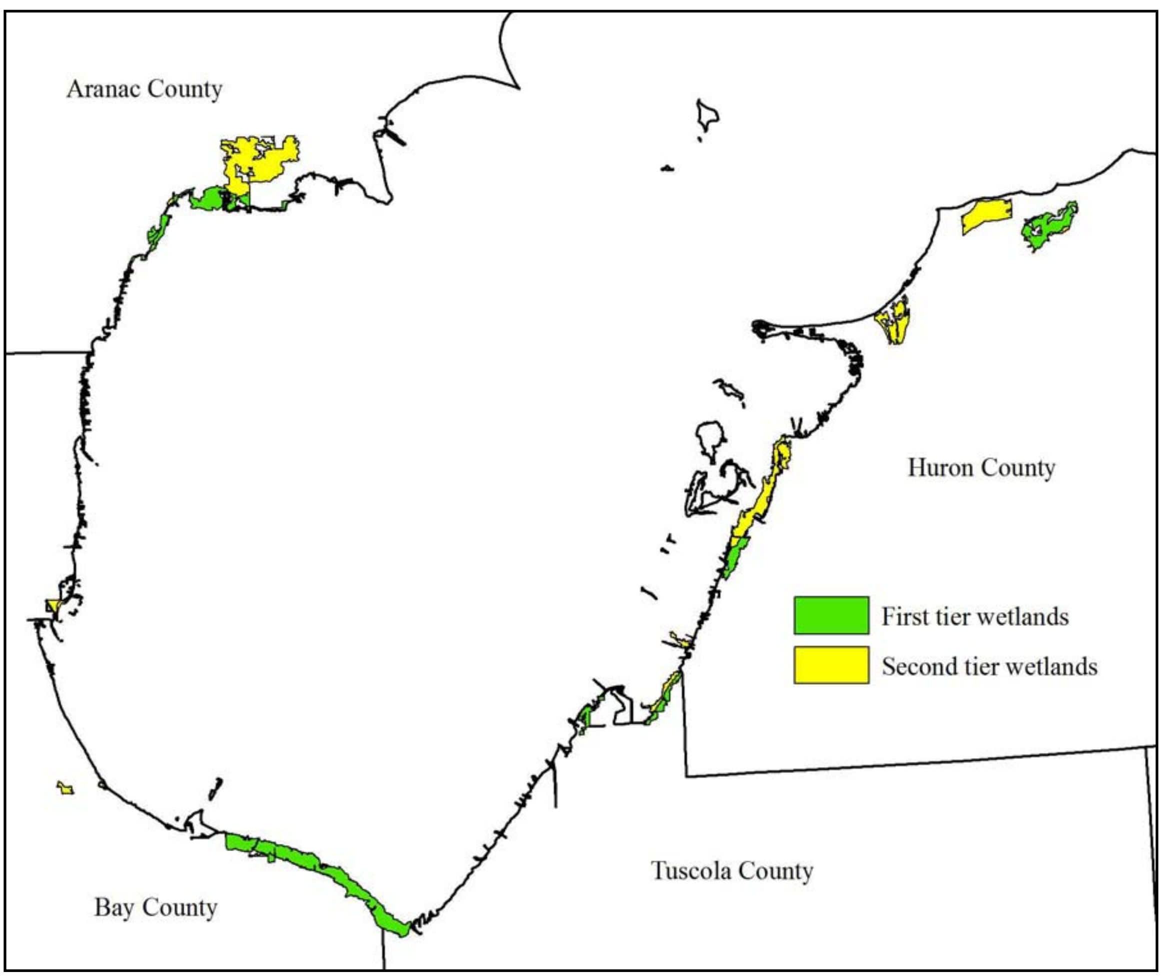

Figure 6. Map of the study area showing wetlands sampled.

Table 3. Targeted species documented in the study area during 2009 surveys.

Scientific Name	Common Name
Alliaria petiolata	garlic mustard
Alnus frangula	glossy buckthorn
Elaeagnus umbellata	autumn olive
Epilobium hirsutum	hair willow-herb
Hesperis matronalis	dame's rocket
Lysimachia nummularia	moneywort
Lythrum salicaria	purple loosestrife
Myriophyllum spicatum	Eurasian water milfoil
Phalaris arundinacea	reed canary grass
Phragmites australis	phragmites
Rhamnus cathartica	common buckthorn
Rosa multiflora	multiflora rose
Solanum dulcamara	bittersweet nightshade
Typha angustifolia	narrow leaved cat-tail
Typha x*glauca*	hybrid cat-tail

established species in wetlands prioritized for acquisition was not surprising, as these were already known to be widespread in the region. However the exploratory sampling conducted during the study demonstrate the enormity and complexity of documenting and preventing the spread of invasive species throughout a large region. Only 28 of 1031 Tier 1 and Tier 2 wetland polygons and an even smaller subset of the total number of wetland polygons in the study area were sampled. Providing detailed coverage throughout the entire region would be hugely expensive and time-consuing. More effective means of assessing the extent of widespread invasive species are needed to help focus survey efforts in areas that are not already highly invaded. Detecting and treating isolated infestations of emerging species outside of heavily invaded areas before they become larger source infestations will, in most cases, be a more effective approach.

Surveys also showed that many of the globally significant lakeplain prairie remnants in the region are severely threatened by the invasion of non-native phragmites, narrow-leaved cat-tail (*Typha angustifolia*), hybrid cat-tail (*Typha* x*latifolia*), and reed-canary grass (*Phalaris arundinacea*). Yet, meander surveys of some of these invaded sites revealed pockets of lakeplain prairie that remain relatively intact. Comprehensive surveys targeting previously identified lakeplain prairie occurrences in the Saginaw Bay Region are recommended for the development of a regional conservation strategy. Pockets of un-invaded remnants may serve as core areas for restoration and linkages across the region, and may also hold critical

Table 4. Species widespread or locally established in southern Michigan but not documented in the study area during 2009 surveys.

Scientific Name	Common Name
Butomus umbellatus	flowering rush
Egeria densa	Brazilian waterweed
Eichhornia crassipes	common water hyacinth
Humulus japonicus	Japanese hops
Hydrocharis morsus-ranae	common frog-bit
Impatiens glandulifera	ornamental jewelweed
Iris pseudacorus	yellow iris
Lysimachia vulgaris	garden yellow loosestrife
Myriophyllum aquaticum	parrot feather water-milfoil
Najas minor	brittle water-nymph
Nitellopsis obtusa	starry stonewort
Pastinica sativa	wild parsnip
Pistia stratiotes	water lettuce
Polygonum cuspidatum	Japanese knotweed
Polygonum sachalinensis	giant knotweed
Ranunculus ficaria	fig buttercup

information regarding the invasion dynamics of these highly aggressive species. It will also be useful to investigate whether newer remote sensing techniques can discern higher quality remnants of native communities within heavily infested regions to increase survey efficiency.

Mapping Application

The simple mapping application was quick, easy to use and avoided the time-consuming process of mapping polygons. For regional assessments, the latter is unproductive for the information gained and detracts from a focus on emerging invasive species. Capturing points and density estimates using standardized drop-down menus, provided adequate documentation of distribution data for individual species. Scoring criteria could be developed based upon the species and density estimates for each mapped point and a summed score for each site. These data could then be factored into analyses that seek to compare sites using various criteria. The need for more detailed polygon mapping of infestations is better considered after sites have been prioritized for management. The application would benefit form the inclusion of a comments field where surveyors can add pertinent notes such as tips for re-locating the site or observations about dispersal. For newly documented sparse infestations, such details can be indispensable.

Figure 7 shows all points mapped in the study area and a close-up view of points for three species in a

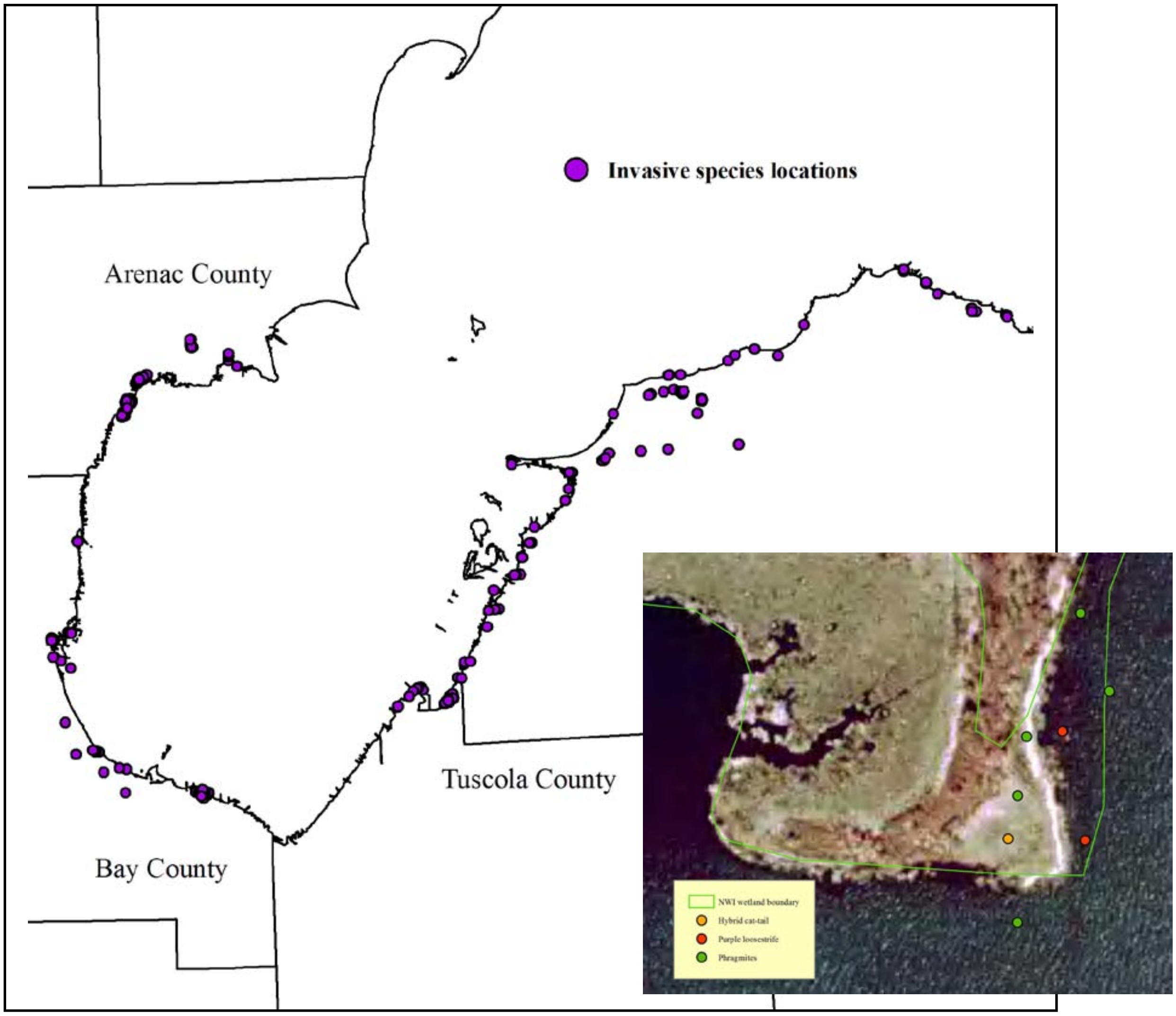

Figure 7. Map of the study area showing all points mapped and a close up view of mapped points for individual species in a sampled wetland polygon.

selected wetland polygon. Similar data were captured for all sites sampled. These point data are stored on a secure DNRE server and will be uploaded to the MISIN mapping application for use by registered users. As the MISIN grows, it is intended that these data will be served back out to users through standard and customized queries. These data will also be provided to the GLANSIS and made available to DNRE upon request.

Status of Early Detection Monitoring

Conservancies and DNRE Offices queried for Saginaw Bay study area are mostly focused on site specific restoration efforts, many of which address well established invasive species or specific wildlife habitat. For the most part, they lack formally established early detection monitoring programs or protocols. Numerous lakeplain prairie restoration efforts are on-going in the region, however, they would benefit from regional conservation planning to coordinate threat analyses, prioritize and focus management efforts, and share information and expertise. Regional conservation planning would also help sustain long-term restoration efforts and coordinate early detection and reporting in the region.

Lake and stream monitoring is regularly conducted on a five year cycle by professional DNRE Water Bureau staff. Some data collection forms have fields for observations of invasive plants, however these do not appear to be routinely utilized yet for any but the most well-known plants such as purple loosestrife, Eurasian water-milfoil, and more recently, hydrilla. The Michigan Clean Water Corps (MiCorps) Cooperative Lake Monitoring Programs (CLMPs) are active in some regions of the state, typically where Lake Associations have strong leaders (Latimore 2010). Historically, they have focused on traditional water quality measures, such as nutrient levels and dissolved oxygen. Specific training for identifying and monitoring aquatic and emergent invasive plants was initiated by MiCorps in 2007. There has been limited participation to date, however, participation and training are anticipated to increase over time. The current training includes only a few of the more widely distributed and well known invasive plants in the state and will benefit from the information on emerging species presented in this study. Volunteer stream monitoring through MiCorps is also gaining momentum, but could benefit similarly from data on emerging invasive plants. The field guide accompanying this report will be an important resource for all of these efforts.

There is a strong need for training both professionals and volunteers how to identify and report new infestations, particularly those of emerging invasive plants. Web-based identification and reporting tools such as the MISIN and GLANSIS will help address this need. The MISIN species identification training modules have been enthusiastically received by professional resource managers, teachers, volunteers, and the general public. Currently, modules are available for ten species and funding is being sought to develop more. The MISIN on-line mapping capability enables users to zoom into aerial photos and map occurrences directly. The GLANSIS holds a wealth of information on aquatic invasive species in the Great Lakes Region and users can report occurrences and sign up for auto-alert of new findings. They are also in the initial stages of serving distribution data out to users. Both the MISIN and GLANSIS are gaining recognition and it is recommended that future EDRR efforts build upon their work. It is essential, however, to accompany web-based learning with field-based training using live plants in their natural setting. Field training with experienced botanists will improve detection rates substantially (Higman 2010).

There is a similarly strong need for a lead agency or consortium to promote and coordinate early detection monitoring and establish standard reporting procedures statewide. Numerous strategic plans in the Great Lakes region are available to help guide such an effort (Lake Superior Work Group 2009, USEPA 2008, Higman et al. 2009, Hydrilla Task Force 2006) and professionals and volunteers alike are seeking such guidance and coordination. Groups such as the Stewardship Network (TSN), and Cooperative Weed Management Areas (CWMAs) are growing and poised to help implement it (TSN 2010, USFS 2008, Huron Pines 2010). These groups along with the many new and on-going projects funded through the Great Lakes Restoration Initiative and other sources will provide local training, needed support structures, and many other educational materials and opportunities.

There remains an equally strong need to build capacity for conducting rapid response once species are reported. Early detection monitoring and reporting can proceed, however, reporting will likely flag if it repeatedly results in no action taken. Early detection will be most effective if detection protocols are established in concert with response protocols and capacity building as part of an overarching EDRR program for the state.

Early Detection Monitoring Protocols

Detailed survey and monitoring protocols for invasive aquatic and wetland plant species have been developed by a number of agencies and workgroups, including the United States Environmental Protection Agency (2000, 2007), Hart et al. (2000), and Hill and Williams (2007). In general, these protocols provide guidance on the identification of non-native species and native look-alikes, lists of necessary supplies, and suggested methodologies for systematically sampling lakes and streams and identifying the location(s) of target species using maps and GPS. In addition, many protocols provide sample field forms and contact information for the reporting of invasive species observations to the appropriate local agency or consortium. Some resources outline strategies to prevent the spread of particular species and/or reduce or eradicate the particular species once it has become established (e.g., Hart et al. 2000). Appendix A provides an annotated bibliography of selected programs and protocols.

Most protocols provide sufficient detail to guide survey and monitoring activities, however most, to date, focus on a limited number of potential inasive species and tend to be targeted towards teams of trained volunteers with access to necessary equipment and infrastructure. There remains a need to provide information and guidance to individuals and small groups of people for early detection of invasive aquatic and wetland plant species.

Due to the variety and specificity of early detection sampling protocols required to address the spectrum of species that pose a threat, a single universal monitoring protocol is not presented here. Rather, a general approach to early detection monitoring is discussed here with more details incorporated into the field guide accompanying this report. The challenge for early detection monitoring lies not so much in detailing the sampling techniques, but in the following:

- establishing and mobilizing a user-friendly reporting and curating system for distribution data,
- better understanding dispersal pathways to help prioritize where detection monitoring occurs,
- determining how much sampling effort should be invested, and
- building professional and volunteer capacity, for early detection and response efforts statewide

To develop statistically rigorous early detection sampling, field testing of species-specific meander surveys and systematic random sampling strategies in proximity known target occurrences, where liklihood of detection is higher, are needed. Here, sampling protocols such as those presented in the Cooperative Lake Monitoring Program and Maine's Field Guide to Aquatic Plants, should be tested against one another and against expert driven meander surveys using micro-habitat feaures to hone-in on particular species. Over time better, statisticially reliable sampling protocols will likely emerge. However, this is not practical in the short-term for the promotion of monitoring and reporting of emerging invasive species statewide. Where possible and where resources allow, meander surveys targeting the heterogeneity of a given site can be highly effective. Even the hetergenity of aquatic systems can be assessed and used to develop stratified sampling within key zones based upon species microhabitat preferences (Hill and Williams 2007). The challenge lies in determining the highest risk sites for any given species. For monitoring of identified high quality, valued sites, intensive sweeping of the sites may be warranted, particularly if emerging invasive species are known nearby (Fahlsing 2010). This is more easily accomplished in shallow water or terrestrial systems.

Landowner Auto-alert System

Key contact information was gathered from Conservancies and DNR Offices in the study area for uploading into the MISIN auto-alert system, however, at the completion of this study, this component of the MISIN was not yet complete. These contact data will be stored for later use by MISIN and for potential use by the GLANSIS. Due to the lack of a clear, coordinated procedures for responding to new detections, private landowner data were not gathered for this study. Alerting landowners will be an important component of an EDDR program, but better undertaken once response procedures are in place.

Field Guide

The field guide accompanying this report was designed to strike a balance between:

- including as many potentially relevant species as possible,
- providing sufficient information for successful identification of species—or at least to flag suspicious plants for further scrutiny,
- presenting the information in a format that was easy to use, and
- keeping the resulting document to a convenient size for field work.

It is organized into two major sections: a pictorial key based on simple characteristics such as leaf type and arrangement, and a section of species accounts, arranged alphabetically by scientific name. It also includes introductory comments, monitoring guidance, a glossary, a listing of useful online resources and references, and a summary table showing the natural communities each species is likely to establish in. Crosswalk tables of common and scientific names are also included for ease of use.

The pictorial key helps users hone-in on species quickly and accurately by providing key characters that separate out groupings of species. The species accounts include photographs showing different aspects of the plants, a map showing their current known distributions in the state, brief diagnostic descriptions, notes on habitats they are most likely to be found it, dispersal mechanisms, and survey dates when the species will be easiest to detect. Each species is coded with one or more of four broad habitat categories where they are most likely to be found: aquatic (A), shorelines and stream and riverbanks (S), emergent wetlands (E), and forested wetlands (F). Finally, where possible, information is provided on how particular species can be distinguished from similar species.

The distribution maps show general abundance in each of four of Michigan's ecoregions: Western Upper Peninsula, Eastern Upper Peninsula, Northern Lower Michigan, and Southern Lower Michigan. These data were gathered from published accounts on key web sites such as the MISIN and GLANSIS, Michigan and North American floras, herbarium records, the authors, and others with local or statewide expertise. The four categories of distribution are: a) not known from this region, b) isolated occurrences known from this region, c) locally abundant in this region, and d) widespread in this region. These maps represent a point in time based on existing data and will need to be updated regularly. Currently, they are at a very coarse scale because distribution data is limited. As data is gathered over time through the MISIN, GLANSIS, and others, more precise distribution data can be presented.

Most of the photos were provided by Bugwood.org, which makes its extensive photo library of invasive species available for educational purposes. Under their terms of use the photos can only be used for non-commercial, not-for-profit purposes unless written permission is obtained from each from the contributing photographers. For some of Bugwood's contributing photographers, payment for commercial use of photos is expected. Additional photos were provided by the University of Florida's IFAS Center for Aquatic and Invasive Plants, which has similar restrictions. A list of photos used with the names of the photographers and the web addresses where each of the photos are included in the field guide.

The field guide is intended to focus early detection efforts on species that are currently believed to be of greatest concern to Michigan's lakes, streams, and wetlands and to facilitate their monitoring and detection. Using the monitoring guidance and learning key characters, likely habitats, and survey times when species are most easy to detect, will increase the probability of detecting these species early.

Dissemination of Findings

The aquatic and wetland invasive plant occurrence data collected during this project was designed to mirror the MISIN mapping application and will be uploaded and available to MISIN users. These data will also be provided to the GLANSIS and to DNRE upon request. Two copies of the final report summarizing the project and its findings, will be provided to DNRE Water Bureau and posted on the MNFI digital library. Copies of the field guide will be provided to DNRE Water Bureau and the original will be posted to the MNFI web site. A flyer announcing the on-line version will also be posted on the MNFI Web Site. An original copy will be stored in MNFI's digital library for potential updates and reprints as needed and as funding allows. *The photos included in the booklet were derived from many sources, and are strictly prohibited for use in commercial endeavors or profit.* As MNFI conducts future workshops and research related to invasive species, data from this study will be shared and/or incorporated where appropriate.

Conclusions

Currently, only a few high profile invasive aquatic and wetland plants are widely known in Michigan and no single, widely accepted standard for determining the likelihood of establishment or potential impacts of individual species is in use. The production of *A Field Guide to Invasive Plants of Aquatic and Wetland Habitats* provides a critical reference for a broader array of invasive plants that currently occur in Michigan or have the potential to establish and spread in the state. It is recommended that this guide be widely distributed to professionals and volunteers and that follow-up training be provided throughout the state. Training should include an overview of the threat of invasive species, key identification characters, distribution information, reproductive and dispersal mechanisms and optimal survey times for individual species. Professionals and volunteers should also be trained on survey, mapping, and reporting protocols. Standard risk assessment(s) and a regular review process should be adopted for ranking potential impacts and likelihood of establishment of invasive species to better target those species posing the greatest and most immediate threat.

Critical to the efficacy of an early detection-rapid response protocol is the identification of known source populations of emerging invasive plants and the survey and monitoring of potential dispersal pathways for these species. Known locations of emerging invasive plant species that are currently isolated or localized in or near Michigan should be carefully mapped and monitored. Surveys of dispersal pathways and high risk water bodies and wetlands in the immediate vicinity and elsewhere, where known, should be conducted. Limited surveys of lower risk sites should also be conducted occasionally to test assumptions about likely disperal sites. Pathway studies and predictive modeling should be researched or undertaken to improve the identification and prioritization of high and low risk sites and dispersal pathways. Statistically rigorous field-testing of existing and novel species-specific sampling protocols should be conducted and refined where needed.

The lack of a widely recognized lead agency or consortium focused on the early detection and rapid response to emerging invasive plants and responsible for the collection and curation of monitoring data, is a significant limitation to cost-effective mitigation of invasive species impacts in Michigan. Identifying a lead entity to create and promote a sustainable, statewide EDRR Program should be a top priority and will greatly enhance the conservation of Michigan's natural resources. Recommended elements of this program include: a) providing training and resources to staff and volunteers, b) developing and/or distributing monitoring guidelines, c) receiving and processing field data, d) coordinating and assisting in the mapping of target species, and e) assessing and managing identified populations of target species. The program will be most effective if roles, responsibilities, and authorities for the identification, assessment, and treatment of target species are clearly defined.

As increasing funds are directed towards restoration of important highly degraded areas in the state, an equal or greater emphasis should be placed on keeping highly quality, valued sites from becoming invaded. This is rarely explicitly spelled out by managers, yet is critical to cost-effective mitigation. Success in the latter endeavor is dependant upon a well staffed, statewide EDRR Program and will lower cumulative ecological and treatment costs exponentially in Michigan.

Summary of Recommendations for Early Detection of Emerging Invasive Plants

- Identify a lead organization or consortium to create a statewide EDRR program and assign roles and responsibilities to pertinent agencies and organizations.
- Adopt standardized risk assessment(s) for ranking potential impacts and likelihood of establishment of invasive plants; include watch-list categories.
- Complete risk assessments for target species; review and update these regularly. Do not be complacent about species not yet in Michigan.
- Promote centralized GIS invasive species reporting with auto-alert capability. Establish reporting protocols in concert with response protocols for confirming, assessing, and responding to new detections. Build upon current efforts of the MISIN and GLANSIS.
- Conduct rapid coarse scale surveys of the highest threat and fastest dispering species, statewide to identify leading edges of invasion.
- Identify highest risk entry points in the state and implement detection monitoring. Use pathway studies and predictive modeling to identify and prioritize these sites.
- Survey and map known source populations of emerging invasive plant species and near-by dispersal pathways and habitat; establish regular monitoring of these sites.
- Identify and monitor sites more distant to known source populations, using pathway studies and predictive modeling to help guide where this monitoring should occur.
- Identify and monitor high quality, valued sites with the region of interest and prioritize them for monitoring for new invasions. While it is important to do this throughout the state, it is particularly important in highly invaded regions, where it is easy to become overwhelmed. In Saginaw Bay, for example. this includes conducting intensive surveys of lakeplain prairie remnants in order to prioritize restoration of this globally significant community.
- Train professionals and volunteers in the identification, detection, mapping, reporting, assessment, and treatment monitoring of emerging invasive plants.
- Integrate invasive plant detection monitoring and reporting into existing monitoring efforts.
- Expand research on dispersal pathways and novel detection techniques such as DNA sampling and remote sensing techniques.
- Conduct statistically reliable, species-specific tests of survey strategies where emerging target species are known to occur. This will help identify micro-habitat or othr features that may guide surveys to increase detection probabilities.
- Field test the plant keys and the utility of the field guide accompanying this report; improve and update them as needed.
- Monitor key populations of species that have been mapped in the MISIN, GLANSIS or elsewhere to determine if these data are being used to prioritize and control/eradicate populations.

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Appendix A.

Annotated Bibliography of Selected References on the Detection and Management of Invasive Species

Chicago Wilderness Coalition and the US Fish and Wildlife Service. 2010. New Invaders Watch List: Early Detection and Rapid Response Network. Available http://ctap.inhs.uiuc.edu/newinvaders/login.aspx. (Accessed: March 23, 2010)

Scope:

- This website is an online field guide to invasive plant species of upland, wetland, and aquatic habitats in the Chicago region. The website provides characters for identification, collecting and reporting guidelines, and field reporting forms. The website also provides online training presentations and coordinates field trainings for volunteers in the region.

Strengths:

- list of target species with identification and habitat information, look-alike species, and distribution
- collecting and reporting guidelines
- standardized reporting form

Hart, S., M. Klepinger, H. Wandell, D. Garling, and L. Wolfson. 2000. Integrated Pest Management for Nuisance Exotics in Michigan Inland Lakes. Michigan State University Extension Water Quality Series: WQ-56, East Lansing, MI.

Scope:

- This manual discusses the importance of aquatic invasive species, and provides general guidelines to landowners for the development of integrated pest management strategies for lakes. The manual also provides detailed descriptions of several invasive animals and plants that are causing particular problems in Michigan waters, and describes the invasion process and control strategies for these organisms. Last, the manual provides a very brief summary of a few non-native species that do not yet occur in Michigan water bodies, but have the potential to become significant threats in the state.

Strengths:

- provides general guidelines for the development of invasive pest management strategies that outline the process from the organization of volunteers to the review of the control program for effectiveness
- detailed descriptions of several species that currently threaten Michigan water bodies, including specific strategies for the control and eradication of the target organisms
- a list of references on the management of water bodies and invasive aquatic plants and animals

Hill, R., and S. Williams. 2007. Maine Field Guide to Aquatic Invasive Plants and Their Common Native Look-Alikes. Maine Volunteer Lake Monitoring Program, Auburn, ME.

Scope:

- This book is primarily a field guide to invasive aquatic plant species that currently threaten and/or have the potential to threaten water bodies in Maine, and includes a section on native aquatic plant species that may be confused with invasive species. In addition to the species treatments, the book provides guidelines for conducting screening surveys in Maine lakes and streams for aquatic invasive plant species. The book also includes a small section on invasive animals, wetland plants, and algae that also threaten or have the potential to threaten Maine waters.

Strengths:

- comprehensive treatment of invasive aquatic plants, including information on habitat,

identification, origin and range, life cycle, and look-alikes
- broad coverage of native aquatic plant species that may be confused for at least some of the invasive aquatic plants
- brief overview of conducting screening surveys for aquatic invasive plants with directions on how to report occurrences

Michigan Clean Water Corps. 2009. Cooperative Lakes Monitoring Program. Michigan Department of Natural Resources and Environment, Report No. MI/DEQ/WB-10/003, Lansing, MI.

Scope:
- This report discusses the stresses placed on Michigan's lakes by human activities in these water bodies and surrounding watersheds. The guide discusses nutrient-based lake classification and several attributes of lake water quality, including nutrient levels, primary productivity, transparency, dissolved oxygen, sediments, fish communities, and temperature. A brief discussion of the Exotic Aquatic Plant Watch pilot project is also included, which focuses on curly-leaf pondweed, Eurasian milfoil, and hydrilla. Several appendices report specific measurements from lakes sampled during 2009.

Strengths:
- overview of lake quality that frames the importance of environmental monitoring
- appendices with environmental data that illustrate the differences in water quality properties among different lake types

University of Connecticut. 2009. Invasive Plant Atlas of New England. University of Connecticut, Storrs, CT. Available http://nbii-nin.ciesin.columbia.edu/ipane/aboutproject/about.htm. (Accessed: March 23, 2010).

Scope:
- This web-accessible database provides a substantial list of invasive plant species known to occur in the northeastern United States. The website has a particular emphasis on early detection of plant invasions. In addition to the comprehensive descriptive listing of invasive plants species, the website provides links to invasive plant management strategies, news stories related to invasive species, online training resources and reporting forms, and links to discussion on related to invasive species.

Strengths:
- extensive database of invasive species with identification and habitat information, look-alike species, impacts, and distribution
- collecting and reporting guidelines
- standardized reporting form
- coordinated volunteer program

USEPA. 2000. Volunteer Wetland Monitoring: An Introduction and Resource Guide. EPA 843-B-00-001. U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Wetlands Division, Washington, DC.

Scope:
- This guide discusses the purposes of wetland monitoring programs and discusses broadly the various strategies that can be used to monitor wetlands for a variety of purposes. A particular emphasis is placed on the development and mobilization of volunteer wetland monitoring programs, with a focus on the development of skills and values among volunteers, data collection and quality assurance, and the development of specific research objectives to guide wetland monitoring strategies.

Strengths:

- general synthesis of the uses of wetland monitoring data and types of monitoring data most commonly collected
- focuses on the importance of educating and training wetland volunteers
- discusses the importance of formulating monitoring goals and identifying the level of scientific rigor required by the specific goal(s)
- includes an annotated bibliography of manuals and handbooks on volunteer monitoring of wetlands and associated species

USEPA. 2007. Survey of the Nation's Lakes. Field Operations Manual. EPA 841-B-07-004. U.S. Environmental Protection Agency, Washington, DC.

Scope:

- This report and manual is a detailed description of an EPA project to assess the environmental status of the nation's lakes, ponds, and reservoirs. The manual describes in detail the procedures to be followed by EPA employees and contractors to assess various environmental attributes of sample water bodies.

Strengths:

- Detailed descriptions of how to sample water bodies for vegetative cover and presence of invasive aquatic plants

Wandell, H.D., and L.G. Wolfson. 2007. A Citizen's Guide for the Identification, Mapping and Management of the Common Rooted Aquatic Plants of Michigan Lakes. Michigan State University Extension, East Lansing, MI, Water Quality Series: WQ-55.

Scope:

- This manual begins with a basic discussion of nutrient-based lake classification and the implications of nutrient status for watershed management, followed by a description of aquatic plant communities and a guide to rooted aquatic plants that includes keys and line drawings. The manual also provides descriptions of the growth characteristics, habitat, and beneficial and nuisance traits for each species. Last, the manual provides guidelines for making plant collections, mapping aquatic plants, and several alternative management plans documenting the strengths and weaknesses of each approach

Strengths:

- keys of basic characters with accompanying simple line drawings that can be used by non-botanists to identify plants to genus or species
- genus and species accounts describe important attributes, including a comparison of beneficial versus nuisance traits
- easy-to-follow methodologies for collecting and mapping aquatic plants
- detailed goal-focused examination of management options and tools
- overview of the process of developing a specific management plan

Wisconsin Department of Natural Resources. 2008. Wisconsin Invasive Plants Reporting & Prevention Project. Wisconsin DNR, Madison, WI. Available http://www.dnr.state.wi.us/invasives/futureplants/index.htm. (Accessed: March 23, 2010).

Scope:

- This website is an online field guide to invasive plant species of upland, wetland, and aquatic habitats in Wisconsin. The website provides characters for identification, collecting and reporting guidelines, and field reporting forms. The website also serves as a recruiting tool for "Wisconsin

Weed Watchers," volunteers who are alerted to target plant sitings, tips and strategies for sampling and managing invasive plants, and other websites or resources useful for the purpose of detecting and controlling invasive plant species in the state.

Strengths:

- list of target species with identification and habitat information, look-alike species, impacts, and control techniques
- collecting and reporting guidelines
- standardized field forms for the reporting of invasive species occurrences

Appendix B.

General Monitoring Approach for Early Detection of Emerging Invasive Plants

1. Define area or region of interest.

2. Learn to identify species of concern in or approaching identified area or region, their optimal survey times, and their habitat affinities (see Field Guide). Ideally, develop species search images through actual field based training.

3. To integrate invasive plant monitoring into on-going lake and stream monitoring with an already specified sampling strategy, learn the plants that are likely to be in the habitats to be sampled and keep a sharp look-out for them during sampling (see Table 3 and Field Guide). Where possible enhance existing monitoring of aquatic habitats using the sampling rake described in the CLMP Manual or similar tool.

4. Identify and map important and highly valued sites in the area or region and establish regular monitoring of these sites, focusing on obvious entry points.

5. Identify and map known occurrences of locally established target species and species near-by that are not yet established.

6. Identify and map potential dispersal corridors in the immediate vicinity of the known occurrences (see Field Guide)

   a. <u>Deep and shallow aquatic species</u>: outlets, ditches, and boat launches associated with adjacent wetlands

   b. <u>Open and forested wetland species</u>: adjacent wetlands, outlets, and ditches

   Dispersal corridors vary with the individual species as well as with the particular habitat that is being invaded. For species that are carried on soil, boots, tires or equipment, dispersal typically occurs in a linear fashion, along paths, roads, ditches, canals, or streams. For species with fruits that are eaten by birds, dispersal occurs across a broad front, spanning multiple habitat types. For the latter species, knowledge of their habitat affinities will help in predicting where they may end up (Table 3, Field Guide). For species that are commonly used in water gardens or aquaria, initial dispersal is associated with human habitations, but once escaped it will be important to assess whether any natural means of dispersal is occurring.

7. Identify water bodies or wetlands in proximity of the occupied site that may be at high risk of invasion due to human activity (including operation of watercraft) and sample these sites (see Table 3 and Field Guide for appropriate habitat.)

   a. <u>Deep and shallow aquatic species</u>: Follow the procedures of the Cooperative Lakes Monitoring Program (CLMP 2009). For example, transects may be used to survey for species rooted below water that are undetectable from above. For highest detection probability using systematic surveys, broad coverage of the site is needed and higher sample sizes will provide higher levels of certainty.

b. Near shore, open and forested wetland species: Conduct meander surveys of the extent of potential habitat where possible, focusing on appropriate microhabitats for target species (see Field Guide). Systematic random sampling may be needed for submerged or relatively inconspicuous species. For highest detection probability using systematic surveys, broad coverage of the site is needed and higher sample sizes will provide higher levels of certainty.

8. Conduct targeted surveys of "low risk" bodies of water or wetlands more distant from known occurrences of target species or human population centers. Use pathway studies, local expertise, and habitat affinities to prioritize survey sites (NISC 2006, Leung et al. 2006, Table 3, and Field Guide).

a. Deep and shallow aquatic species: Follow the procedures of the Cooperative Lakes Monitoring Program (2009). Target surveys at potential ports of entry, including boat launches, slips, docks, and inlets.

b. Near shore, open and forested wetland species: Survey appropriate microhabitats for target species. Surveys may be conducted systematically or visually, depending on the target species. Some species are readily identifiable from a distance, and may require only targeted meander surveys. Relatively inconspicuous species may be best detected and monitored through the use of a systematic sampling protocol.

9. Conduct surveys according to phenologies of target species (see Field Guide), e.g., when individual species are most easily detected, lowering costs of survey and increasing detection probabilities. More experienced monitors may be able to survey effectively during other points of their life cycle.

10. Report detections to appropriate agencies, organizations, and landowners for confirmation, assessment, rapid response, and treatment monitoring.