Developing Rare and Exotic Plant Geographic Information System Databases for Indiana Dunes and Sleeping Bear Dunes National Lakeshores

Noel B. Pavlovic
Karen M. Quinlan
and
Thomas Ford

USGS, Biological Resources Discipline
Great Lakes Science Center
Lake Michigan Ecological Research Station
1100 N. Mineral Springs Rd.
Porter, IN 46304

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FOIA NOTE **4**

MANAGEMENT SUMMARY **4**

INTRODUCTION **6**

Problem Statement **6**

Goals and Objectives **8**

METHODS **9**

Data collection methods for Pitcher's thistle (*Cirsium pitcheri*) mapping **9**

Data collection methods for rare plants **11**

Data collection methods for exotic plants **13**

Common reed (*Phragmites australis*) sampling **16**

Data analysis **17**

RESULTS **19**

Pitcher's thistle (*Cirsium pitcheri*) **19**

Rare plants **22**

Exotic plants **43**

Common reed (*Phragmites australis*) sampling **46**

SUMMARY **47**

Indiana Dunes National Lakeshore **47**

Sleeping Bear Dunes National Lakeshore **50**

CONCLUSIONS **53**

REFERENCES **54**

APPENDICES **57**

Appendix 1. Indiana listed endangered, threatened, and rare plants found and reported from Indiana Dunes National Lakeshore. **57**

Appendix 2. Michigan Federal, state, rare and conservative species for which surveys were proposed to be conducted at Sleeping Bear Dunes National Lakeshore. **62**

Appendix 3. List of plants that may possibly occur at SLBE and INDU by Emmet Judiewitz. **65**

Appendix 4. Proposed target alien plants that were to be mapped by park. **72**

Appendix 5. Cross comparison of the data fields in the North American Weed Mapping Association (NAWMA) Mapping Standard, the Michigan Natural Features Inventory (MNFI) Special Plant Population Data Form, and the National Park Service Natural Resource (NPS-NR) Data Template **73**

Appendix 6. Maps **78**

Appendix 7. Voucher photographs for new ferns to SLBE **85**

Appendix 8. Voucher photographs for new exotic populations found at SLBE. **88**

FOIA NOTE

This document contains sensitive rare plant information and maps that are exempt from Freedom of Information Act (FOIA) requests. Thus, when the public requests copies of this document, the maps in Appendix 6 must be removed.

MANAGEMENT SUMMARY

Populations of rare and exotic plants were mapped at Indiana Dunes and Sleeping Bear Dunes National Lakeshores during the summer of 2003. At Indiana Dunes, 127 populations of state-listed plants and 205 populations of the federally threatened Pitcher's thistle (*Cirsium pitcheri*) were mapped. Rare plant species that were mapped included *Actaea rubra* (Ait.) Willd., *Aster sericeus* Vent., *Calla palustris* L., *Carex eburnea* Boott, *Clintonia borealis* (Ait.) Raf., *Habenaria ciliaris* (L.) R. Br. ex Ait. f., *Hudsonia tomentosa* Nutt., *Lathyrus japonicus* Willd. var. *glaber* (Ser.) Fern., *Lathyrus venosus* Muhl. ex Willd., *Phlox bifida* Beck, *Satureja arkansana* (Nutt.) Briq., *Scirpus hallii* Gray, *Spiranthes lucida* (H.H. Eat.) Ames, *Talinum rugospermum* Holz., *Trillium cernuum* L. var. *macranthum* Eames & Wieg., and *Valerianella chenopodiifolia* (Pursh) DC. A nearly complete distribution map of Pitcher's thistle was created of the patches at the Indiana Dunes; these varied greatly in numbers of plants and area. At Sleeping Bear Dunes, 341 populations of rare plants were mapped. Species sampled included *Asplenium rhizophyllum* L., *Bartonia virginica* (L.) B.S.P., *Berula erecta* (Huds.) Coville, *Botrychium campestre* W.H. Wagner & Farrar, *Bromus pumpellianus* Scribn., *Carex platyphylla* Carey, *Castanea dentata* (Marsh.) Borkh., *Chimaphila maculata* (L.) Pursh, *Cypripedium arietinum* Ait. f., *Cypripedium reginae* Walt., *Eleocharis rostellata* (Torr.) Torr., *Medeola virginiana* L., *Mimulus glabratus* Kunth var. *michiganensis* (Pennell) Fassett, *Muhlenbergia glomerata* (Willd.) Trin., *Orobanche fasciculata* Nutt., *Panax quinquefolius* L., *Platanthera blephariglottis* (Willd.) Lindl., *Platanthera obtusata* (Banks ex Pursh) Lindl., *Polystichum lonchitis* (L.) Roth, *Sarracenia purpurea* L., *Thelypteris noveboracensis* (L.) Nieuwl., *Trillium cernuum* L. var. *macranthum* Eames & Wieg., *Triphora trianthophora* (Sw.) Rydb. New populations of many species were found. The analysis of associated species demonstrated the habitat specificity for most species. The data indicated the presence of human trampling and animal browsing in the populations of some species (showy orchids) that may be a concern for the viability of the species. The maps generated should not be considered complete (except for Pitcher's thistle), since neither park was thoroughly surveyed. The GIS data can be used to model species distributions in the parks.

At Indiana Dunes, 335 populations of exotic species were mapped. We focused our efforts on species and genera that are significant threats to the dunes ecosystems: *Alliaria petiolata* (Bieb.) Cavera & Grande, *Celastrus orbiculatus* Thunb., *Centaurea maculosa* auct. non Lam., *Cirsium arvense* (L.) Scop., *Elaeagnus* L., *Gypsophila scorzonerifolia* Ser., *Lonicera* L., *Lythrum salicaria* L., *Phalaris arundinacea* L., *Phragmites australis* (Cav.) Trin. ex Steud., *Polygonum cuspidatum* Sieb. & Zucc., *Rhamnus cathartica* L., *Robinia pseudoacacia* L., and *Rosa multiflora* Thunb. ex Murr. Of the exotic species invading the Indiana Dunes, spotted knapweed is of great concern

because of the extensive railroad corridor populations adjacent to the high quality savanna/woodland complex.

In addition to mapping both rare and exotic species, we also genotyped (native/nonnative) *Phragmites australis* plants using morphological characters. We discovered three populations of the native *Phragmites australis* ssp. *americanus* at Indiana Dunes. We recommend that these be protected while the pervasive alien is eradicated. At Sleeping Bear Dunes only the exotic common reed (*Phragmites australis*) was mapped, while the NPS exotic plant management team focused on other invasive plants. The majority of *Phragmites* was the native subspecies. Focused efforts to eliminate the minority alien subspecies should go far to protect the native subspecies in the park.

INTRODUCTION

Problem Statement

Managers of Great Lakes National Parks need accurate and accessible resource information to guide management for restoration and preservation. Besides managing vegetation, managers need to inventory and monitor federally and state listed plants and invasive alien plants. The latter may impact the rare plants being protected as well as alter vegetation dynamics and ecosystem properties (Pyke and Knick 2003, Brooks et al. 2004, Louda et al. 2005). Inventories of rare plants and non-indigenous invasive plants (NIPs) at Indiana Dunes National Lakeshore (INDU) and Sleeping Bear Dunes National Lakeshore (SLBE) are at various stages of completion. Meanwhile, resource managers are forced to make important development, restoration, recreational, and management decisions without a comprehensive data source to access. Compiling information on rare and alien plant occurrences and distribution, entering it into a geographic information system (GIS), and searching for new populations will greatly aid resource managers.

INDU is approximately one fourth the area of SLBE (6475 ha versus 23,490 ha, respectively). Despite the difference in park area, INDU harbors over seven times the state listed plant species compared to SLBE (144 to 20). However, if we include special rare plants (Hazlett 1991) and those listed with coefficients of conservatism of 10 (Herman et al. 1996), the total number of species at SLBE reaches 99. Coefficients of conservativism are numerical rankings assigned to species based on their fidelity to high quality indigenous plant communities. Coefficients of conservativism of 10 represent species that are only found in high quality communities, whereas values of 0 represent species that are found unbiquitously, especially in anthropogenic habitats (Swink and Wilhelm 1994).

Rare plant surveys have been conducted at INDU (Bowles et al. 1990, Wilhelm 1990, Pavlovic and Bowles 1996) and SLBE (Hazlett 1991), but rare plant digitization has only occurred for the Keiser and Tamarack units at INDU and partial mapping of selected species throughout the remainder of the Lakeshore. One of these selected species is Pitcher's thistle (*Cirsium pitcheri*), which was mapped and digitized for INDU in 1991. At SLBE, Pitcher's thistle locations were mapped only in a general manner and hence, are not in a form that can be digitized or used for management decisions. Despite the abundance of Pitcher's thistle on the open dunes at SLBE, there is a great need for a replicable and accurate map of Pitcher's thistle populations, to reduce and eliminate impacts from development and recreation. In addition to Pitcher's thistle, populations and individuals of five other rare species have been located and digitized at SLBE: Michigan monkey flower (*Mimulus glabratus* var. *michiganensis*) (threatened, federal), calypso (*Calypso bulbosa*) (threatened, state), ram's head lady's slipper (*Cypripedium arietinum*) (special concern, state), American ginseng (*Panax quinquefolius*) (threatened, State), and three-birds orchid (*Triphora trianthophora*) (threatened, state) (Hazlett 1991, National Park Service 1991, Albert 1992).

In addition to detailed information on rare plants, digital maps of the distributions of non-indigenous invasive species are also becoming available for both INDU and SLBE. For both parks, the maps will be based on distribution interpolation among random sampling points (Klick et al. 1989, Loope and Pavlovic 1998). At INDU, maps currently are being developed of locations of purple loosestrife (*Lythrum salicaria*), garlic mustard (*Alliaria petiolata*), common reed (*Phragmites australis*), black locust (*Robinia pseudoacacia*), Japanese knotweed (*Polygonum cuspidatum*), multiflora rose (*Rosa multiflora*), and dame's rocket (*Hesperis matronalis*). At SLBE, species for which extensive digitized maps exist include leafy spurge (*Euphorbia esula*), purple loosestrife, and garlic mustard. Less detailed maps exist for sweet clover (*Melilotus* spp.) and baby's breath (*Gypsophila paniculata*) (Edwards 1995, Loope et al. 1995, Loope and Siterlet 2000).

The purpose of this project was to inventory selected rare plant species at both parks, and to inventory invasive non-indigenous plants at INDU and incorporate the data into GIS compatible digital maps. This will be highly valuable since both parks actively use GIS for resource management and mapping. This one-year project was proposed to assist these parks in achieving their inventory goals. General needs are listed below and further development of these needs is presented in Goals and Objectives.

INDU
- Continue digitizing data on federally and state listed rare plant species.
- Locate new populations of high priority plant species.
- Digitize 1991 Pitcher's thistle maps and remap and digitize new map of metapopulations (McEachern 1992).
- Prioritize and digitize selected invasive plant species.

SLBE
- Map and digitize population patches of Pitcher's thistle (McEachern 1992), baby's breath, and spotted knapweed in the dunes.
- Train staff to complete Pitcher's thistle mapping in future years.
- Inventory high priority rare plants where additional information is needed.
- Note populations of new rare and alien species to the park, if found.

Goals and Objectives

1. Map patches of Pitcher's thistle in the dune landscapes of both INDU and SLBE. The methodology was based on previous mapping at INDU and Pictured Rocks National Lakeshore (PIRO) in 1991 (McEachern 1992).
2. Compile information and map locations of populations of rare plants from fieldwork and from paper maps at INDU and SLBE (including Michigan Natural Features Inventory (MNFI) data). Appendices 1 and 2 list high priority species for INDU and SLBE, respectively. We proposed to digitize location data of approximately 35% (50/144) of the state listed species present at INDU, and 60% (12 /20) of the state listed species present at SLBE (further species were added beyond these: 23 SLBE rare and 19 conservative). The minimum goal was to document the occurrence of all federally listed rare species believed to occur within SLBE and INDU, as well as document the occurrence of the highest priority of all state listed rare plant species.

Beyond these two minimum goals, we hoped to fulfill the following objectives:

3. Document the recent occurrence information (reports, studies, databases, voucher specimens, observation cards, etc) for all rare plants believed to be present in each park.
4. Geographically locate and record the GPS coordinates of the populations of rare plants throughout each park with completion levels correlated with political status as shown below:
    - Federal Threatened – all known populations of Pitcher's thistle (complete at INDU and start survey at SLBE)
    - All G2 and G3 ranked species
    - State Endangered – 50% of known populations
    - State Threatened – 25% of known locations
    - Michigan Special Concern – 25% of known locations
    - Indiana Rare – 25%
    - Indiana Watch List – 25%
    - Plants that are locally rare at SLBE, but lack status – 25%
5. Search for some of the potential new plants for SLBE from the list created by Emmet Judziewicz (Appendix 3).
6. Map the patches of emerging and selected established invasive species at INDU and SLBE. Appendix 4 lists those species to be mapped by park. Collect specimens of common reed to identify the origin, native or exotic, of the patches, based on morphological characters.

GIS results may be used to identify areas needing immediate management for rare plants because of the threats from NIPs. The data may also be used to identify further gaps in our knowledge of rare and invasive species.

METHODS

Data collection methods for Pitcher's thistle (*Cirsium pitcheri*) mapping

A data dictionary and supplemental data sheet were created and field checked before mapping began. These were based loosely on data required for the MNFI program, and were taken directly from those used in the rare plant study (below). Locations for populations of Pitcher's thistle were taken from maps generated by A. Kathryn McEachern in 1991, and Dr. Pavlovic provided additional directions when needed.

A thorough search was made for Pitcher's thistle plants at each site. Searches were also conducted in areas near known populations that contained suitable habitat for Pitcher's thistle. Plants were flagged as they were found, and if plants were located in patches, their perimeters were flagged. Plant populations were then mapped using a Trimble GeoExplorer3, as follows. Individual plants were mapped using the "individual" data dictionary, which creates a point feature. Patches of plants smaller than 5 × 5 meters were mapped using the "small patch" data dictionary, which also creates a point feature; several populations larger than 5 × 5 meters were also mapped as small patches. One hundred twenty positions were logged for point features whenever possible. Patches of plants larger than 5 × 5 meters were mapped using the "large patch" data dictionary, which creates a polygon feature. Positions were logged as the data collector walked along the perimeter of the patch while pausing and logging at appropriate locations. A new file was created for each feature mapped. The data dictionary information was gathered while positions were logged when possible, as in point features, or after the positions were logged, as was common for large patches. A data sheet was also filled out for each feature mapped unless the data were identical for more than one feature, in which case they were combined onto one data sheet.

The data dictionary "Cirsium pitcheri.ddf" was used to collect data on Pitcher's thistle populations, in combination with data sheet "INDU/SLBE Rare Plant Study 2003." Data dictionary attributes are defined in Table 1, and data sheet attributes follow. Field procedures for gathering data, when not self-explanatory, are included in the descriptions.

Information on the following attributes was logged on paper data sheets:

Microhabitat: A brief description of the community and environment in which the plant or population is growing, including factors that may favor or limit the plant.

Associates: A list of the species growing in the immediate vicinity of the plant or population, broken into herbaceous, understory/shrub, and overstory/tree layers. Species may be included in more than one layer; for example, the presence of young trees might result in black oak being listed in both the shrub and tree layers. If an associate species could not be identified in the field, a sample was brought back to the office and keyed out. Abundance codes are a measure of how abundant an associate species is in the

community: D (Dominant) indicates a species that dominates all other species, C (Codominant) indicates a species that grows throughout the community but does not dominate, O (Occasional) indicates a species that has several or a few plants scattered throughout the community, and R (Rare) indicates a species that has only one or two plants present. If an associate was an exotic plant, a check was placed in the "Exotic?" column.

Table 1. Description of the data fields in the Pitcher's thistle data dictionary. The fields shown are those created for data collection in large patches, which is the most comprehensive data dictionary.

Field	Type	Description
Date	Date	Generated by the GeoExplorer3
Observers	Text	Enter initials of data collectors
Park	Menu	Choose INDU or SLBE
Slope	Numeric	Enter percent slope as measured with a clinometer
Aspect	Numeric	Enter the direction the slope is facing as measured with a 360 degree compass
Canopy cover	Menu	Choose open, <50%, >50%, or closed
Percent bare soil	Menu	Choose 0-25%, 25%, 25-50%, 50%, 50-75%, 75%, 75-100%, or 100%
Number of plants	Numeric	Enter exact count of plants in population being mapped
Number of adults	Numeric	Enter exact count of adult (flowering) plants in population being mapped
Number of juveniles	Numeric	Enter exact count of juvenile plants in population being mapped
Number of seedlings	Numeric	Enter exact count of seedlings in population being mapped
Dispersion	Menu	Choose scattered individuals, scattered clumps, clumped, or continous (See Figure 1 for definitions of dispersion types)
Vigor	Menu	Choose thriving, surviving, or poor

Disturbances: A brief description of any observable disturbances, natural or human, which could have affected the plant or population.

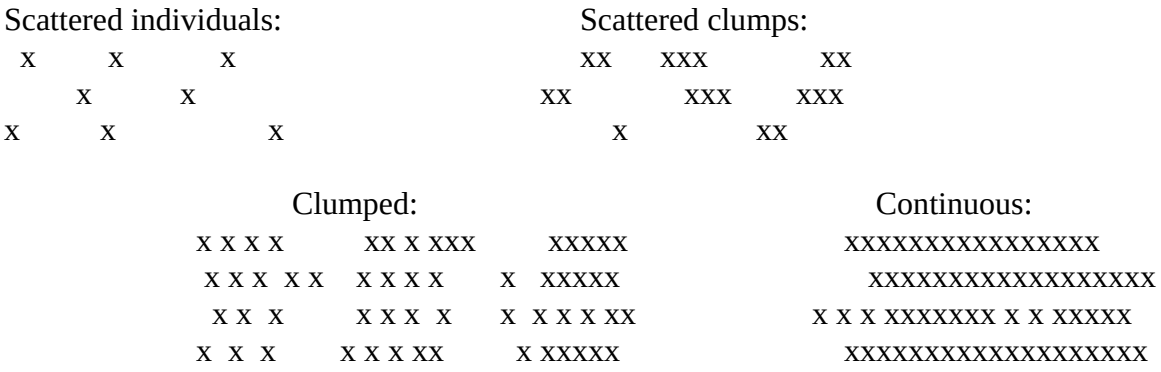
Immediate threats: A brief description of the presence of any factor that may threaten the plant or population in the immediate future.

Long-range threats or management needs: A brief description of the presence of any factor that may threaten the plant or population in the future, and any recommendations for management to ensure the continuing survival of the plant or population.

Additional notes: Anything else that was not described elsewhere in the data dictionary or data sheet.

Files were downloaded into GPS Pathfinder Office upon return from the field, and differentially corrected. Corrected files were viewed and points were edited as necessary. Files were then exported as ArcView shapefiles.

Figure 1. Dispersion of individuals in a population.



A file for one small patch in Cowles Bog could not be corrected, and so was digitized over the digital orthophoto based on a position provided by Quinlan. A second patch was hand digitized over the digital orthrophoto of the Cowles Bog area based on a map and position provided by the NPS Fire Monitoring staff.

Data collection methods for rare plants

A data dictionary and supplemental data sheet were created and field checked before mapping began as described above, under Pitcher's thistle mapping. A list of potential rare plants to be mapped at INDU was made from the file "Induflora2003.sav", a database maintained by Dr. Pavlovic. With assistance from Kim Struthers, GIS Specialist at SLBE, a similar list was generated for that park based on existing information from the MNFI. Priorities were discussed periodically by Dr. Pavlovic, Karen Quinlan, and Tom Ford, as well as with resource management staff from each park, as necessary during the field season. It was clear from the outset of this project that there would not be enough time to map all species on the list.

At INDU, locations for populations of rare plants were determined using several sources, including "Special Vegetation of the Indiana Dunes National Lakeshore" (Wilhelm 1990) and "An Assessment of the Monitoring Program for Special Floristic Elements at INDU" (Bowles et al. 1985, Bowles et al. 1986b, Bowles 1988, 1989). The INDU Sensitive Species Database and accompanying maps were also consulted, and Dr. Pavlovic provided additional directions when needed. At SLBE, Tom Ford was provided location information for many records from the MNFI; however, Tom's local knowledge was so extensive that he had a broader knowledge of the rare plants of SLBE, than indicated by the MNFI information.

For SLBE, we developed a CD containing photographs and biological information about the rare plants for which we were searching. Much of this information was obtained from the internet. If data collectors were unfamiliar with species to be mapped, line drawings, photographs, and herbarium specimens were viewed before a search was begun. A thorough search was made for the target species at each site. If

target plants were located, data were recorded in the same manner as with Pitcher's thistle.

The data dictionary "rare plants.ddf" was used to collect data on rare plant populations, in combination with data sheet "INDU/SLBE Rare Plant Study 2003." Data dictionary attributes are defined in Table 2, and data sheet attributes follow. Field procedures for gathering data, when not self-explanatory, are included in the descriptions.

Upon return from the field, areas searched were marked on INDU 1:2400 base topographic maps, whether the target plant was found or not. If the plant was found, the number of populations mapped was noted on the map.

Table 2. Description of the data fields in the rare plant data dictionary. The fields shown are those created for data collection in large patches, which is the most comprehensive data dictionary.

Field	Type	Description
Date	Date	Generated by the GeoExplorer3
Observers	Text	Enter initials of data collectors
Park	Menu	Choose INDU or SLBE
Species	Text	Enter species name or code
Site	Menu	Choose new (if site has not been mapped previously), or resample (if it has)
Slope	Numeric	Enter percent slope as measured with a clinometer
Aspect	Numeric	Enter the direction the slope is facing as measured with a 360° compass
Canopy cover	Menu	Choose open, <50%, >50%, or closed
Soil type	Menu	Choose sand, gravel, loam, clay, muck, peat, or other
Soil type if other	Text	Enter type of soil if not on list above
Moisture	Menu	Choose dry, moist, wet, saturated, or inundated
Patch length	Numeric	Enter length of patch in meters (usually used only for small patches and smaller large patches)
Patch width	Numeric	Enter width of patch in meters (usually used only for small patches and smaller large patches)
Number of plants	Numeric	Enter exact count of plants in population being mapped if possible, or an estimate if not. If a total number of plants for the population cannot be accurately counted or estimated, the number of plants per square meter may be estimated and entered in the next field; enter 0 in this field if this procedure is followed
Plants m^{-2}	Numeric	Enter estimate after counting plants in representative square meter areas and averaging them
Count method	Menu	Choose estimate or actual count
What counted	Menu	Choose individuals or clumps
Dispersion	Menu	Choose scattered individuals, scattered clumps, clumped, or continous (See Figure 1 for definitions of dispersion types)
% vegetative	Numeric	Enter the percent of the population that is in vegetative form
% flowering	Numeric	Enter the percent of the population that is flowering
% fruiting	Numeric	Enter the percent of the population that is fruiting
Vigor	Menu	Choose thriving, surviving, or poor

Files were downloaded into GPS Pathfinder Office upon return from the field, and differentially corrected. Corrected files were viewed and points were edited as necessary. Files were then exported as ArcView shapefiles.

Seven patches of *Calla palustris* at Pinhook Bog (INDU) could not be accurately mapped because of difficult access; these were digitized over the digital orthophoto, based on various individual, small patch, and linear population features that could be mapped. The GPS location of a patch of *Valerianella chenopodiifolia* in Tremont (INDU) could not be obtained in the field due to abberant satellite reception and receiver behavior, and was digitized over a digital orthophoto based on positions reported by Karen Quinlan.

Data collection methods for exotic plants

A list of exotic plants to be mapped, locations of known populations, and areas to be searched were provided by Dr. Pavlovic. Priorities and timing of mapping were discussed periodically by Dr. Pavlovic and Karen Quinlan as necessary during the field season. A data dictionary and supplemental data sheet were created and field checked before mapping began. These were based on a compilation of the North American Weed Mapping Association standard data fields, the National Park Service (NPS) Inventory and Monitoring for Invasive Plant Guidelines, and the NPS MS Access Natural Resource Database Template requirements (Appendix 5); later revisions of the data dictionary are to include NPS Exotic Plant Management Team (EPMT) data requirements that had been overlooked.

If data collectors were unfamiliar with species to be mapped, line drawings, photographs, and herbarium specimens were viewed before a search was begun. At INDU, the technician who worked closely with the EPMT program also coordinated and assisted this project. If target plants were located, data were collected in the same maner as with Pitcher's thistle.

The data dictionary "exotics.ddf" was used to collect data on exotic plant populations, in combination with data sheet "INDU/SLBE Exotic Plant Study 2003." Data dictionary attributes are defined in Table 3, and data sheet attributes follow. Field procedures for gathering data, when not self-explanatory, are included in the descriptions.

Information on the following attributes was logged on paper data sheets:

Management activities: Briefly describe any activities performed to manage the exotic population if not included in the data dictionary menu choices.

Additional notes: Briefly describe any information not specifically addressed in the data dictionary.

Upon return from the field, areas searched were marked on INDU topographic maps. Files were downloaded into GPS Pathfinder Office, and differentially corrected.

Corrected files were viewed and points were edited as necessary. Files were then exported as ArcView shapefiles.

Evelyn Greiner, the technician working with the Exotic Plant Management Team at INDU, digitized seven large patches of exotics (1 patch of *Celastrus orbiculatus*, 2 patches of *Phalaris arundinacea*, 2 patches of *Polygonum cuspidatum*, 1 patch of *Robinia pseudoacacia*, and 1 patch of *Rosa multiflora*) that could not be recorded using GPS. These were digitized over the appropriate digital orthophotograph.

Table 3. Description of the data fields in the exotic plant data dictionary. The fields shown are those created for data collection in large patches, which is the most comprehensive data dictionary.

Field	Type	Description
Date	Date	Generated by the GeoExplorer3
Observers	Text	Enter initials of data collectors
Park	Menu	Choose INDU or SLBE
Species	Menu	Choose from list of commonly found exotics, or other
Species if other	Text	Enter name of species if not on list above
Size of plant	Numeric	Enter radius of plant (for individual data dictionary only)
DBH if tree	Menu	Choose <5" or >5"
Note other species	Text	Enter other exotic species observed in the area of the species being mapped
Infestation	Menu	Choose gross infested (<100% density) or infested (100% density)
Slope	Numeric	Enter percent slope as measured with a clinometer
Aspect	Numeric	Enter the direction the slope is facing as measured with a 360° compass
Canopy cover	Menu	Choose open, <50%, >50%, or closed
Overstory dominant(s)	Text	Enter the dominant overstory tree(s), or none if the canopy is open
Soil type	Menu	Choose sand, gravel, loam, clay, muck, peat, or other
Soil type if other	Text	Enter type of soil if not on list above
Moisture	Menu	Choose dry, moist, wet, saturated, or inundated
Patch length	Numeric	Enter length of patch in meters
Patch width	Numeric	Enter width of patch in meters
Density	Menu	Choose trace 0-25%, light 25-50%, moderate 50-75%, or heavy 75-100%
Number of plants	Numeric	Enter exact count of plants in population being mapped if possible, or an estimate if not. If a total number of plants for the population cannot be accurately counted or estimated, the number of plants per square meter may be estimated and entered in the next field; enter 0 in this field if this procedure is followed
Plants m^{-2}	Numeric	Enter estimate after counting plants in representative square meter areas and averaging them
Count method	Menu	Choose estimate or actual count
What counted	Menu	Choose individuals or clumps
Dispersion	Menu	Choose scattered individuals, scattered clumps, clumped, or continous (See Figure 1 for definitions of dispersion types)
% vegetative	Numeric	Enter the percent of the population that is in vegetative form
% flowering	Numeric	Enter the percent of the population that is flowering
% fruiting	Numeric	Enter the percent of the population that is fruiting
Vigor	Menu	Choose thriving, surviving, or poor
Values at risk	Menu	Choose T/E species, special concern species, prime/unique habitat, proposed wilderness, wetland/riparian habitat, research natural area, wildlife habitat, critical environmental concern, developed recreation site, administrative, cultural/landscape, or other
Values2	Menu	Same choices as Values at risk to allow for multiple concerns
Values3	Menu	Same choices as Values at risk to allow for multiple concerns
Species at risk	Text	Enter name of species if T/E species or special concern species was chosen as Values at risk
Values if other	Text	Enter values at risk if not on list above

Field	Type	Description
Disturbance	Menu	Choose right-of-way, railroad, utility corridor, ORV/road, trail, house site, wind/erosion, animal disturbance, flooding, irrigation/ditching, wildfire, fire suppression, grazing, recreation/visitors, mining/quarries, construction/development, other, or none apparent, to describe past and current disturbance at and around the population
Disturb2	Menu	Same choices as Disturbance to allow for multiple disturbance types
Disturb3	Menu	Same choices as Disturbance to allow for multiple disturbance types
Disturb4	Menu	Same choices as Disturbance to allow for multiple disturbance types
Disturb5	Menu	Same choices as Disturbance to allow for multiple disturbance types
Disturb if other	Text	Enter disturbance type if not on list above
Recovery likelihood	Menu	Choose high, medium, or low to describe likelihood of plant community to return to its native state if the exotic population were to be removed
Removal	Menu	Choose not removed, pulled, foliar sprayed, cut, cut & sprayed stump, mowed, scorched, biological control, or other, to describe control measures performed on the exotic population at the time of mapping
Removal if other	Text	Enter control measures if not on list above
Management activity	Menu	Choose none apparent, Rx burn (recent), Rx burn (evidence), cut, mowed, or other (see data sheet) to describe known management activities on the population or in the area
Notes?	Menu	Choose no or yes (see data sheet)

Common reed (*Phragmites australis*) sampling

During *Phragmites* mapping, samples were collected and sent to Bernd Blossey at Cornell University for determination of whether they were native or exotic. Directions for collection and data submission listed on the Phragmites Diagnostic Service web page (http://www.invasiveplants.net/diag/diagnostic.asp) were followed.

At INDU, the data dictionary "Phragmites.ddf" was used to collect data on *Phragmites* populations, in combination with data sheet "Phragmites Morphological Differences Study 2003." Data dictionary attributes are defined in Table 4; the data sheet contained the site name and number and a location description. The data dictionary was created in C:\Pfdata\2003 Plant Study and copied to F:\Data\Plant\KarenQuinlan\Pfdata\2003 plant study and F:\Data\Plant\KarenQuinlan. The data sheet is stored as F:\Data\Plant\KarenQuinlan\PhragmitesDataSheet.doc. If the site was mapped as an exotic, the GPS file number for the patch was noted.

Upon return from the field, data files were downloaded into GPS Pathfinder Office, and differentially corrected. Latitude and longitude for each sampling site were read from the corrected files, and added to the data sheets. Files were then exported as ArcView shapefiles, which were managed following the same system as other exotics shapefiles. The data were submitted into the Phragmites Diagnostic Service web page, and the pages with data submission and the resulting page showing the assigned sample

ID number were printed. Printouts were placed into the bags containing the samples after a copy of the sample ID number page was made for the Phragmites folder.

At SLBE, data sheets downloaded from the Phragmites Diagnostic Service web page were used instead of the Phragmites data dictionary. In addition, all *Phragmites* sites were mapped as exotics. An exotic plant data sheet was filled out for each population, containing the GPS file number for the population as well as a unique identifier called Location ID. The Location ID was the File number assigned during sampling using the Phragmites data sheet, and was used to cross-reference the exotics.ddf file with the Phragmites.ddf file. Digital photographs were taken of each population; a CD was created and is on file with the data sheets. Photographs were also sent to Bernd Blossey.

One linear population of *Phragmites australis* in Tremont (INDU) could not be completely mapped due to abberant satellite reception and receiver behavior, and so was completed by digitizing it over the digital orthophoto.

Table 4. Description of the data fields in the *Phragmites* data dictionary.

Field	Type	Description
Date	Date	Generated by the GeoExplorer3
Site name	Menu	Choose Cowles Bog, Inland Marsh, Keiser Woods, Miller Woods, Pinhook Bog, Tolleston, West Beach, or other
Site if other	Text	Enter site name if not on list above
Sample number	Numeric	Enter sequential numbers for each site name
Habitat	Menu	Choose floating mat, marsh, swamp, fen, spring, bog, pond, lakeshore, upland, along stream/creek, roadside ditch, agricultural field, or other
Habitat if other	Text	Enter habitat type if not on list above
Growing conditions	Menu	Choose permanently flooded, periodically flooded, tidal, or rarely flooded
Size of population	Menu	Choose few m^2, 10x10m, 20x20m, 50x50m, 100x100m, or extensive
Appearance of stand	Menu	Choose sparse, medium, dense
Digital photo?	Menu	Choose yes or no

Data analysis

Summary statistics were generated for the rare populations mapped at both INDU and SLBE, using SPSS for Windows. Statistics for Pitcher's thistle populations at INDU were generated separately from those of other rare species. Summary statistics were also generated for the exotic plant populations mapped at INDU.

Ordination diagrams were generated for the rare plant data taken at both INDU and SLBE, using the non-metric multidimensional scaling method (NMS) in PC-ORD (McCune and Mefford 1999). Ordination is a data reduction technique that allows the modeling or representation of a multivariate community in several dimensions (usually two or three) rather than in the full species n dimensional space. The associate species listed on these data sheets were used to place the rare species populations in ordination space, and the following habitat data were applied to view their effect on species

groupings: aspect, slope, canopy cover, soil type, soil moisture, patch area, number of plants, dispersion, vigor, and disturbance. Since the data taken for canopy cover, soil type, soil moisture, dispersion, vigor, and disturbance were descriptive rather than quantitative, they were transformed into numeric codes for entry into PC-ORD. A cluster analysis was also performed on the rare plant populations for each park, using the associate species for each rare plant population to place populations into groups. Cluster information was incorporated into the ordinations in order to examine the habitat specificity of the rare plant populations.

Data were organized and stored in a database based on the Microsoft Access Natural Resources Database Template. The database, **Inventory2003.mdb**, was structured to allow easy retrieval of data, and to allow modification should additional mapping and data collection occur. It contains tables for all data dictionary and data sheet fields, as well as GPS location information, for all rare, exotic, and *Phragmites* populations mapped. Species, population and associate data, and location and event information tables are all linked via a unique Observation ID number for each population mapped.

RESULTS

Pitcher's thistle (*Cirsium pitcheri*)

All previously known and several new populations of Pitcher's thistle at INDU were located and their locations recorded using GPS (Appendix 6 - 1). A total of 6536 plants were found and mapped in 205 populations of three feature types: individuals (> 5 m from any other plant), small patches (< 5 × 5 m), and large patches (> 5 × 5m). Table 5 shows the distribution of adult (flowering), juvenile (vegetative), and seedling (first year) plants across the three features. A total of 828 adult plants, 3624 juveniles, and 2084 seedlings were mapped. Fifty-eight of the features mapped were single plants; of these, 17 were adults, 39 were juveniles, and 2 were seedlings. Forty-seven small patches were mapped, containing 157 plants: 35 adults, 100 juveniles, and 22 seedlings. Two small patches were digitized, but the plants within them were counted and included in the above summaries. One hundred large patches were mapped, containing 6321 plants: 776 adults, 3485 juveniles, and 2060 seedlings. Mean patch size was 384 m^2, with a range from 1 m^2 to 20,376 m^2 (Table 6). Most of the patches were smaller than 400 m^2, and contained fewer than 100 plants (Figure 2). The number of plants in a patch was strongly correlated with the size of the patch ($r = 0.809$, $P < 0.01$). The largest patch represents a different methodology, where the entire blowout was mapped as a single population regardless of the distance between plants; all other geographical areas were mapped according to the definitions of individuals, small patches, and large patches outlined in the methods section.

The ordination diagram for rare plants mapped at INDU showing communities delineated by cluster analysis (Figure 3) includes the populations of Pitcher's thistle

Table 5. INDU Pitcher's thistle summary statistics.

		Size classes			
Feature name	Statistics	adults	juveniles	seedlings	Total
Individual	Number in size class	17	39	2	58
Small patch	Size class means ± 1 SE	1 ± 0.13	2 ± 0.22	0	3
(n=47)	Size class range	0-3	0-6	0-6	2-15
	Total number of plants	35	100	22	157
Large patch	Size class means ± 1 SE	8 ± 2.6	35 ± 8.0	21 ± 4.7	64
(n=100)	Size class range	0 - 243	0 - 657	0 - 299	3 - 1199
	Total number of plants	776	3485	2060	6321
Total	Size class means ± 1 SE	5 ±	19 ±	14 ±	32
(n=205)	Standard deviation	20.3	60.5	39.2	96.4
	Size class range	0 - 243	0 - 657	0 - 299	0 - 965
	Total number of plants	828	3624	2084	6536

Table 6. INDU Pitcher's thistle patch size summary statistics.

Feature	Number of patches	Mean patch size (m^2)	Standard deviation	Smallest patch (m^2)	Largest patch (m^2)
Small patch	47	9.7	17.8	1.000	100
Large patch	100	560.6	2096.9	2.371	20,376
Total	147	384.5	1745.9	1.000	20,376

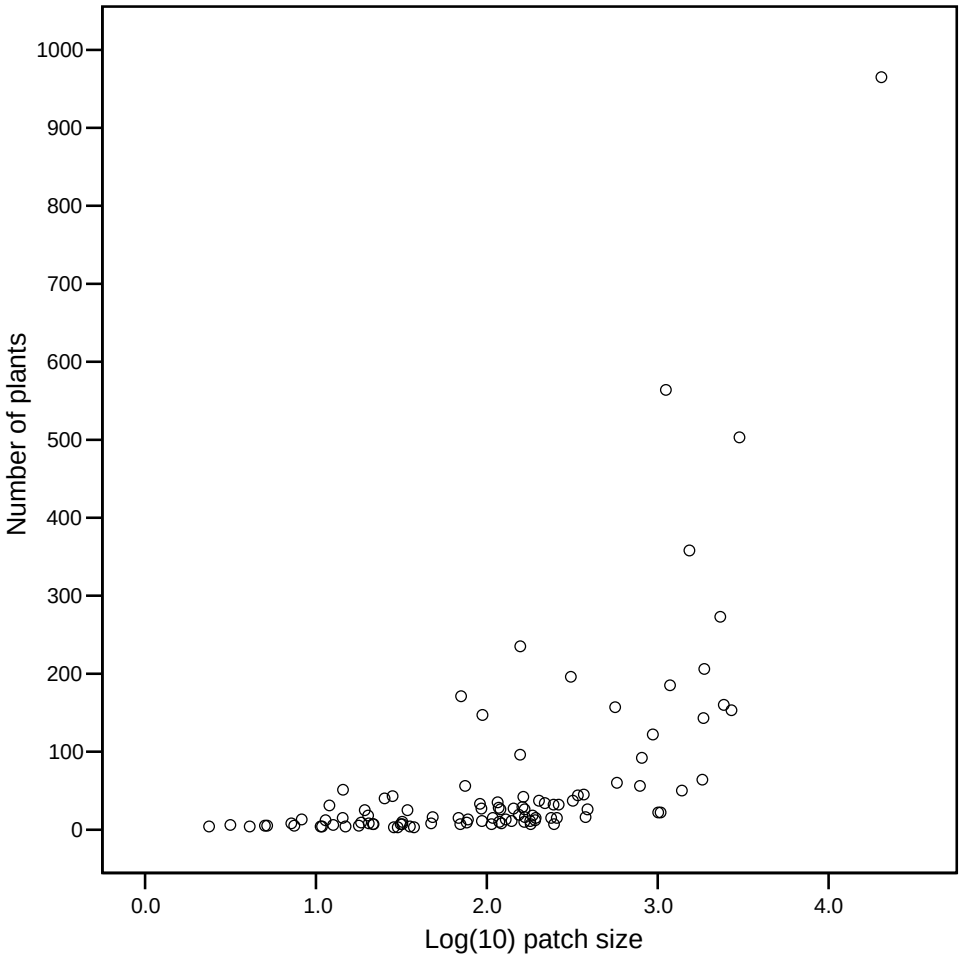
mapped for this project. Due to missing habitat and/or associate data, two populations were not included in the ordinations.

Pitcher's thistle was found almost exclusively in the open sand environments of the dunes and blowouts near the lakeshore; six populations grouped with the *Hudsonia tomentosa* populations of the sand mines due to an unusually high abundance of *Panicum villosissimum pseudopubescens* (false white-haired panic grass) as an associate, and a low abundance and absence of *Calomovilfa longifolia* (sand reed) and *Ammophila breviligulata* (marram grass), respectively. One other population grouped with the cluster of species that did not separate out as distinct communities (AllElse). This was due to its location on top of a sand ridge on the far end of a blowout, which was dominated by *Vitis riparia* (river grape), an uncommon species within the blowouts, as well as a more typical blowout species, *Ammophila breviligulata*; other uncommon associates included *Tilia americana* (basswood) and *Elymus canadensis* (Canada wild rye). The Foredune group was smaller, containing 82 populations, while the successional dune environments on older dune formations and in blowouts (SuccDune) supported 114 populations. All Pitcher's thistle populations grouped on the dry sand end of the soil moisture and soil type gradients, as well as on the low end of the canopy cover gradient, and were grouped near the high end of the slope gradient.

Foot traffic was common in the dunes and blowout habitats, making many populations vulnerable to trampling. Hiking trails, both official and rogue, passed directly through, were adjacent to, or were within a few meters of, many populations. In addition to trampling, some populations are also threatened by adjacent invasive species, including *Celastrus orbiculatus*, *Rhus aromatica*, and *Vitis riparia*; many populations will eventually be affected by succession, particularly in the blowouts.

Populations of Pitcher's thistle in the SLBE landscape were in much larger habitat patches, with a much wider distribution of plants within them than those at INDU. SLBE park staff decided to postpone Pitcher's thistle mapping and concentrate on the other rare species. Survey methods were proposed and discussed, but no populations were mapped this season. Below is the draft protocol for mapping Pitcher's thistle at SLBE. Kim Struthers (pers. comm.) tried this protocol in 2004 and plans to modify it. The intention is to map Pitcher's thistle over a period of years.

Figure 2. Distribution of Pitcher's thistle patch sizes at Indiana Dunes National Lakeshore.



All of the dune areas throughout SLBE (2,209 hectares) will be divided into 40 × 40 m plots, each with a geo-referenced center, using the Park's GIS and GPS units. These grid plots will cover the beach, foredune, secondary dunes, and any blowout systems that extend inland into habitat unsuitable for Pitcher's thistle. Portions of the plot grids will extend into Lake Michigan so that future aggrading and degrading of the shoreline will be taken into account. As field researchers systematically survey an area and a Pitcher's thistle plant is found, they will navigate to the geo-referenced center of the plot in which a particular plant is located. Each plot will then be subdivided into four 20 × 20 m subplots, and all Pitcher's thistle plants will be counted by life form stage in each subdivision. Life form stages will be seedling, juvenile, and adult. The presence and abundance of non-native invasive plants in each subplot will also be recorded. The habitat zones (lower beach, upper beach, *Ammophila* foredune, little bluestem secondary dune, blowout, shrub zone) will be recorded for each subplot sampled to identify lake level fluctuations relative to Pitcher's thistle distribution. The compilation of these data will provide park managers with a complete Pitcher's thistle abundance and distribution map, and semi-complete invasive dune plant abundance and distribution map, specifically related to Pitcher's thistle occurrences.

The abundance classification scheme and scale that will be used is a modification of the methodology used by McEachern (McEachern 1992); densities will be converted to abundance classes based on the plot size.

Abundance class	Density (20x20m subplot)	Density (40x40m plot)
Absent	0 plants	0 plants
Rare	1 plant	<4 plants
Common	2 - 4 plants	4 - 16 plants
Abundant	> 4 plants	>16 plants

Abundance classes will then be color coded for display on maps of dune landscapes. This will allow managers to compare data from previous Pitcher's thistle studies, and to compare population dynamics from Pitcher's thistle data collected at INDU in 2003. SLBE's data will be shared with Dr. Pavlovic to help produce a more accurate model for determining Pitcher's thistle population dynamics.

Once Pitcher's thistle and invasive plants data have been collected, abundance polygons will be developed, using the Park's GIS, to demarcate the most abundant Pitcher's thistle and non-native plant zones. This information will provide a direct approach for rare and invasive plants management by targeting the overlapping areas that have abundant populations of both. In addition, the 2003 data on the location of MI threatened dune plants will be incorporated. This approach will maximize conservation of the park's rare resources throughout the 2,209 hectares of Lakeshore dunes by directing invasive plants management and visitor usage.

Rare plants

At INDU, 16 rare plant species (approximately 11% of the state-listed plants known to occur in the Park) were mapped (Table 7 and Appendix 6-2). An estimated total of 58,123 plants were mapped in 126 populations (Table 8). Mapped entities ranged in size from single plants to patches containing between 9 and 29,115 plants. Mean population size ranged from 2 to 29,115 plants, with a mean of 493 plants over the 126 populations mapped. For species with more than one population mapped, mean population size was between 2 and 365 plants with high variation for all species. The number of plants in most populations was counted as described in the Methods section, which ensured highly accurate results. However, several patches were so large that it was impractical to count individual plants across the entire population. In these cases, the number of plants in the patch was estimated by multiplying the number of plants meter^{-2} (determined by averaging the number of plants in representative square meter plots) by the patch size. This process was used for *Aster sericeus*, four *Carex eburnea* patches, seven *Hudsonia tomentosa* patches, *Lathyrus japonicus* var. *glaber*, one *Satureja*

Table 7. Number of rare plant populations mapped, by species and Park, excluding Pitcher's thistle.

Species	INDU	SLBE	Total
Actaea rubra (Ait.) Willd.	2		2
Asplenium rhizophyllum L.		8	8
Aster sericeus Vent.	1		1
Bartonia virginica (L.) B.S.P.		2	2
Berula erecta (Huds.) Coville		3	3
Botrychium campestre W.H. Wagner & Farrar		2	2
Bromus pumpellianus Scribn.		10	10
Calla palustris L.	25		25
Carex eburnea Boott	18		18
Carex platyphylla Carey		21	21
Castanea dentata (Marsh.) Borkh.		1	1
Chimaphila maculata (L.) Pursh		7	7
Clintonia borealis (Ait.) Raf.	1		1
Cypripedium arietinum Ait. f.		23	23
Cypripedium reginae Walt.		13	13
Eleocharis rostellata (Torr.) Torr.		4	4
Habenaria ciliaris (L.) R. Br. ex Ait. f.	7		7
Hudsonia tomentosa Nutt.	40		40
Lathyrus japonicus Willd. var. *glaber* (Ser.) Fern.	1		1
Lathyrus venosus Muhl. ex Willd.	5		5
Medeola virginiana L.		23	23
Mimulus glabratus Kunth var. *michiganensis* (Pennell) Fassett		9	9
Muhlenbergia glomerata (Willd.) Trin.		5	5
Orobanche fasciculata Nutt.		76	76
Panax quinquefolius L.		66	66
Phlox bifida Beck	2		2
Platanthera blephariglottis (Willd.) Lindl.		12	12
Platanthera obtusata (Banks ex Pursh) Lindl.		2	2
Polystichum lonchitis (L.) Roth		30	30
Sarracenia purpurea L.		13	13
Satureja arkansana (Nutt.) Briq.	8		8
Scirpus hallii Gray	1		1
Spiranthes lucida (H.H. Eat.) Ames	10		10
Talinum rugospermum Holz.	2		2
Thelypteris noveboracensis (L.) Nieuwl.		1	1
Trillium cernuum L. var. *macranthum* Eames & Wieg.	3	4	7
Triphora trianthophora (Sw.) Rydb.		6	6
Valerianella chenopodiifolia (Pursh) DC.	1		1
Total populations mapped	127	341	468

Table 8. INDU rare plant summary statistics, excluding Pitcher's thistle. Numbers of populations in bold font include populations in which the plant count is not known. Mean, standard deviation, smallest and largest population, and total number of plants for these species were calculated based on the number of populations where the plant count is known. The number of populations lacking counts are given in parentheses.

Species	Number of populations	Mean population size	Standard deviation	Smallest population	Largest population	Total number of plants
Actaea rubra (Ait.) Willd.	2	10	12.7	1	19	20
Aster sericeus Vent.	1	29,115	.	29,115	29,115	29,115
Calla palustris L.	**25** (17)	13	14.6	1	50	217
Carex eburnea Boott	18	210	262.2	9	907	3,778
Clintonia borealis (Ait.) Raf.	1	42	.	42	42	42
Habenaria ciliaris (L.) R. Br. ex Ait. f.	7	2	1.9	1	6	17
Hudsonia tomentosa Nutt.	40	365	1,534.9	1	9,662	14,610
Lathyrus japonicus Willd. var. *glaber* (Ser.) Fern.	1	2,989	.	2,989	2,989	2,989
Lathyrus venosus Muhl. ex Willd.	5	37	38.8	10	100	186
Phlox bifida Beck	2	250	70.7	200	300	500
Satureja arkansana (Nutt.) Briq.	8	139	348.2	1	1,000	1,113
Scirpus hallii Gray	1	4,930	-	4,930	4,930	4,930
Spiranthes lucida (H.H. Eat.) Ames	10	5	5.6	1	19	47
Talinum rugospermum Holz.	2	29	6.4	24	33	57
Trillium cernuum L. var. *macranthum* Eames & Wieg.	3	13	15.9	1	31	39
Valerianella chenopodiifolia (Pursh) DC.	1	470	-	470	470	470
Total	**127** (119)	489	2,842.0	1	29,115	58,130

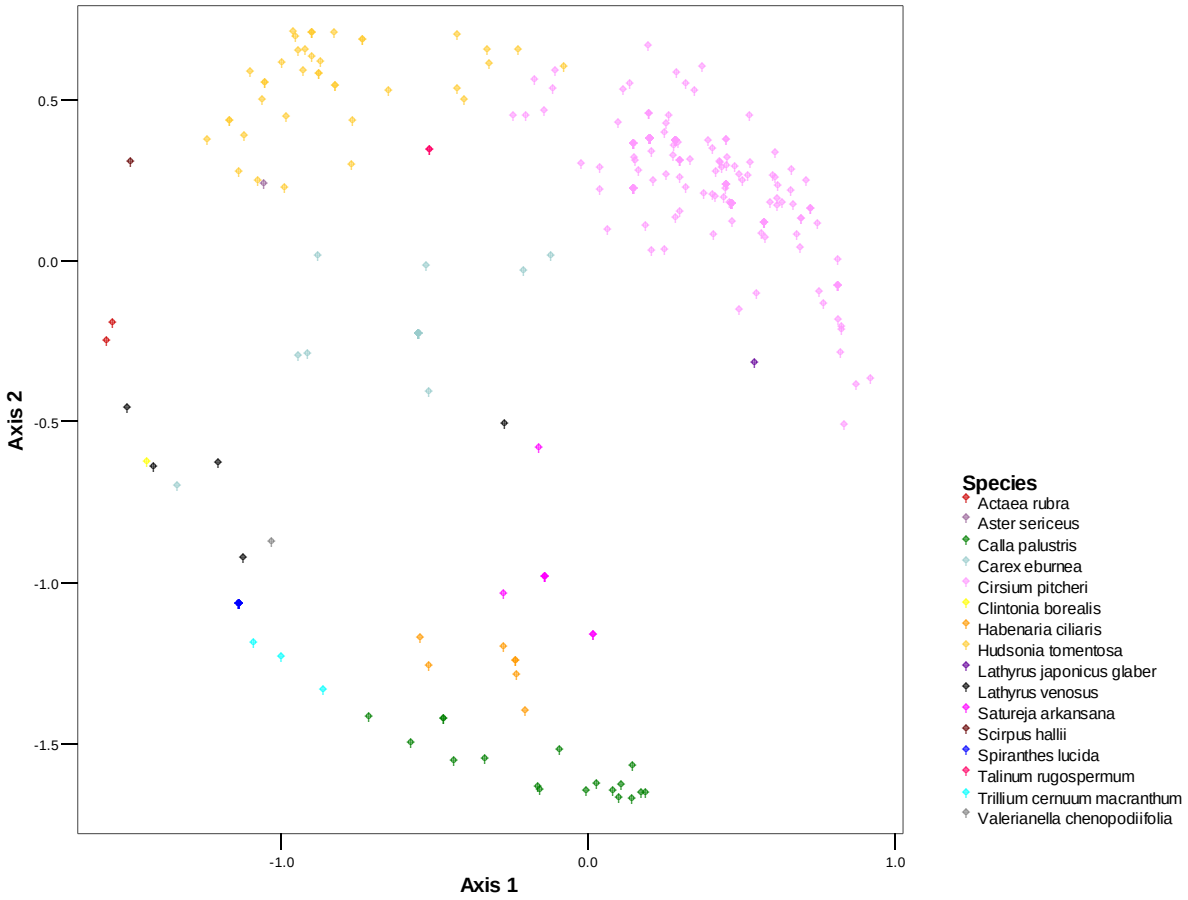
arkansana patch, and *Scirpus hallii*, and may have resulted in artificially high counts for some of these species. The number of plants in eight of the 25 populations of *Calla palustris* could not be accurately estimated due to lack of accessibility; seven of those populations were digitized. This resulted in an artificially low estimate for the total number of plants for *Calla palustris*.

A newly discovered population of *Spiranthes lucida* was mapped in a restored homesite in the Keiser Unit. The only previously known record for this species at INDU was from a homesite on Waverly Road in 1987 (Wilhelm 1990). Previously known populations of three species, *Aralia hispida*, *Lycopodium tristachyum*, and *Polytaenia nuttallii*, were searched for, but could not be found. A previously known population of *Valerianella chenopodiifolia* at Heron Rookery could not be found, while a new population in Tremont was mapped.

Ordination showed general separation of rare species by associate species composition (Figure 3). Due to missing associate data, seven *Calla palustris*, two *Cirsium pitcheri*, and two *Phlox bifida* populations were not included in the ordinations.

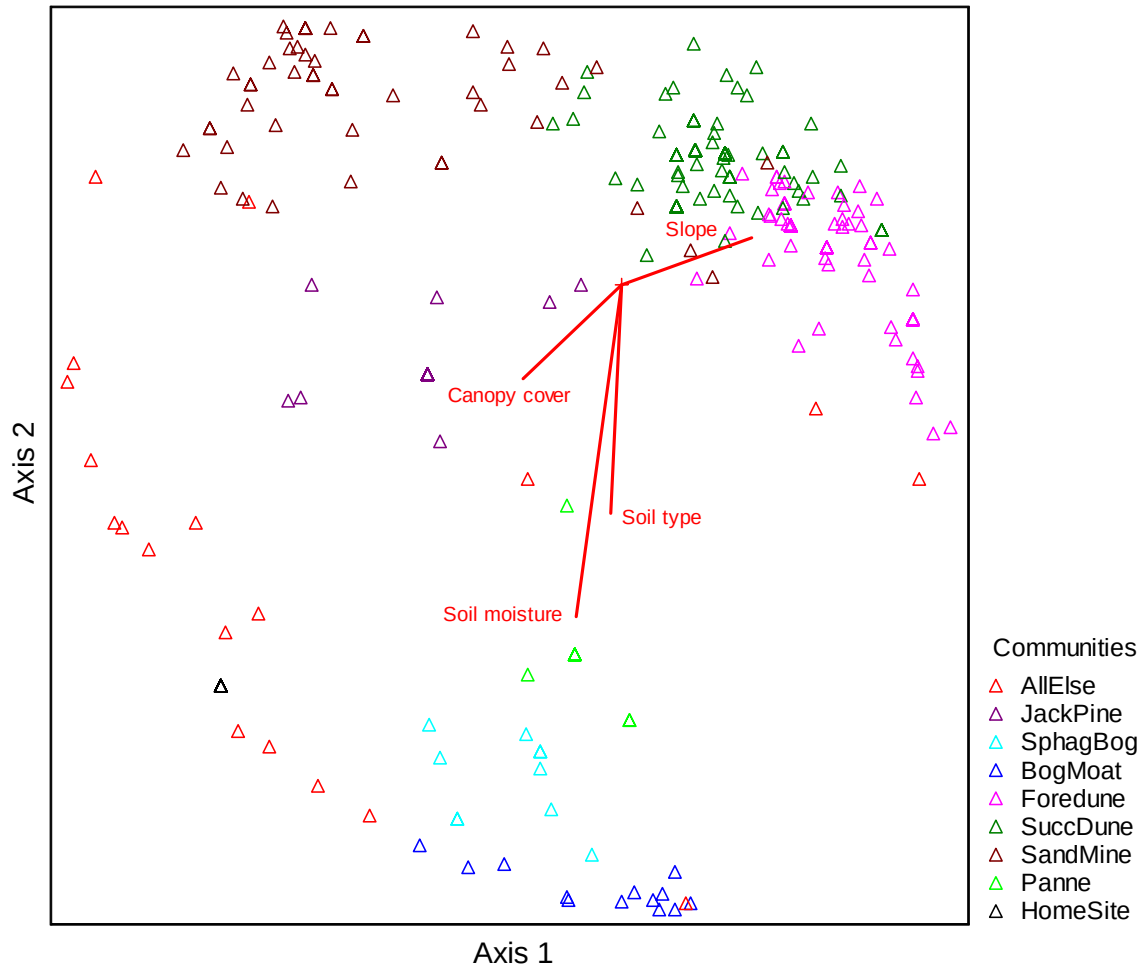
Cluster analysis revealed eight distinct communities in which the rare plants were distributed, plus a ninth (labeled AllElse), which did not represent a single community (Figure 4 and see Table 9 for associate species composition). Rather, the AllElse group was composed of populations of various species whose associates were too unlike those of the other 8 clusters to be included in them, yet were not different enough from each other to create more than one group. Each species either contained too few samples to provide enough data to base separate groups on, or associates that were too unlike those that created the more distinct clusters. Many of the species' placements in ordination space were closely related to the other eight community clusters. For example, *Hudsonia tomentosa* and *Talinum rugospermum* grouped exclusively in the sand mine community. All but one *Carex eburnea* population grouped in the Jack pine community; the one that did not was included in the AllElse group. This one population was mapped in a mesic woods dominated by *Quercus velutina* (black oak), *Tilia americana* (basswood), and *Sassafras albidum* (sassafras) in the overstory, and *Carex pensylvanica* (Pennsylvania sedge) and *Anemonella thalictroides* (rue anemone) in the herbaceous layer. All of the *Satureja arkansana* and *Spiranthes lucida* populations grouped in the panne and homesite communities, respectively. The Sphagnum bog community (SphagBog) contained all of the *Habenaria ciliaris* populations and three of the *Calla palustris* populations; thirteen of the remaining *C. palustris* populations comprised the moat community adjacent to the bog (BogMoat), while the other two were included in the AllElse group. Both of these populations were missing the *Sphagnum* (Sphagnum moss) and *Vaccinium corymbosum* (highbush blueberry) as dominants that would have placed them into the bog community, as well as many of the abundant species in the moat community.

Figure 3. Ordination diagram for rare plant populations mapped in 2003 at Indiana Dunes National Lakeshore, showing species.



Of the habitat variables for which data were taken, soil moisture had the strongest relationship to the clustering of communities in the ordination; soil type was also important. Canopy cover and slope were less important (Figure 4). The sand mine and successional dune communities clustered at the dry end of the soil moisture gradient, as well as the end of the soil type gradient that represented sand. The foredune community was grouped more loosely near the dry sand ends of the soil moisture and soil type gradients. The sphagnum bog, moat, and homesite communities clustered at the wet end of the soil moisture gradient, and the panne community, although it had a wider spread, also placed near the wet end of the soil moisture gradient. The foredune and successional dune communities clustered near the low end of the canopy cover gradient, and the high end of the slope gradient.

Figure 4. Ordination diagram for rare plant populations mapped in 2003 at Indiana Dunes National Lakeshore, showing communities delineated by cluster analysis and habitat variables influencing their grouping.



Many populations were in danger of being trampled, as hiking or deer trails passed directly through them; many others were either adjacent to or within a few meters of trails (Table 10). Of the Pitcher's thistle populations, 83% had trails running through them, reflecting the disturbance dependence of the species and the general proliferation of trails due to human activity. ATV trails were commonly seen at the Hobart Prairie Grove Unit, and could threaten some of the *Lathyrus venosus* populations. Animal browse rates were generally absent or low (Table 10). There were deer exclosures in place over the populations of *Clintonia borealis* and *Trillium cernuum* var. *macranthum*. While the entire *C. borealis* population was covered by the exclosure, the *T. cernuum macranthum* population was only partially covered, and the plants outside exclosures showed evidence of browse. Several other rare species showed signs of browse, but the number of populations sampled was small. Exotic plants, such as *Alliaria petiolata*, *Hesperis matronalis*, *Lonicera* spp., *Phalaris arundinacea*, and *Robinia pseudoacacia* were noted around several populations; encroachment was not noted, but would be likely if left uncontrolled.

Table 9. Communities delineated by cluster analysis at Indiana Dunes National Lakeshore. The number of populations of rare species are shown for each community, as are the associate species with mean abundances ≥1. Prefixes before the species name in the associate column identify the strata where the species were found: H = herb layer, S = shrub layer, T = tree layer.

Community	Rare species	Number of populations	Associate species	Mean abundance
AllElse	*Actaea rubra* (Ait.) Willd.	2	T *Quercus velutina* Lam.	1.2
	Aster sericeus Vent.	1		
	Calla palustris L.	2		
	Carex eburnea Boott	1		
	Cirsium pitcheri (Torr.) T. & G.	1		
	Clintonia borealis (Ait.) Raf.	1		
	Lathyrus japonicus var. *glaber* (Ser.) Fern.	1		
	Lathyrus venosus Muhl.	5		
	Scirpus hallii Gray	1		
	Trillium cernuum var. *macranthum* Wieg.	3		
	Valerianella chenopodiifolia (Pursh) DC.	1		
JackPine	*Carex eburnea* Boott	17	T *Pinus banksiana* Lamb.	3.9
			S *Rhus aromatica arenaria* (Greene) Fern.	2.2
			H *Celastrus orbiculatus* Thunb.	2.0
			S *Juniperus communis* L.	1.8
			S *Lonicera* L.	1.5
			S *Salix* L.	1.5
			H *Vitis riparia* Michx.	1.2
			T *Juniperus virginiana crebra* Fern. & Grisc.	1.2
			H *Hypericum kalmianum* L.	1.2
SphagBog	*Calla palustris* L.	3	H *Sphagnum* L.	3.7
	Habenaria ciliaris (L.) R. Br.	7	S *Vaccinium corymbosum* L.	3.5
			T *Larix laricina* (Du Roi) K.Koch	1.4
			H *Chamaedaphne calyculata* (L.) Moench var *angustifolia* (Ait.) Rehd.	1.3
			H *Carex* L.	1.2
			T *Rhus vernix* L.	1.2
			H *Rhynchospora alba* (L.) Vahl	1.2
			T *Acer rubrum* L.	1.0

Community	Rare species	Number of populations	Associate species	Mean abundance
BogMoat	*Calla palustris* L.	13	H *Polygonum* L.	1.9
			S *Cephalanthus occidentalis* L.	1.9
			S *Ilex verticillata* (L.) Gray	1.4
			H *Phalaris arundinacea* L.	1.2
			H *Lemna* L.	1.1
			T *Acer rubrum* L.	1.0
Foredune	*Cirsium pitcheri* (Torr.) T. & G.	82	H *Ammophila breviligulata* Fern.	3.8
			H *Andropogon scoparius* Michx.	2.3
			H *Calamovilfa longifolia* (H ook.) Scribn.	1.9
			H *Lithospermum croceum* Fern.	1.1
SuccDune	*Cirsium pitcheri* (Torr.) T. & G.	114	H *Andropogon scoparius* Michx.	3.7
			H *Calamovilfa longifolia* (Hook.) Scribn.	2.1
			H *Ammophila breviligulata* Fern.	2.1
			H *Lithospermum croceum* Fern.	1.7
			H *Corispermum hyssopifolium* L.	1.4
			H *Panicum villosissimum pseudopubescens* (Nash) Fern.	1.4
			H *Arabis lyrata* L.	1.2
			H *Artemisia caudata* Michx.	1.0
SandMine	*Cirsium pitcheri* (Torr.) T. & G.	6	H *Panicum villosissimum pseudopubescens* (Nash) Fern.	2.4
	Hudsonia tomentosa Nutt.	40	H *Artemisia caudata* Michx.	1.6
	Talinum rugospermum Holzinger	2	H *Panicum virgatum* L.	1.5
Panne	*Satureja arkansana* (Nutt.) Briq.	8	S *Hypericum kalmianum* L.	4.0
			H *Cladium mariscoides* (Muhl.) Torr.	2.9
			H *Scirpus pungens* Vahl	2.6
			H *Rhynchospora capillacea* Torr.	1.9
			T *Pinus banksiana* Lamb.	1.5
			H *Calamagrostis canadensis* (Michx.) Nutt.	1.5
			H *Aster ptarmicoides* (Nees) Torr. & Gray	1.3
			H *Aster dumosus* L.	1.1
			H *Pycnanthemum virginianum* (L.) Durand & Jackson	1.0

Community	Rare species	Number of populations	Associate species	Mean abundance
Homesite	*Spiranthes lucida* (H. H. Eaton) Ames	10	H *Scirpus acutus* Muhl.	4.0
			H *Salix* L.	3.0
			H *Carex* L.	3.0
			H *Scirpus cyperinus* (L.) Kunth	3.0
			H *Carex lacustris* Willd.	3.0
			H *Eleocharis* R. Br.	3.0
			H *Eleocharis erythropoda* Steud.	3.0
			H *Eupatorium* L.	3.0
			H *Glechoma hederacea* L.	3.0
			H *Juncus effusus* L.	3.0
			H *Carex stricta* Lam.	2.0
			H *Phragmites australis* (Cav.) Trin. ex Steud.	1.0
			H *Typha* L.	1.0
			T *Salix* L.	1.0

Table 10. Populations of rare plants threatened by human or animal disturbance at Indiana Dunes National Lakeshore.

	Disturbance			
	Foot traffic / trail through pop'n		Animal browse	
Species	# of pop'ns	% of pop'ns	# of pop'ns	% of pop'ns
Actaea rubra (Ait.) Willd.	0	0	0	0
Aster sericeus Vent.	0	0	0	0
Calla palustris L.	0	0	0	0
Carex eburnea Boott	10	55.6	0	0
Cirsium pitcheri (Torr. ex Eat.) Torr. & Gray	168	82.8	1	0.5
Clintonia borealis (Ait.) Raf.	0	0	0	0
Habenaria ciliaris (L.) R. Br. ex Ait. f.	0	0	1	14.3
Hudsonia tomentosa Nutt.	18	45.0	0	0
Lathyrus japonicus Willd. var. *glaber* (Ser.) Fern.	1	100.0	0	0
Lathyrus venosus Muhl. ex Willd.	5	100.0	0	0
Phlox bifida Beck	0	-	0	-
Satureja arkansana (Nutt.) Briq.	6	75.0	0	0
Scirpus hallii Gray	1	100.0	0	0
Spiranthes lucida (H.H. Eat.) Ames	10	100.0	10	100.0
Talinum rugospermum Holz.	2	100.0	0	0
Trillium cernuum L. var. *macranthum* Eames & Wieg.	0	0	2	66.7
Valerianella chenopodiifolia (Pursh) DC.	0	0.0	0	0
Total rare plants (excluding *Cirsium pitcheri*)	53	44.9	13	11.0
Total rare plants	221	68.8	14	4.4

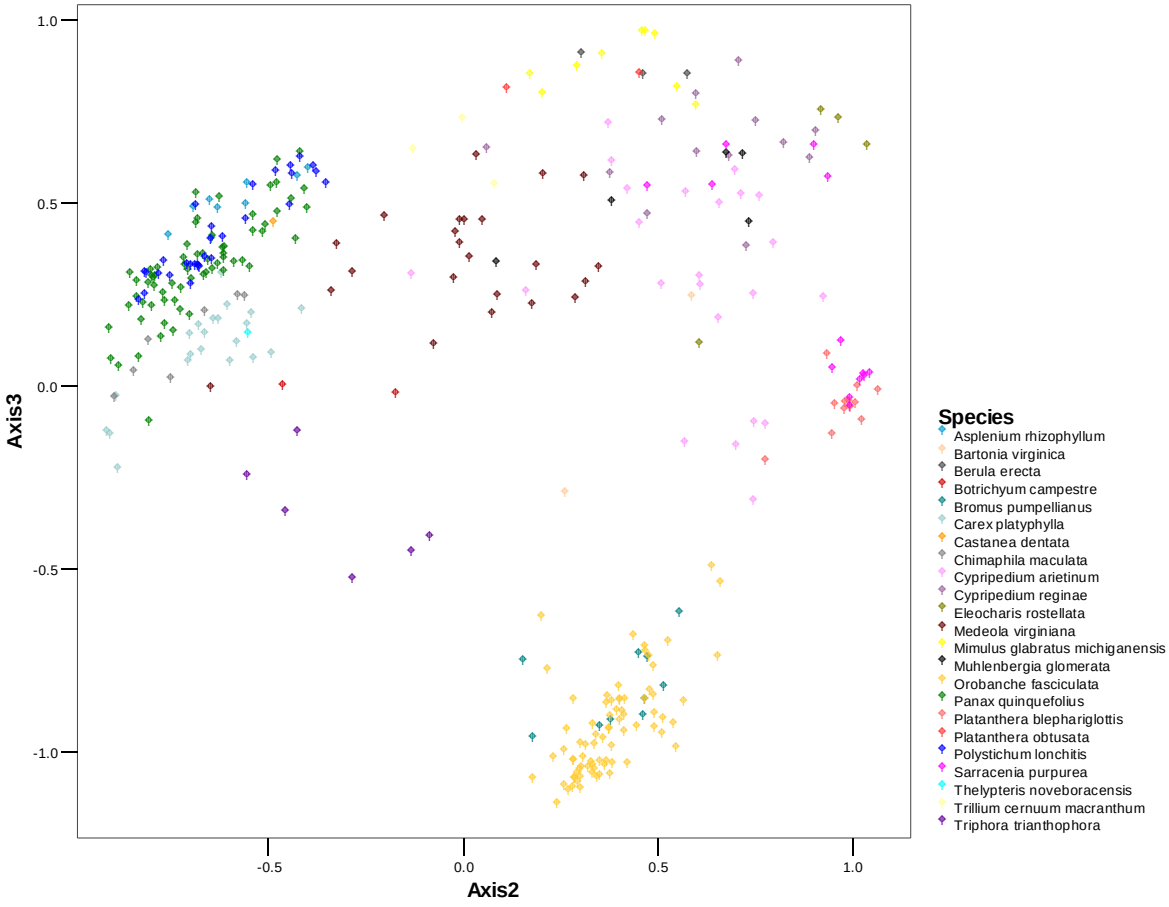
At SLBE, 23 rare species were mapped (Appendix 6-3). One, *Mimulus glabratus* var. *michiganensis*, is federally endangered, eleven are state listed (representing 61% of the state-listed plants known to occur in the Park), four were SLBE rare, six were listed as conservative, and one was on the list created by Emmet Judziewicz of species may occur in the park. Table 11 shows the number of populations for each species, and the mean number of plants per population. Three populations that were missing GPS data, and therefore do not appear on the map, were included in the summary statistics: one each of *Asplenium rhizophyllum*, *Orobanche fasciculata*, and *Panax quinquefolius*. Although previously known populations of *Cypripedium arietinum*, *Mimulus glabratus* var. *michiganensis*, *Panax quinquefolius*, and *Triphora trianthophora* had been digitized, new populations of these species were mapped as they were found; the locations of four previously digitized populations of *T. trianthophora* were recorded. Abundances of the rare species located ranged in size from single plants to patches of 2 to 41,594 plants. Mean patch size ranged from 2 - 4197 plants with high variation for most species. There were several patches for which the number of plants was estimated from meter square plots, which may have resulted in artificially high counts for one *Bromus pumpellianus* patch, one *Carex platyphylla* patch, and one *Eleocharis rostellata* patch. Only one plant species from the list by Emmet Judziewicz was found: a single population of *Thelypteris noveboracensis* in the Platte Bay Unit. In addition, *Dryopteris goldiana* (Goldie's woodfern) and *Phegopteris connectilis* (long beechfern), two ferns not previously recorded from the Park, were seen on the mainland and photographed.

Ordination showed that many rare species share similar habitats based on associate species composition (Figure 5). Due to missing associate species data, one *Trillium cernuum macranthum* population was not included in the ordinations.

Table 11. SLBE rare plant summary statistics.

Species	Number of populations	Mean population size	Standard deviation	Smallest population	Largest population	Total number of plants
Asplenium rhizophyllum L.	9	140	119.8	9	300	1,262
Bartonia virginica (L.) B.S.P.	2	39	44.5	7	70	77
Berula erecta (Huds.) Coville	3	237	246.1	12	500	712
Botrychium campestre W.H. Wagner & Farrar	2	5	.71	4	5	9
Bromus pumpellianus Scribn.	10	4,197	13,140.0	15	41,594	41,974
Carex platyphylla Carey	21	203	515.3	8	2,408	4,271
Castanea dentata (Marsh.) Borkh.	1	1	.	1	1	1
Chimaphila maculata (L.) Pursh	7	8	3.8	2	15	55
Cypripedium arietinum Ait. f.	23	174	215.1	1	999	3,996
Cypripedium reginae Walt.	13	36	38.0	1	106	469
Eleocharis rostellata (Torr.) Torr.	4	4,171	7,530.0	35	15,448	16,683
Medeola virginiana L.	23	50	69.9	3	346	1,143
Mimulus glabratus Kunth var. *michiganensis* (Pennell) Fassett	9	68	91.0	10	300	608
Muhlenbergia glomerata (Willd.) Trin.	5	88	90.8	35	250	441
Orobanche fasciculata Nutt.	77	2	2.8	1	18	185
Panax quinquefolius L.	67	6	5.4	1	23	372
Platanthera blephariglottis (Willd.) Lindl.	12	1	.7	1	3	17
Platanthera obtusata (Banks ex Pursh) Lindl.	2	3	2.1	1	4	5
Polystichum lonchitis (L.) Roth	30	5	5.1	1	17	164
Sarracenia purpurea L.	13	68	114.2	5	400	882
Thelypteris noveboracensis (L.) Nieuwl.	1	300	.	300	300	300
Trillium cernuum L. var. *macranthum* Eames & Wieg.	4	58	65.9	1	120	232
Triphora trianthophora (Sw.) Rydb.	6	4	2.1	2	8	26
Total	344	215	2,392.4	1	41,594	73,885

Figure 5. Ordination diagram for rare plant populations mapped in 2003 at Sleeping Bear Dunes National Lakeshore, showing species.



Eleven distinct communities were delineated by the cluster analysis, five of which were variations of the northern hardwood forest type (see Table 12 for species composition of the eleven communities). Many of the species' placements in ordination space were closely related to the community clusters. For example, *Bromus pumpellianus* and *Orobanche fasiclulata* grouped exclusively in the open dune community, and *Triphora trianthophora* grouped exclusively in the oak-aspen community. *Eleocharis rostellata* and *Muhlengergia glomerata* grouped exclusively in the sedge mat community. *Platanthera blephariglottis* grouped exclusively in the sphagnum bog (SphagBog) community. All but two populations of *Cypripedium reginae* grouped in the cedar-tamarack swamp (CTSwamp); the lack of *Larix laricina* (tamarack) as an associate caused the other two populations to group in the cedar swamp-northern hardwoods community (CSwamp/NH). Both the cedar-tamarack swamp and the sphagnum bog communities contained populations of *Sarracenia purpurea*; those populations with a high abundance of *Thuja occidentalis* (white cedar), *Larix laricina*, and *Thelypteris palustris* (eastern marsh fern) grouped in the cedar-tamarck swamp community, while those associated with *Chamaedaphne calyculata* (leatherleaf), *Sphagnum*, *Larix laricina*, *Picea mariana* (black spruce), and *Vaccinium oxycoccos* (small cranberry) grouped in the sphagnum bog community. *Cypripedium arietinum* grouped almost exclusively in the coastal forest community (CoastFor), with the exception of three populations that grouped in the mesic northern hardwoods community (MesicNH), due to either a high abundance of *Acer rubrum* (red maple) and *Maianthemum canadense* (Canda mayflower), or missing species that were of high abundance in the coastal forest community, such as *Pinus banksiana* (jack pine).

While the collections of associate species present in the five northern hardwood communities were quite distinct, the relationships of the rare species populations to those communities were less clear. Several of the rare species grouped in only one northern hardwood cluster, but many of the rare species appeared in more than one. The cedar swamp-northern hardwoods community contained the only populations of *Berula erecta*, *Mimulus glabratus* var. *michiganensis*, and *Platanthera obtusata*, as well as the two populations of *Cypripedium reginae* that were not part of the cedar-tamarack swamp community. The mesic northern hardwoods community (MesicNH) contained the only populations of *Bartonia virginica* and *Trillium cernuum* var. *macranthum*, the three populations of *Cypripedium arietinum* not in the coastal forest community, and all but one of the *Medeola virginiana* populations. The one other *Medeola virginiana* population grouped into the young northern hardwoods community (YoungNH) due to a high abundance of *Acer saccharum* (sugar maple) and *Fagus grandifolia* (American beech), and the absence of *Acer rubrum* (red maple) and *Pteridium aquilinum* (bracken fern). This community also contained the only populations of *Castenea dentata*, *Carex platyphylla*, *Chimaphila maculata*, and *Thelypteris noveboracensis*, as well as the two populations of *Cypripedium arietinum* that were not part of the cedar-tamarack swamp community. *Asplenium rhizophyllum* and *Botrychium campestre* grouped exclusively in the northern hardwoods-giant cedar (NH/GCedar) and the typical northern hardwoods (TypicNH) communities, respectively. *Panax quinquefolius* and *Polystichum lonchitis* were split into three northern hardwoods communities: giant cedar (ten and nine populations, respectively), typical (53 and 20 populations, respectively), and young (four and one populations, respectively).

Table 12. Communities delineated by cluster analysis at Sleeping Bear Dunes National Lakeshore. The number of populations of rare species are shown for each community, as are the associate species with mean abundances ≥1. Prefixes before the species name in the associate column identify the strata where the species were found: H = herb layer, S = shrub layer, T = tree layer.

Community	Rare species	Number of populations	Associate species	Mean abundance
NH/GCedar	*Asplenium rhizophyllum* L.	9	T *Acer saccharum* Marsh.	3.7
	Panax quinquefolius L.	10	H *Arisaema triphyllum* (L.) Schott	3.5
	Polystichum lonchitis (L.) Roth	9	S *Taxus canadensis* Marsh.	3.4
			S *Acer spicatum* Lam.	2.8
			H *Aralia nudicaulis* L.	2.1
			T *Thuja occidentalis* L.	1.8
			T *Fraxinus americana* L.	1.5
			H *Cystopteris bulbifera* (L.) Bernh.	1.5
			S *Sambucus pubens* Michx.	1.5
			H *Aralia racemosa* L.	1.3
			H *Actaea pachypoda* Ell.	1.2
			H *Smilacina racemosa* (L.) Desf.	1.2
			S *Cornus alternifolia* L.f.	1.0
			H *Allium tricoccum* Ait.	1.0
MesicNH	*Bartonia virginica* (L.) B.S.P.	2	T *Acer rubrum* L.	2.7
	Cypripedium arietinum Ait. f.	3	H *Maianthemum canadense* Desf.	2.4
	Medeola virginiana L.	22	H *Pteridium aquilinum* (L.) Kuhn	2.4
	Trillium cernuum var. *macranthum* Wieg.	3	H *Trientalis borealis* Raf.	1.4
			H *Aralia nudicaulis* L.	1.2
			T *Abies balsamea* (L.) P. Mill.	1.2
			T *Betula papyrifera* Marsh.	1.0
CSwamp/NH	*Berula erecta* (Huds.) Coville	3	T *Thuja occidentalis* L.	4.0
	Cypripedium reginae Walt.	2	H *Impatiens capensis* Meerb.	2.4
	Mimulus glabratus Kunth var. *michiganensis* (Pennell) Fassett	9	H *Nasturtium officinale* R.Br.	1.9
			T *Betula papyrifera* Marsh.	1.1
	Platanthera obtusata (Banks ex Pursh) Lindl.	2	H *Equisetum arvense* L.	1.0
			S *Acer spicatum* Lam.	1.0

Community	Rare species	Number of populations	Associate species	Mean abundance
TypicNH	*Botrychium campestre* W.H. Wagner & Farrar	2	H *Aralia nudicaulis* L.	3.4
			T *Acer saccharum* Marsh.	3.3
	Panax quinquefolius L.	53	H *Osmunda claytoniana* L.	2.0
	Polystichum lonchitis (L.) Roth	20	T *Fraxinus americana* L.	1.6
			S *Fraxinus americana* L.	1.5
			T *Ostrya virginiana* (Mill.) K.Koch	1.5
			H *Allium tricoccum* Ait.	1.3
			H *Arisaema triphyllum* (L.) Schott	1.1
			H *Maianthemum canadens*e Desf.	1.0
OpenDune	*Bromus pumpellianus* Scribn.	10	H *Calamovilfa longifolia* (Hook.) Scribn.	3.1
	Orobanche fasciculata Nutt.	77	H *Artemisia caudata* Michx.	2.8
			S *Prunus pumila* L.	1.3
			H *Koeleria macrantha* (Ledeb.) J.A. Schultes	1.0
			H *Andropogon scoparius* Michx.	1.0
			H *Gypsophila paniculata* L.	1.0
YoungNH	*Carex platyphylla* Carey	21	T *Acer saccharum* Marsh.	3.4
	Castanea dentata (Marsh.) Borkh.	1	T *Fagus grandifolia* Ehrh.	2.5
	Chimaphila maculata (L.) Pursh	7	H *Maianthemum canadense* Desf.	1.7
	Medeola virginiana L.	1	H *Solidago caesia* L.	1.7
	Panax quinquefolius L.	4	T *Ostrya virginiana* (Mill.) K.Koch	1.5
	Polystichum lonchitis (L.) Roth	1	S *Acer saccharum* Marsh.	1.4
	Thelypteris noveboracensis (L.) Nieuwl.	1		

Community	Rare species	Number of populations	Associate species	Mean abundance
CoastFor	*Cypripedium arietinum* Ait. f.	20	T *Pinus banksiana* Lamb.	2.9
			T *Thuja occidentalis* L.	2.6
			T *Quercus rubra* L.	1.7
			S *Prunus virginiana* L.	1.5
			S *Arctostaphylos uva-ursi* (L.) Spreng var. *coactilis* Fern. & Macbr.	1.5
			H *Smilacina stellata* (L.) Desf.	1.4
			H *Zigadenus glaucus* Nutt.	1.3
			H *Taraxacum officinale* Weber	1.2
			S *Pinus banksiana* Lamb.	1.2
			T *Abies balsamea* (L.) P. Mill.	1.1
			H *Poa compressa* L.	1.0
			S *Toxicodendron radicans* (L.) Kuntze	1.0
			T *Pinus strobus* L.	1.0
CTSwamp	*Cypripedium reginae* Walt.	11	T *Thuja occidentalis* L.	3.7
	Sarracenia purpurea L.	5	T *Larix laricina* (Du Roi) K.Koch	2.6
			H *Thelypteris palustris* Schott	2.4
			H *Equisetum arvense* L.	1.6
			S *Alnus rugosa* (Du Roi) Spreng.	1.4
			H *Maianthemum canadense* Desf.	1.2
			S *Larix laricina* (Du Roi) K.Koch	1.1
			S *Toxicodendron radicans* (L.) Kuntze	1.1

Community	Rare species	Number of populations	Associate species	Mean abundance
SedgeMat	*Eleocharis rostellata* (Torr.) Torr.	4	H *Equisetum laevigatum* A. Braun	1.9
	Muhlenbergia glomerata (Willd.) Trin.	5	H *Carex* L.	1.8
			H *Parnassia glauca* Raf.	1.8
			H *Solidago ulmifolia* Muhl.	1.6
			H *Eleocharis rostellata* Torr.	1.6
			S *Larix laricina* (Du Roi) K.Koch	1.3
			H *Equisetum arvense* L.	1.3
			S *Thuja occidentalis* L.	1.2
			H *Eupatorium perfoliatum* L.	1.1
			H *Lobelia kalmii* L.	1.1
			T *Larix laricina* (Du Roi) K.Koch	1.0
			H *Lycopus americanus* Muhl.	1.0
SphagBog	*Platanthera blephariglottis* (Willd.) Lindl.	12	S *Chamaedaphne calyculata* (L.) Moench	3.9
			H *Sphagnum* L.	3.4
	Sarracenia purpurea L.	8	T *Larix laricina* (Du Roi) K.Koch	3.3
			T *Picea mariana* (P. Mill.) B.S.P.	3.1
			S *Vaccinium oxycoccos* L.	3.0
			H *Gaultheria hispidula* (L.) Muhl. ex Bigelow	2.3
			S *Vaccinium myrtilloides* Michx.	2.3
			S *Kalmia polifolia* Wangenh.	2.2
			H *Carex trisperm*a Dew.	1.7
			H *Smilacina trifolia* (L.) Desf.	1.4
			T *Pinus strobu*s L.	1.4
OakAspen	*Triphora trianthophora* (Sw.) Rydb.	6	T *Populus grandidentata* Michx.	3.7
			T *Fagus grandifolia* Ehrh.	2.3
			T *Quercus rubra* L.	1.8
			S *Acer pensylvanicum* L.	1.7

Of the habitat data taken, canopy cover had the strongest relationship to the clustering of communities in the ordination; soil moisture was less important (Figure 6). The open dune and Sphagnum bog communities clustered at the low end of the canopy cover gradient, the oak-aspen and sedge mat communities grouped at its mid-range, and the northern hardwood-giant cedar community clustered at the high end; all the other communities were spread among these extremes. The cedar swamp-northern hardwoods, cedar-tamarack swamp, and sedge mat communities spread across the high end of the soil moisture gradient, the sphagnum bog community clustered at its mid-range, and the open dune and oak-aspen communities spread across its low end.

Several threats to populations of rare plants were noted (Table 13), although these threats were not as great as those at INDU. Several populations had hiking trails passing directly through them, and many others were either adjacent to or within a few meters of trails. These were often rogue trails, e.g. to one of the populations of *Berula erecta*. Several populations of orchids (especially *Cypripedium reginae* and *Triphora trianthophora*) and surrounding plants were trampled, presumably by nature photographers, and showed signs of being trampled continuously over a number of years. Damage by animals was also noted in many populations, usually in the form of deer browse on plants (Table 13). Other signs of abundant deer populations were often noted, usually without direct damage to plants. Species with high proportions of populations with deer browse were *Cyprpedium reginae*, *Mulhenbergia glomerata*, and *Plantanthera obtusata*. The presence of exotic species, such as *Centaurea maculosa*, *Gypsophila paniculata*, *Melilotus* spp., *Poa compressa*, *Silene vulgaris*, and *Vinca minor*, was also noted often, and was most commonly described as scattered patches near rare populations. In several cases, however, *Gypsophila paniculata* and *Vinca minor* were noted as directly encroaching on a rare plant population.

Figure 6. Ordination diagram for rare plant populations mapped in 2003 at Sleeping Bear Dunes National Lakeshore, showing communities delineated by cluster analysis and habitat variables influencing their grouping.

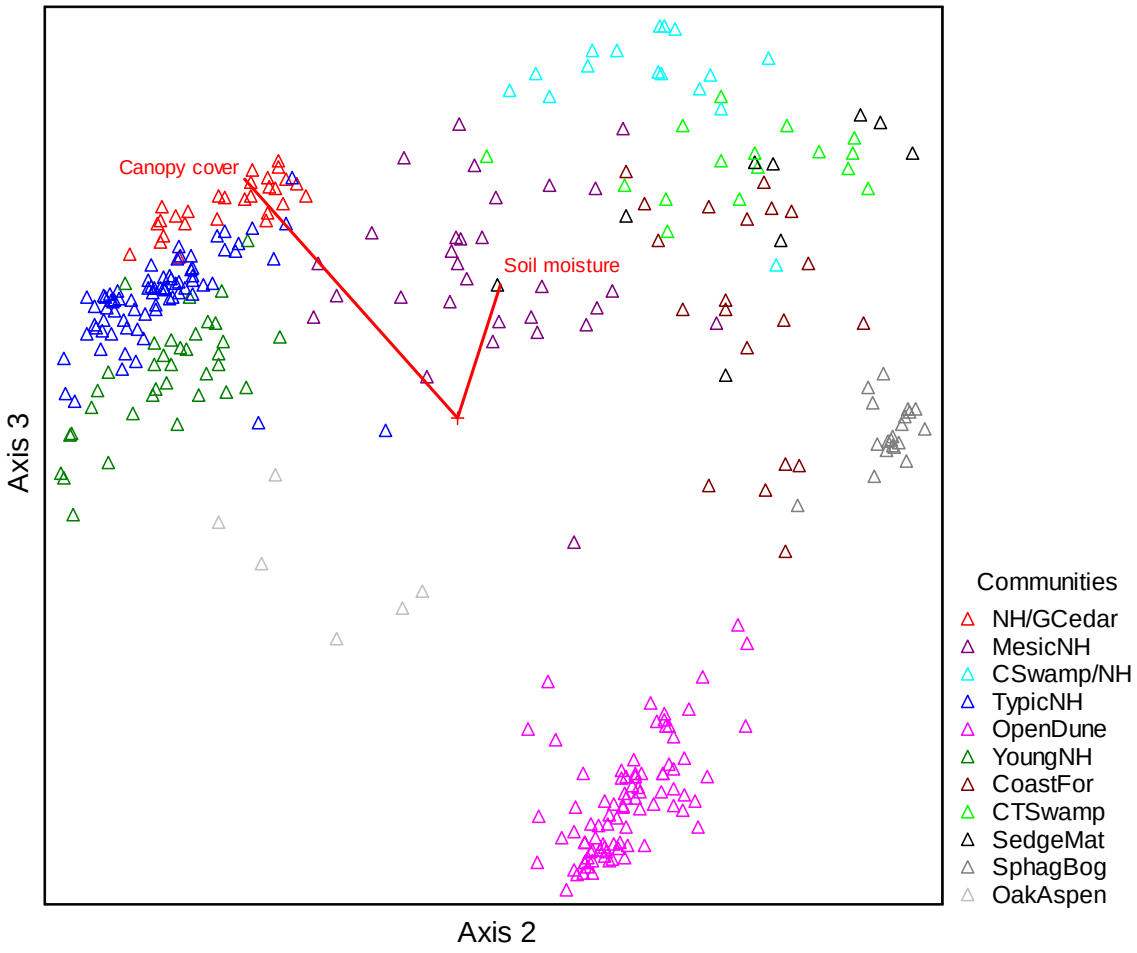


Table 13. Populations of rare plants threatened by human or animal disturbance at Sleeping Bear Dunes National Lakeshore.

	Disturbance			
	Foot traffic / trail through pop'n		Animal browse	
Species	# of pop'ns	% of pop'ns	# of pop'ns	% of pop'ns
Asplenium rhizophyllum L.	0	0	0	0
Bartonia virginica (L.) B.S.P.	0	0	0	0
Berula erecta (Huds.) Coville	1	33.3	0	0
Botrychium campestre W.H. Wagner & Farrar	0	0	0	0
Bromus pumpellianus Scribn.	0	0	0	0
Carex platyphylla Carey	0	0	0	0
Castanea dentata (Marsh.) Borkh.	0	0	0	0
Chimaphila maculata (L.) Pursh	0	0	1	14.3
Cypripedium arietinum Ait. f.	0	0	5	20.0
Cypripedium reginae Walt.	5	38.5	8	61.5
Eleocharis rostellata (Torr.) Torr.	0	0	1	25.0
Medeola virginiana L.	1	4.3	0	0
Mimulus glabratus Kunth var. *michiganensis* (Pennell) Fassett	0	0	0	0
Muhlenbergia glomerata (Willd.) Trin.	0	0	2	40.0
Orobanche fasciculata Nutt.	1	1.3	0	0
Panax quinquefolius L.	3	4.5	1	1.5
Platanthera blephariglottis (Willd.) Lindl.	0	0	1	8.3
Platanthera obtusata (Banks ex Pursh) Lindl.	0	0	1	50.0
Polystichum lonchitis (L.) Roth	0	0	0	0
Sarracenia purpurea L.	0	0	0	0
Thelypteris noveboracensis (L.) Nieuwl.	0	0	0	0
Trillium cernuum L. var. *macranthum* Eames & Wieg.	0	0	0	0
Triphora trianthophora (Sw.) Rydb.	1	16.7	0	0
Total rare plants	12	3.5	20	5.8

Exotic Plants

At INDU, 335 populations of exotic plants were recorded by GPS (Appendix 6-4). There were 35 single plants mapped, 66 small patches, 95 large patches, and 139 linear patches (Table 14). Of the original target species, *Alliaria petiolata*, *Celastrus orbiculatus*, and *Polygonum cuspidatum* were mapped throughout the Park; *Lythrum salicaria* was mapped in the East Unit, and mapping was begun in Miller Woods. The locations of other species were recorded by GPS as they were encountered during exotic or rare plant mapping or during common reed sampling. The populations mapped do not represent all the exotic plants present in the Park, except in the case of *Centaurea maculosa*, which was mapped along the major train corridor. The mapping of *Centaurea maculosa* was therefore the most comprehensive in the park, while that of other species was less complete.

An estimated total of 534,448 exotic plants were mapped (Table 15). Mapped plants ranged in size from single plants to patches containing between 7 and 121,141 plants. Mean population size ranged from 7 to 13,773 plants, with high variation for most species. The mean population size for the 335 populations mapped was 1,624 plants. The number of plants in most populations was counted as described in the Methods section, which ensured highly accurate results. However, many patches were so large or densely populated that it was impractical to count individual plants across the entire population. In these cases, the number of plants in the patch was estimated by multiplying the number of plants per square meter (determined by averaging the number of plants in representative square meter plots) by the patch size. This process was used for 93 *Centaurea maculosa* populations, 6 *Lythrum salicaria* populations, and 29 *Phragmites australis* populations. There were no population size estimates for some of the digitized patches: one patch each of *Celastrus orbiculatus*, *Phragmites australis*, *Robinia*

Table 14. INDU exotic plant populations mapped, by feature type.

Species	Individual	Small patch	Large patch	Linear patch	Total
Alliaria petiolata (Bieb.) Cavera & Grande	7	18	16	4	45
Celastrus orbiculatus Thunb.	1	4	6	2	13
Centaurea maculosa auct. non Lam.	20	35	23	126	204
Cirsium arvense (L.) Scop.		1	4		5
Elaeagnus L.	2				2
Gypsophila scorzonerifolia Ser.			1		1
Lonicera L.			2		2
Lythrum salicaria L.	3	4	5	4	16
Phalaris arundinacea L.		3	2		5
Phragmites australis (Cav.) Trin. ex Steud.		1	22	2	25
Polygonum cuspidatum Sieb. & Zucc.		1	4	1	6
Rhamnus cathartica L.	1				1
Robinia pseudoacacia L.			2		2
Rosa multiflora Thunb. ex Murr.	1		1		2
Total	35	67	88	139	329

pseudoacacia, and *Rosa multiflora*, and 2 *Phalaris arundinacea* patches. These populations that lacked counts were not included in the analysis; this resulted in an artificially low estimate for the total number of plants for these species.

At SLBE, exotics were mapped by the Exotic Plant Management Team. Common reed was the only exotic plant species of which we recorded GPS coordinates for this project; results are presented in the next section. Two new exotics to the Park were seen and photographed: *Datura stramonium* and *Lamium galeobdolon* (Appendix 7).

Table 15. INDU exotic plant summary statistics. Numbers of populations in bold font include populations with zero values for number of plants. Mean, standard deviation, smallest and largest population, and total number of plants for these species were calculated based on the number of populations excluding the zero values (in parentheses).

Species	Number of populations	Mean population size	Standard deviation	Smallest population	Largest population	Total number of plants
Alliaria petiolata (Bieb.) Cavera & Grande	45	942	1,793.6	1	10,000	42,372
Celastrus orbiculatus Thunb.	**13** (12)	1,683	3,702.2	1	10,001	21,874
Centaurea maculosa auct. non Lam.	204	563	2,443.1	1	32,485	114,870
Cirsium arvense (L.) Scop.	5	1,108	1,095.1	7	2,500	5,538
Elaeagnus L.	2	1	0.000	1	1	2
Gypsophila scorzonerifolia Ser.	1	14	-	14	14	14
Lonicera L.	2	600	565.7	200	1,000	1,200
Lythrum salicaria L.	16	434	1,010.8	1	3,705	6,950
Phalaris arundinacea L.	**5** (3)	73	128.3	17	300	367
Phragmites australis (Cav.) Trin. ex Steud.	**25** (24)	13,308	26,021.6	16	121,237	332,698
Polygonum cuspidatum Sieb. & Zucc.	6	203	154.7	25	436	1,216
Rhamnus cathartica L.	1	1	-	1	1	1
Robinia pseudoacacia L.	**2** (1)	25	35.4	50	50	50
Rosa multiflora Thunb. ex Murr.	2	131,475	185,932.3	1	262,949	262,950
Total	**329** (323)	2,402	16,529.1	1	262,949	790,101

Common reed (*Phragmites australis*) sampling

At INDU, specimens from 27 patches of common reed were sent to the Phragmites Diagnostic Service web page. Four patches were determined to be of native origin; 23 patches were exotic (Appendix 6-5).

At SLBE, specimens from 71 patches of common reed were sent to the Phragmites Diagnostic Service web page. 54 patches were determined to be of native origin; 17 patches were exotic (Appendix 6-6).

SUMMARY

Indiana Dunes National Lakeshore

Based on data taken at 329 populations of rare plants at INDU, some generalizations may be made about the populations and habitat specificity of the species that were mapped.

A total of 6536 *Cirsium pitcheri* plants were mapped in 205 populations. McEachern (1992a) estimated 2370 plants; however, the difference in methods used for the two studies contributes to the difference in number of plants. Each individual plant was counted for this study, while McEachern estimated the number of plants on a landscape scale (e.g. in a blowout). Searches for plants, especially the diminutive seedlings, were more intensive in this study; 2084 of the plants counted were seedlings. Several of the populations mapped in 1992 were not relocated, but there were many new populations found during this study, including several beach and foredune populations in Dune Acres and the Dunes State Park. In addition, many of the patches mapped in 1992 had spread in size and increased in number, most notably at West Beach. All populations were found in the same habitat types as the 1992 study. *Cirsium pitcheri* occurs in non-forested dunes of the Great Lakes, most frequently in near-shore communities (Pavlovic et al. 2002). At INDU, the species has been known from early- to mid-successional patches on the dry sand of beaches, simple linear foredunes, and blowouts, associating with sparse prairie-like communities (Bowles et al. 1986a, McEachern 1992). The dune communities in which *Cirsium pitcheri* were found during this study were dry sandy habitats with little to no tree canopy cover. The most common associate species were *Ammophila breviligulata* (marram grass), *Andropogon scoparius* (little bluestem grass), and *Calomovilfa longifolia* (sand reed). The main difference between the two communities that contained almost all of the *C. pitcheri* populations was the abundance of the main associate species; the foredune communities were dominated by *A. breviligulata*, while the successional dune communities were dominated by *A. scoparius*. The six *C. pitcheri* populations that were the exception to this generalization were also dominated by *A. scoparius*, but had no *A. breviligulata* and very little *C. longifolia*; instead they had a high abundance of *Panicum villosissimum pseudopubescens* (false white-haired panic grass). While these populations were not physically located in areas that had a history of sand mining, this difference in associate species made them more similar to the sand mine community than either dune community.

The communities in which the *Hudsonia tomentosa* populations were found were also dry sandy habitats. Several factors distinguished these habitats from the dune communities in which most of the *C. pitcheri* populations were found. The sand mine communities often included a tree layer, which was dominated by *Quercus velutina* (black oak). They were also composed of a different suite of herbaceous associates; *Panicum villosissimum pseudopubescens* dominated the herbaceous layer, and *Artemesia caudata* (beach wormwood) and *Panicum virgatum* (switchgrass) were common. Another difference was the disturbance history, which was noted but not quantified during data collection. Almost all of the populations mapped occurred in or adjacent to recovering sand mines; most populations not within sand mines were in powerline rights-of-way or old railroad beds nearby. At INDU, *H. tomentosa* is associated with open, disturbed, sandy sites (Bowles et al. 1986a, Swink and Wilhelm 1994).

Once we have obtained the population size data from 1991, we will perform a geospatial analysis of Pitcher's thistle patches on the dune landscape. We want to know how many patches have been extirpated, how many are new, and how many have remained generally the same of the 12 year period. These kinds of staitistics are important for the restoration and conservation of Pitcher's thistle metapopulations.

Carex eburnea, a species more common in the northern hardwoods region, was found primarily in jack pine stands, a later successional community within the sand dune complex. It was common at the limited sites in which it was found. At INDU, it is known to occur in several kinds of habitats, including low sand ridges, mesic sand forests on high dunes, and the edge of a panne (Bowles et al. 1985, Swink and Wilhelm 1994).

Calla palustris, *Habenaria ciliaris*, *Satureja arkansana*, and *Spiranthes lucida* were all associated with wetter communities, on loam, peat, or muck soils. At INDU, *C. palustris* was only known from the moat around Pinhook Bog, where it was the dominant species (Bowles et al. 1985, Swink and Wilhelm 1994); it was also found in the *Sphagnum*-dominated bog community during this study. Thus, it appeared to have a wider range of habitat requirements than *H. ciliaris*, which was found only in the *Sphagnum*-dominated bog. *Habenaria ciliaris* requires a slightly acidic substrate and high light levels, and at INDU was known to grow only in sphagnum peat within canopy gaps at Pinhook Bog (Bowles et al. 1986a, Swink and Wilhelm 1994)). In contrast, most of the populations mapped during this study were found under a canopy of *Vaccinium corymbosum* (highbush blueberry), with some *Larix laricina* (tamarack), *Rhus vernix* (poison sumac), and *Acer rubrum* (red maple). *Satureja arkansana* was found only in the panne community; it was known at INDU in calcareous, sandy, wet-mesic pannes and prairies (Bowles et al. 1986a). *Spiranthes lucida* was found only in a restored homesite; it has been known in this area mainly in marly fens and wet calcareous praires (Swink and Wilhelm 1994), and at INDU was previously known in only one location, at another old homesite (Wilhelm 1990).

The rarity of populations of *Actaea rubra*, *Aster sericeus*, *Clintonia borealis*, *Lathyrus japonicus* var. *glabra*, *L. venosus*, *Scirpus hallii*, *Trillium cernuum* var. *macranthum*, and *Valerianella chenopodiifolia* made it difficult to generalize about habitat requirements. Respectively, these species were found in oak woodland, savanna, floodplain forest, blowout, open oak woods, seasonally flooded wetland, red maple swamp and oak forest, and ephemeral swamp edge communities.

Newly arriving invasive species, *Centaurea maculosa*, *Gypsophila scorzonerifolia*, *Polygonum cuspidatum*, and *Rhamnus cathartica*, should be high priorities for eradication. The first two species are invading the park along the major railroad corridors, so will require coordination with railroads for their removal. Spotted knapweed has been present along the Indiana Harbor Belt railroad bed since the early 1980's in very small numbers, but the extensive populations now present along the major railroad corridors, suggests the lag phase of invasion will soon transition into the expansion phase. In light of the 2004 discovery of *Centaurea maculosa* in high quality savanna in Miller Woods (Paul Labus, pers. comm.) and the inherent biochemical means for successful proliferation of this species (Callaway and Aschehoug 2000, Callaway and Ridenour 2004), delay could be devastating for the habitat of the Karner blue

butterfly and other species. This species is now expanding along the NIPSCO right of way from the South Shore Train line tracks in the East Unit.

Despite the ubiquity of nonindigenous *Phragmites australis* (Cav.) Trin. ex Steud. in the wetlands of the park, a small percentage was found to consist of native genotypes. *Phragmites australis* subsp. *americanus* Saltonstall, P.M. Peterson & Soreng populations should not be eradicated (Saltonstall et al. 2004); however, they should be monitored to document whether they are aggressive. Now that the North American genotype has been elevated to the species level, some states are considering listing it as being endangered or threatened.

Sleeping Bear Dunes National Lakeshore

Based on data taken at 341 populations of rare plants at SLBE, some generalizations may be made about the populations and habitat specificity of the species that were mapped. *Bromus pumpellianus* and *Orobanche fasciculata* were found only on open dunes, in dry sand with no overstory canopy. The range of both species in Michigan is restricted to the shore of the lake, where *B. pumpellianus* occurs on sandy shores, and both species occur on sandy dunes (Voss 1996); at SLBE, both species have been known from perched dunes, and *O. fasciculata* is also known from bay dunes (Hazlett et al. 1983, Hazlett 1991).

Triphora trianthophora was found only in moist sand under a partial canopy dominated by *Populus grandidentata* (bigtooth aspen), *Fagus grandifolia* (American beech), and *Quercus rubra* (northern red oak). This species grows in deep humus in rich beech-sugar maple or mixed deciduous forests (Case 1987); it was previously known only from northern hardwoods at SLBE (Hazlett 1991).

Eleocharis rostellata and *Muhlenbergia glomerata* were found only in inundated clay or muck soils of sedge mats, at edges of or openings in a cedar-tamarack swamp. While both species are known from marshes, shores, bogs, boggy meadows, often at calcareous sites, throughout their ranges in Michigan (Voss 1972), at SLBE they are only known from sedge mats (Hazlett 1991).

Platanthera blephariglottis was found in a single Sphagnum bog, in saturated peat soils with little to no canopy. This is the only habitat in which this species occurs throughout its Michigan range, including at SLBE (Voss 1972, Hazlett 1991).

All but two populations of *Cypripedium reginae* were found in swamps dominated by *Thuja occidentalis* (white cedar) and *Larix laricina* (tamarack), in moist loam soils under a partial canopy. The other two populations were found in a wet northern hardwoods community dominated by *Thuja occidentalis*, in moist loam or clay soils under a partial canopy. This species is known to occur in bogs and coniferous swamps throughout the state (Voss 1972); at SLBE, it is known from cedar swamps and wet woods (Hazlett 1991).

Populations of *Sarracenia purpurea* were found in a Sphagnum bog as well as in cedar-tamarack swamps. All populations grew in saturated peat soils; the swamp populations had a partial canopy, while some of the bog populations were in canopy openings. This species occurs in bogs and tamarack swamps, where it can tolerate substantial shading, and in fens and boggy interdunal flats and pools throughout the state, (Voss 1985); at SLBE, it is known from bogs and some sedge mats (Hazlett 1991).

All but three populations of *Cypripedium arietinum* occurred in coastal forests dominated by *Pinus banksiana* (jack pine) and/or *Thuja occidentalis*; the other three populations were found in mesic northern hardwood forests dominated by *Acer rubrum* (red maple). All populations grew in moist sand under a partial canopy. This species is known primarily from low dunes along northern shores in the state, where it grows best in partial shade of fringing conifers (Voss 1972); at SLBE, it is known from jack pine stands and coastal forests (Hazlett 1991).

Berula erecta, *Mimulus glabratus* var. *michiganensis*, and *Platanthera obtusata* were found only in cedar swamps and wet northern hardwood forests dominated by *Thuja occidentalis*, on wet to inundated soils under a partial canopy. *Berula erecta* populations were found in inundated sand and clay soils. This species usually occurs in calcareous soils, in cold streams, marshes, and tamarack swamps (Voss 1985), and at SLBE is known from springs (Hazlett 1991). *Mimulus glabratus michiganensis* grew in inundated sand. This species occurs in calcareous soils in marly springs, cold streams through cedar swamps, shores, and associated ditches (Voss 1996), and at SLBE is known from shore habitats (Hazlett 1991) . *Plantanthera obtusata* grew in wet loam soils. This species occurs in coniferous swamps and woods, boggy spots in mixed woods, and coniferous bog borders (Voss 1972), and at SLBE is known from cedar swamps (Hazlett 1991).

All populations of *Bartonia virginica* and *Trillium cernuum* var. *macranthum*, and all but one population of *Medeola virginiana* were found in mesic northern hardwood communities dominated by *Acer rubrum*. *Berula virginica* populations were found in moist peat soils under a partial canopy. This species occurs in moist sandy ditches, shores, and hollows, depressions in woods, low woods, and mossy swamps throughout the state (Voss 1996); at SLBE, it has been found in moist woods (Hazlett 1991). *Trillium cernuum macranthum* populations were found in dry to moist sand and loam soils, under open or partial canopy. This species occurs in coniferous swamps and borders of bogs, moist or swampy mixed woods, and thickets along streams throughout the state (Voss 1972); at SLBE, it has been found in northern hardwoods (Hazlett 1991). *Medeola virginiana* populations were found in moist to wet sand or loam soils under fuller partial canopy. This species occurs in moist or swampy woods, such as beech-maple forests, hemlock knolls, cedar bogs throughout the state (Voss 1972); at SLBE, it has been found in northern hardwoods (Hazlett 1991).

All populations of *Castanea dentata*, *Carex platyphylla*, *Chimaphila maculata*, and *Thelypteris noveboracensis* were found in young northern hardwoods dominated by *Acer saccharum* (sugar maple) and *Fagus grandifolia* (American beech). All populations were found under greater than 50% canopy cover; the one population of *T. noveboracensis* was found in moist loam, and the other three species were found in moist to dry sand. *Castenea dentata* occurrences in northern Michigan are thought to be progeny of specimens planted after the near extermination of the species further south in the state (Voss 1985); at SLBE, it is known from two sites just within woods (Hazlett 1991). *Carex platyphylla* was once known only from wooded slopes in St. Clair county (Voss 1972); it has since been recorded in dry northern hardwoods at SLBE (Hazlett 1991). *C. maculosa* occurs in Michigan in several kinds of deciduous forests (Voss 1996), and at SLBE in moist woods (Hazlett 1991). *Thelypteris noveboracensis* is known to occur in moist woods, especially near swamps, streams, and in vernal seeps (Flora of North America Editorial Committee 1993), at SLBE, the species has been recorded in northern hardwoods and coastal forests (Hazlett et al. 1983).

All populations of *Asplenium rhizophyllum* occurred on moist loam soils in northern hardwood-giant cedar communities dominated by *Acer saccharum* with a fuller partial canopy. This species occurs in shaded, rocky woods (Flora of North America Editorial Committee 1993),

and at SLBE has been known from rich northern hardwoods, particularly a grove known as "Giant Cedars" on South Manitou Island (Hazlett 1991).

The two populations of *Botrychium campestre* occurred in *Acer saccharum-Fraxinus americana* (white ash) dominated northern hardwoods on a perched dune, on moist sand under a fuller partial canopy. This species occurs in prairies, dunes, grassy railroad sidings, and fields over limestone (Flora of North America Editorial Committee 1993), and has been known from perched dunes at SLBE (Hazlett 1991).

Populations of *Panax quinquefolius* and *Polystichum lonchitis* were found in three distinct northern hardwood communities: a northern hardwood-giant cedar community dominated by *Acer saccharum*, a typical northern hardwood community dominated by *Acer saccharum* and *Fraxinus americana*, and a young northern hardwood community dominated by *Acer saccharum* and *Fagus grandifolia*. All populations of both species grew in moist sand under greater than 50% canopy cover, regardless of which northern hardwood community they were found in, with the exception of four populations of *P. quinquefolius* that were found in dry sand in the typical northern hardwood community. *Panax quinquefolius* occurs in rich even swampy forests throughout the state (Voss 1985). *Polystichum lonchitis* occurs mostly in boreal and subalpine forests or alpine regions, in rock crevices or at the base of boulders (Flora of North America Editorial Committee 1993). Both species are known to occur in rich hardwoods at SLBE (Hazlett 1991).

Datura stramonium (Jimson-weed) and *Lamium galeobdolon* (yellow archangel) are new to the Park. *Datura stramonium* is an annual that thrives in cultivated fields and waste places; it is probably of American origin, and has become widespread across the United States and into southern Canada (Muenscher 1955, Gleason and Cronquist 1991, Voss 1996). It is distributed in almost every state in the U.S., including Michigan, but has not been previously recorded from Benzie and Leelanau counties (Voss 1996, USDA NRCS 2004); it is considered an invasive weed (USDA NRCS 2004). *Lamium galeobdolon* is an exotic perennial that has only been recorded from several northeastern states, and has not previously been seen in Michigan (USDA NRCS 2004); it is widely cultivated in the U.S. and can spread invasively under optimum growing conditions (Missouri Botanical Garden 2004). In 2005 we discovered a population of this 'dead nettle' growing adjacent to an abandoned homesite at Indiana Dunes.

The few nonindigenous invasive populations of *Phragmites australis* (Cav.) Trin. ex Steud. found at SLBE should be eradicated as soon as possible to prevent their further spread and genetic crossing with the dominant native subspecies (*Phragmites australis* subsp. *americanus* Saltonstall, P.M. Peterson & Soreng).

CONCLUSIONS

Respectively, a total of 16 and 23 rare plant species in 331 and 341 populations were mapped at Indiana Dunes National Lakeshore and Sleeping Bear Dune National Lakeshore. Both parks harbor considerable populations of state-listed species, which should be protected. The habitat specificity of the rare plants sampled is striking; this observation strongly supports the importance of habitat preservation. National parks with high quality indigenous habitats are therefore special places that need to be preserved. Major threats to rare plant populations and high quality habitats, besides climate change and atmospheric deposition, include habitat and population fragmentation, trampling by both humans and animals, deer browsing, and encroachment by exotic species. Some species, especially some orchids, appear to be experiencing high rates of browse; further research needs to be conducted on whether these species are being impacted. The rare plant data can be used to model plant distribution across the parks using GIS spatial analysis on habitat and environmental variable associations.

Both parks have substantial problems with exotic species. Here we document, for the first time, the large scale invasion of spotted knapweed into the Indiana Dunes, a species that is ubiquitous in the old fields and dunes at Sleeping Bear Dunes. Spotted knapweed represents a significant threat to high quality savanna/woodland complex at the Indiana Dunes. We also document the persistence of the native *Phragmites* subspecies at Indiana Dunes despite the onslaught of the Eurasian invasive, as well as the considerable reserves of the native Phragmites harbored at Sleeping Bear Dunes. The latter should be protected through eradication of the Eurasian species. The exotic plant data can be used to model their distribution at Indiana Dunes.

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Appendix 1. Indiana listed endangered, threatened, and rare plants found and reported from Indiana Dunes National Lakeshore. Included are The Nature Conservancy (TNC) global and state ranks for each species. The 'Search' column refers to species that were proposed to be searched for during the project. Ranks are defined below. The 'Map and GIS' column refers to species that were proposed to be mapped based on preexisting data and to have the location recorded with GPS when found. Extirpated plants have been searched for extensively and were not searched for explicitly during this project.

Species	State Status	TNC Global Rank	TNC State Rank	Search	Map & GIS
Actaea rubra (Ait.) Willd.	Rare	G5	S2		X
Amelanchier humilis Wieg.	Endangered	G5	S1		
Andromeda glaucophylla Link	Rare	G5	S2		
Arabis glabra (L.) Bernh.	Threatened	G5	S2		
Aralia hispida Vent.	Endangered	G5	S1	X	X
Arctostaphylos uva-ursi (L.) Spreng var. *coactilis* Fern. & Macbr.	Rare	G5	S2		
Arenaria stricta Michx.	Rare	G5	S2		
Aristida intermedia Scribn. & Ball	Rare	G?	S2		
Aristida tuberculosa Nutt.	Rare	G5	S2		
Aster borealis Prov. (*A. junciformis*)	Rare	G5	S2		
Aster furcatus Burgess	Rare	G3G4	S2	X	
Aster ptarmicoides (Nees) T. & G.	Rare	G5	S2		
Aster sericeus Vent.	Rare	G5	S2	X	X
Betula populifolia Marsh.	Extirpated	G5	SX		
Botrychium matricariaefolium A. Br.	Threatened	G5	S2		
Botrychium multifidum var. *intermedium* (D. C. Eat.) Farw.	Extirpated	G5T4T5	SX		
Botrychium simplex E. Hitchc.	Endangered	G5	S1		
Buchnera americana L.	Endangered	G5	S1	X	X
Calla palustris L.	Endangered	G5	S1		X
Carex atherodes Spreng.	Endangered	G5	S1		
Carex atlantica var. *capillacea* (L. H. Bailey) Cronquist	Endangered	G5T5	S1		
Carex aurea Nutt.	Rare	G5	S2		X
Carex bebbii Olney	Threatened	G5	S2		
Carex chordorrhiza L.	Endangered	G5	S1	X	X
Carex conoidea Schkuhr	Endangered	G4	S1		X
Carex cryptolepis Mack. (*C. flava fertilis*)	Threatened	G5	S2		
Carex debilis var. *rudgei* Bailey	Threatened	G5T5	S2		
Carex eburnea Boott	Rare	G5	S2	X	X
Carex folliculata L.	Threatened	G4G5	S2		
Carex garberi Fern.	Threatened	G4	S2		Done
Carex gravida Bailey	Endangered	G5	S1		

Species	State Status	TNC Global Rank	TNC State Rank	Search	Map & GIS
Carex leptonervia Fern.	Endangered	G4	S1		X
Carex limosa L.	Endangered	G5	S1		
Carex pedunculata Muhl.	Rare	G5	S1		
Carex seorsa Howe	Rare	G4	S2		
Catalpa speciosa Warder	Rare	GU	S2		
Chimaphila umbellata cisatlantica Blake	Threatened	G5T5	S2		X
Chrysosplenium americanum Schwein.	Threatened	G5	S2		
Circaea alpina L.	Extirpated	G5	SX		
Cirsium pitcheri (Torr.) T. & G.	Threatened (Federal)	G3	S2	X	X
Clintonia borealis (Ait.) Raf.	Endangered	G5	S1		X
Cornus canadensis L.	Endangered	G5	S1		X
Cornus rugosa Lam.	Rare	G5	S2		
Corydalis sempervirens (L.) Pers.	Endangered	G4G5	S1		
Cyperus houghtonii Torr.	Rare	G4	S2		
Cypripedium calceolus var. *parviflorum* (Salisb.) Fern.	Rare	G5	S2		
Cypripedium candidum Muhl.	Rare	G4	S2	X	
Diervilla lonicera Mill.	Rare	G5	S2		
Drosera intermedia Hayne	Rare	G5	S2		X
Dryopteris clintoniana (D.C. Eaton) Dovell	Extirpated	G5	SX		
Eleocharis geniculata (L.) R. & S.	Threatened	G5	S2		X
Eleocharis melanocarpa Torr.	Threatened	G4	S2		X
Eleocharis microcarpa var. *filiculmis* Torr.	Endangered	G5	S1		X
Eleocharis wolfii Gray	Rare	G4G5	S2		X
Epilobium angustifolium L.	Endangered	G5	S1		
Equisetum variegatum Schleich.	Endangered	G5	S1		
Eriocaulon septangulare With.	Endangered	G5	S1		
Eriophorum angustifolium Honckeny	Rare	G5	S2		
Eriophorum spissum Fern.	Extirpated	G5T5	SX		
Fimbristylis puberula (Michx.) Vahl.	Endangered	G5	S1		
Fuirena pumila Torr.	Threatened	G4	S2		X
Gentiana puberulenta Pringle	Threatened	G4G5	S2		
Geranium bicknellii Britt.	Endangered	G5	S1		
Glyceria borealis (Nash) Batchelder	Endangered	G5	S1		
Habenaria ciliaris (L.) R. Br.	Endangered	G5	S1	X	X
Habenaria flava var. *herbiola* (R. Br.) Ames & Correll	Endangered	G4T4	S1	X	X
Habenaria hookeri Torr.	Extirpated	G5	SX		
Habenaria hyperborea var. *huronensis* (Nutt.) Farw.	Threatened	G5	S2		

Species	State Status	TNC Global Rank	TNC State Rank	Search	Map & GIS
Habenaria psycodes (L.) Spreng.	Rare	G5	S2		
Hemicarpha drummondii Nees	Extirpated	G4G5	SX		
Hudsonia tomentosa Nutt.	Threatened	G5	S2	X	X
Juncus articulatus L.	Endangered	G4	S1		X
Juncus balticus var. *littoralis* Engelm.	Rare	G5T5	S2		
Juncus militaris Bigel.	Extirpated	G4	SX		
Juncus pelocarpus Mey.	Threatened	G5	S2		
Juncus scirpoides Lam.	Threatened	G5	S2		
Juniperus communis L.	Rare	G5	S2		
Lathyrus japonicus var. *glaber* (Ser.) Fern.	Endangered	G5T4T5	S1	X	X
Lathyrus ochroleucus Hook.	Endangered	G4G5	S1		X
Lathyrus venosus Muhl.	Threatened	G5	S2	X	X
Lechea stricta Leggett	Extirpated	G4	SX		
Liatris pycnostachya Michx.	Threatened	G5	S2		
Linnaea borealis var. *americana* (Forbes) Rehd.	Extirpated	G5	SX		
Linum striatum Walt.	Threatened	G5	S2		
Ludwigia sphaerocarpa var. *deamii* Fern. & Grisc.	Endangered	G5	S1		
Lycopodium inundatum L.	Endangered	G5	S1	X	X
Lycopodium obscurum L.	Rare	G5	S2	X	X
Lycopodium tristachyum Pursh	Threatened	G5	S2		X
Malaxis unifolia Michx.	Endangered	G5	S1		
Matteuccia struthiopteris	Rare	G5	S2		
Melampyrum lineare Desr.	Rare	G5	S2		
Milium effusum L.	Rare	G5	S2		
Myosotis laxa Lehm.	Endangered	G5	S1		
Myriophyllum verticillatum var. *pectinatum* Wallr.	Threatened	G5	S2		
Oenothera perennis L.	Rare	G5	S2		
Orobanche fasciculata Nutt.	Endangered	G4	S1	X	X
Oryzopsis asperifolia Michx.	Endangered	G5	S1		
Oryzopsis pungens (Torr.) Hitchc.	Extirpated	G5	SX		
Oryzopsis racemosa (Sm.) Ricker	Threatened	G5	S2		
Panicum boreale Nash	Rare	G5	S2		
Panicum columbianum Schribn.	Rare	G5	S2		
Panicum lucidum Ashe	Endangered	G?	S1		
Panicum verrucosum Muhl.	Threatened	G4	S2		
Pinus banksiana Lamb.	Rare	G5	S2		
Pinus strobus L.	Rare	G5	S2		
Poa alsodes Gray	Rare	G4	S2		

Species	State Status	TNC Global Rank	TNC State Rank	Search	Map & GIS
Poa paludigena Fern. & Weig.	Watch List	G3	S3		X
Polygala paucifolia Willd.	Endangered	G5	S1	X	X
Polygonella articulata (L.) Meisn.	Rare	G5	S2		
Polygonum careyi Olney	Threatened	G4	S2		
Polygonum opelousanum var. *adenocalyx* Stanford	Threatened	G5	S2		
Polytaenia nuttallii DC.	Endangered	G5	S1		X
Populus balsamifera L.	Extirpated	G5	SX		
Potamogeton pulcher Tuckerm.	Endangered	G5	S1		X
Potamogeton pusillus L.	Rare	G5	S2	X	X
Potamogeton richardsonii (Ar. Benn.) Rydb.	Threatened	G5	S2		X
Potamogeton robbinsii Oakes	Threatened	G5	S2		X
Potentilla anserina L.	Threatened	G5	S2		X
Prenanthes aspera Michx.	Rare	G4	S2		
Prenanthes crepidinea Michx.	Rare	G3G4	S2	X	X
Prunus pennsylvanica L. f.	Rare	G5	S2		
Psilocarya nitens (Vahl) Wood	Extirpated	G4	SX		
Psilocarya scirpoides Torr.	Threatened	G4	S2		X
Pyrola rotundifolia americana (Sweet) Fern.	Rare	G5	S2		X
Pyrola secunda L.	Extirpated	G5	SX		
Rhus aromatica var. *arenaria* (Greene) Fern.	Threatened	G5T3T4	S2		
Rhynchospora globularis var. *recognita* Gale	Endangered	G5	S1		
Rhynchospora macrostachya Torr.	Rare	G4	S2		
Rubus odoratus L.	Threatened	G5	S2		
Salix syrticola Fern.	Threatened	G5	S2		
Satureja arkansana (Nutt.) Briq.	Endangered	G5	S1		X
Satureja vulgaris var. *neogaea* Fern.	Endangered	G?	S1		
Scheuchzeria palustris var. *americana* Fern.	Endangered	G5T5	S1		
Scirpus hallii Gray	Endangered	G2	S1		X
Scirpus purshianus Fern.	Endangered	G4G5	S1		
Scirpus smithii Gray	Endangered	G5	S1		
Scleria muhlenbergii Steud.	Rare	??	??		
Scleria reticularis Michx.	Threatened	G3G4	S2		X
Selaginella rupestris (L.) Spring	Threatened	G5	S2		X
Solidago racemosa var. *gillmani* (Gray) Fern.	Threatened	G5T3	S2		
Sparganium androcladum (Engelm.) Morong	Threatened	G4G5	S2		
Spiranthes lucida (H. H. Eaton) Ames	Rare	G5	S2	X	X
Stipa avenacea L.	Threatened	G5	S2		
Strophostyles leiosperma (T. & G.) Piper	Threatened	G5	S2		

Species	State Status	TNC Global Rank	TNC State Rank	Search	Map & GIS
Talinum rugospermum Holzinger	Threatened	G3G4	S2	X	X
Thuja occidentalis L.	Endangered	G5	S1		Done
Trichostema dichotomum L.	Rare	G5	S2		
Trillium cernuum var. *macranthum* Wieg.	Endangered	G5T4T5	S1	X	X
Utricularia cornuta Michx.	Threatened	G5	S2		
Utricularia geminiscapa Benj.	Endangered	G4G5	S1		X
Utricularia minor L.	Endangered	G5	S1		
Utricularia purpurea Walt.	Rare	G5	S2		
Utricularia subulata L.	Threatened	G5	S2		
Vaccinium oxycoccos L.	Threatened	G5	S1		
Valerianella chenopodiifolia (Pursh) DC.	Endangered	G5	S1		X
Viola primulifolia L.	Rare	G5	S2		
Wisteria macrostachya Nutt.	Rare	G5	S2		
Woodwardia areolata (L.) Moore	Rare	G5	S2		

TNC Ranks:

Global: G1=critically imperiled globally, G2=imperiled globally, G3=globally rare or uncommon, G4=globally widespread and apparently secure, G5=globally widespread and secure.
State: S1=critically imperiled in state, S2=imperiled in state, S3=rare or uncommon in state, S4=widespread and apparently secure in state, S5=widespread and secure in state.

Appendix 2. Michigan Federal, state, rare and conservative species for which surveys were proposed to be conducted at Sleeping Bear Dunes National Lakeshore. See Appendix 1 for an explaination of column headings.

Species	Status	TNC Global Rank	TNC State Rank	Search	Map
Arceuthobium pusillum Peck	conservative species			X	X
Asplenium rhizophyllum L.	Michigan threatened	G5	S2S3	X?	X
Asplenium viride Huds.	Michigan threatened			X?	X
Bartonia virginica (L.) B.S.P.	SLBE rare			X	X
Berula erecta (Huds.) Coville	Michigan threatened	G4G5	S2	X?	X
Botrychium campestre W.H. Wagner & Farrar	Michigan threatened	G3	S2	X?	X
Botrychium hesperium (Maxon & Clausen) W.H. Wagner & Lellinger	Michigan threatened	G3	S2	X	X
Bromus pumpellianus Scribn.	Michigan threatened	G4Q	S2	X?	X
Calypso bulbosa (L.) Oakes	Michigan threatened	G5	S2	X?	Done
Carex concinna R. Br.	Michigan special concern	G4G5	S3	X?	X
Carex crawei Dewey	conservative species			X	X
Carex pauciflora Lightf.	conservative species			X	X
Carex platyphylla Carey	Michigan threatened	G5	S1	X?	X
Castanea dentata (Marsh.) Borkh.	Michigan endangered	G4	S1S2	X	X
Chelone glabra L.	SLBE rare			X	X
Chimaphila maculata (L.) Pursh	Michigan special concern			X	X
Cirsium pitcheri (Torr.) T. & G.	Federal threatened	G3	S3	X?	X
Cypripedium arietinum Ait. f.	Michigan special concern	G3	S3	X?	Done
Cypripedium reginae Walt.	SLBE rare			X	X
Eleocharis rostellata (Torr.) Torr.	conservative species			X	X
Eriophorum spissum Fern.	conservative species			X	
Helianthus hirsutus Raf.	Michigan special concern	G5	S3	X	X
Hippuris vulgaris L.	SLBE rare			X	X
Houstonia longifolia Gaertn.	SLBE rare			X	X
Kalmia polifolia Wangenh.	conservative species			X	X
Lemna trisulca L.	SLBE rare			X	X
Linaria canadensis (L.) Chaz.	SLBE rare			X	X
Listera convallarioides (Sw.) Nutt. ex Ell.	conservative species			X	X
Lysimachia terrestris (L.) B.S.P.	SLBE rare			X	X
Medeola virginiana L.	conservative species			X	X

Species	Status	TNC Global Rank	TNC State Rank	Search	Map
Megalodonta beckii (Torr. ex Spreng.) Greene	SLBE rare			X	X
Mimulus glabratus Kunth var. *fremontii* (Benth.) A.L. Grant	SLBE rare			X	X
Mimulus glabratus Kunth var. *michiganensis* (Pennell) Fassett	Federal endangered	G5T1	S1	X?	Done
Muhlenbergia glomerata (Willd.) Trin.	conservative species			X	X
Ophioglossum vulgatum L.	Michigan threatened	G5	S1	X	X
Orobanche fasciculata Nutt.	Michigan threatened	G4	S2	X?	X
Panax quinquefolius L.	Michigan threatened	G3G4	S2S3	X?	Done
Picea glauca (Moench) Voss	SLBE rare			X	X
Platanthera blephariglottis (Willd.) Lindl.	conservative species			X	X
Platanthera dilatata (Pursh) Lindl. ex Beck	conservative species			X	X
Platanthera obtusata (Banks ex Pursh) Lindl.	conservative species			X	X
Pogonia ophioglossoides (L.) Ker-Gawl.	SLBE rare			X	X
Polystichum lonchitis (L.) Roth	SLBE rare			X	X
Potamogeton oakesianus J.W. Robbins	SLBE rare			X	X
Potamogeton robbinsii Oakes	conservative species			X	X
Pterospora andromedea Nutt.	Michigan threatened	G5	S2	X?	X
Ranunculus longirostris Godr.	SLBE rare			X	X
Ranunculus reptans L.	SLBE rare			X	X
Rhynchospora capillacea Torr.	conservative species			X	X
Ribes hudsonianum Richards.	conservative species			X	X
Sarracenia purpurea L.	conservative species			X	X
Scheuchzeria palustris L.	conservative species	G5T1T2	S1	X	X
Selaginella rupestris (L.) Spring	SLBE rare			X	X
Sparganium fluctuans (Morong) B.L. Robins.	conservative species			X	X
Spiraea alba Du Roi	SLBE rare			X	X
Spirodela polyrhiza (L.) Schleiden	SLBE rare			X	X
Taxus canadensis Marsh.	SLBE rare			X	X
Thalictrum dasycarpum Fisch. & Avé-Lall.	SLBE rare			X	X
Thelypteris hexagonoptera (Michx.) Weatherby	SLBE rare			X	X
Thelypteris noveboracensis (L.) Nieuwl.	new to Mainland				
Trillium cernuum var. *macranthum* Wieg.	SLBE rare	G5T4			
Trillium flexipes Raf.	SLBE rare			X	X

Species	Status	TNC Global Rank	TNC State Rank	Search	Map
Triphora trianthophora (Sw.) Rydb.	Michigan threatened	G3G4	S1	X?	Done
Utricularia intermedia Hayne	conservative species			X	X

TNC Ranks:

Global: G1=critically imperiled globally, G2=imperiled globally, G3=globally rare or uncommon, G4=globally widespread and apparently secure, G5=globally widespread and secure.

State: S1=critically imperiled in state, S2=imperiled in state, S3=rare or uncommon in state, S4=widespread and apparently secure in state, S5=widespread and secure in state.

Appendix 3. List of plants that may possibly occur at SLBE and INDU by Emmet Judiewitz.

Family	Species	Habitat	Park Status
Aceraceae	*Acer platanoides*	Exotic	Unconfirmed
Aceraceae	*Acer saccharinum*	Wetland	Probably Present
Alismataceae	*Sagittaria cuneata*	Aquatic	Probably Present
Anacardiaceae	*Rhus copallinum*	Dunes	Unconfirmed
Anacardiaceae	*Rhus glabra*	Woodland	Unconfirmed
Anacardiaceae	*Toxicodendron vernix*	Wetland	Unconfirmed
Apiaceae	*Cicuta maculata*	Wetland	Present in Park
Apiaceae	*Torilis japonica*	Exotic	Unconfirmed
Apiaceae	*Zizia aurea*	Wetland	Unconfirmed
Araceae	*Calla palustris*	Wetland	Probably Present
Araceae	*Symplocarpus foetidus*	Wetland	Unconfirmed
Araliaceae	*Panax trifolius*	Mesic Forest	Unconfirmed
Aristolochiaceae	*Asarum canadense*	Mesic Forest	Unconfirmed
Asclepiadaceae	*Asclepias exaltata*	Mesic Forest	Unconfirmed
Asteraceae	*Ambrosia psilostachya*	Dunes	Present in Park
Asteraceae	*Anthemis cotula*	Exotic	Unconfirmed
Asteraceae	*Anthemis tinctoria*	Exotic	Unconfirmed
Asteraceae	*Artemisia absinthium*	Exotic	Unconfirmed
Asteraceae	*Artemisia biennis*	Exotic	Unconfirmed
Asteraceae	*Artemisia ludoviciana* ssp. *ludoviciana*	Dunes	Unconfirmed
Asteraceae	*Artemisia vulgaris*	Exotic	Unconfirmed
Asteraceae	*Bellis perennis*	Exotic	Unconfirmed
Asteraceae	*Bidens comosa*	Wetland	Present in Park
Asteraceae	*Bidens frondosa*	Wetland	Unconfirmed
Asteraceae	*Centaurea cyanus*	Exotic	Unconfirmed
Asteraceae	*Cirsium discolor*	Woodland	Unconfirmed
Asteraceae	*Crepis tectorum*	Exotic	Unconfirmed
Asteraceae	*Echinacea purpurea*	Exotic	Unconfirmed
Asteraceae	*Gaillardia pulchella*	Exotic	Unconfirmed
Asteraceae	*Helianthus annuus*	Exotic	Unconfirmed
Asteraceae	*Helianthus grosseserratus*	Woodland	Unconfirmed
Asteraceae	*Helianthus hirsutus*	Woodland	Unconfirmed
Asteraceae	*Helianthus laetiflorus* var. *rigidus*	Exotic	Unconfirmed
Asteraceae	*Helianthus maximiliani*	Woodland	Unconfirmed
Asteraceae	*Helianthus tuberosus*	Woodland	Unconfirmed
Asteraceae	*Hieracium umbellatum*	Dunes	Unconfirmed
Asteraceae	*Hypochaeris radicata*	Exotic	Unconfirmed
Asteraceae	*Lactuca serriola*	Exotic	Unconfirmed
Asteraceae	*Leontodon taraxacoides*	Exotic	Unconfirmed
Asteraceae	*Packera aurea*	Wetland	Unconfirmed
Asteraceae	*Petasites frigidus*	Conifer swamp	Unconfirmed
Asteraceae	*Pseudognaphalium macounii*		Unconfirmed
Asteraceae	*Pseudognaphalium obtusifolium* ssp. *obtusifolium*	Dunes	Unconfirmed
Asteraceae	*Rudbeckia laciniata*	Wetland	Unconfirmed
Asteraceae	*Solidago juncea*	Dunes	Present in Park

Family	Species	Habitat	Park Status
Asteraceae	*Solidago ohioense*	Wetland	Unconfirmed
Asteraceae	*Solidago patula*	Conifer swamp	Present in Park
Asteraceae	*Sonchus asper*	Exotic	Unconfirmed
Asteraceae	*Symphyotrichum boreale*	Wetland	Unconfirmed
Asteraceae	*Symphyotrichum cordifolium*	Woodland	Unconfirmed
Asteraceae	*Tanacetum bipinnatum* ssp. *huronense*	Dunes	Unconfirmed
Asteraceae	*Tanacetum vulgare*	Exotic	Unconfirmed
Asteraceae	*Taraxacum laevigatum*	Exotic	Unconfirmed
Asteraceae	*Xanthium strumarium*	Dunes	Unconfirmed
Balsaminaceae	*Impatiens pallida*	Mesic Forest	Unconfirmed
Berberidaceae	*Berberis thunbergii*	Exotic	Unconfirmed
Berberidaceae	*Berberis vulgaris*	Exotic	Unconfirmed
Betulaceae	*Carpinus caroliniana*	Mesic Forest	Unconfirmed
Bignoniaceae	*Campsis radicans*	Exotic	Unconfirmed
Boraginaceae	*Anchusa azurea*	Exotic	Unconfirmed
Boraginaceae	*Anchusa officinalis*	Exotic	Unconfirmed
Boraginaceae	*Lithospermum canescens*	Dunes	Present in Park
Boraginaceae	*Myosotis laxa*	Conifer swamp	Present in Park
Boraginaceae	*Myosotis stricta*	Exotic	Present in Park
Boraginaceae	*Symphytum officinale*	Exotic	Unconfirmed
Brassicaceae	*Alliaria petiolata*	Exotic	Present in Park
Brassicaceae	*Arabis hirsuta*	Rockshore	Unconfirmed
Brassicaceae	*Armoracia rusticana*	Exotic	Unconfirmed
Brassicaceae	*Brassica nigra*	Exotic	Unconfirmed
Brassicaceae	*Cardamine pratensis*	Conifer swamp	Unconfirmed
Brassicaceae	*Lobularia maritima*	Exotic	Unconfirmed
Brassicaceae	*Thlaspi arvense*	Exotic	Unconfirmed
Cactaceae	*Opuntia humifusa*	Exotic	Unconfirmed
Campanulaceae	*Campanula persicifolia*	Exotic	Unconfirmed
Campanulaceae	*Campanula rapunculoides*	Exotic	Unconfirmed
Campanulaceae	*Triodanis perfoliata*	Woodland	Unconfirmed
Cannabaceae	*Cannabis sativa*	Exotic	Unconfirmed
Capparaceae	*Polanisia dodecandra*	Exotic	Unconfirmed
Caprifoliaceae	*Lonicera oblongifolia*	Conifer swamp	Unconfirmed
Caprifoliaceae	*Triosteum perfoliatum*	Mesic Forest	Unconfirmed
Caprifoliaceae	*Viburnum nudum* var. *cassinoides*	Wetland	Unconfirmed
Caprifoliaceae	*Viburnum recognitum*	Exotic	Unconfirmed
Caryophyllaceae	*Gypsophila elegans*	Exotic	Unconfirmed
Caryophyllaceae	*Gypsophila scorzonerifolia*	Exotic	Unconfirmed
Caryophyllaceae	*Myosoton aquaticum*	Exotic	Unconfirmed
Caryophyllaceae	*Petrorhagia saxifraga*	Exotic	Unconfirmed
Caryophyllaceae	*Scleranthus annuus*	Exotic	Unconfirmed
Caryophyllaceae	*Silene latifolia* ssp. *alba*	Exotic	Unconfirmed
Caryophyllaceae	*Silene noctiflora*	Exotic	Unconfirmed
Caryophyllaceae	*Stellaria borealis* ssp. *borealis*	Conifer swamp	Unconfirmed
Caryophyllaceae	*Stellaria longifolia*	Woodland	Unconfirmed
Celastraceae	*Euonymus europaea*	Exotic	Unconfirmed

Family	Species	Habitat	Park Status
Celastraceae	*Euonymus fortunei*	Exotic	Unconfirmed
Chenopodiaceae	*Chenopodium glaucum*	Exotic	Unconfirmed
Chenopodiaceae	*Chenopodium simplex*	Woodland	Unconfirmed
Chenopodiaceae	*Corispermum hyssopifolium*	Dunes	Present in Park
Chenopodiaceae	*Salsola tragus*	Dunes	Unconfirmed
Cistaceae	*Lechea intermedia*	Dunes	Unconfirmed
Clusiaceae	*Hypericum ascyron*	Wetland	Unconfirmed
Clusiaceae	*Hypericum boreale*	Wetland	Unconfirmed
Clusiaceae	*Hypericum prolificum*	Woodland	Unconfirmed
Convolvulaceae	*Calystegia spithamaea*	Woodland	Unconfirmed
Crassulaceae	*Penthorum sedoides*	Wetland	Unconfirmed
Crassulaceae	*Sedum sarmentosum*	Exotic	Unconfirmed
Cucurbitaceae	*Echinocystis lobata*	Wetland	Unconfirmed
Cuscutaceae	*Cuscuta cephalanthi*	Wetland	Unconfirmed
Cuscutaceae	*Cuscuta gronovii*	Woodland	Unconfirmed
Cyperaceae	*Carex albursina*	Mesic Forest	Present in Park
Cyperaceae	*Carex argyrantha*	Dunes	Probably Present
Cyperaceae	*Carex artitecta*	Dunes	Unconfirmed
Cyperaceae	*Carex capillaris*	Conifer swamp	Probably Present
Cyperaceae	*Carex convoluta*	Mesic Forest	Probably Present
Cyperaceae	*Carex crinita*	Wetland	Present in Park
Cyperaceae	*Carex cryptolepis*	Wetland	Probably Present
Cyperaceae	*Carex debilis* var. *rudgei*	Mesic Forest	Probably Present
Cyperaceae	*Carex folliculata*	Wetland	Probably Present
Cyperaceae	*Carex oligocarpa*	Mesic Forest	Present in Park
Cyperaceae	*Carex peckii*	Dunes	Probably Present
Cyperaceae	*Carex prairea*	Wetland	Probably Present
Cyperaceae	*Carex rostrata*	Wetland	Present in Park
Cyperaceae	*Carex schweinitzii*	Springs	Probably Present
Cyperaceae	*Carex sterilis*	Wetland	Probably Present
Cyperaceae	*Carex sychnocephala*	Wetland	Probably Present
Cyperaceae	*Cyperus bipartitus*		Unconfirmed
Cyperaceae	*Cyperus filiculmis*	Dunes	
Cyperaceae	*Cyperus lupulinus*		Unconfirmed
Cyperaceae	*Cyperus schweinitzii*	Dunes	
Cyperaceae	*Eleocharis intermedia*	Wetland	Unconfirmed
Cyperaceae	*Scirpus hudsonianus*	Wetland	Probably Present
Cyperaceae	*Scirpus subterminalis*	Aquatic	Present in Park
Dipsacaceae	*Dipsacus fullonum*	Exotic	Unconfirmed
Elaeagnaceae	*Elaeagnus umbellata*	Exotic	Present in Park
Equisetaceae	*Equisetum pratense*	Wetland	Unconfirmed
Euphorbiaceae	*Chamaesyce maculata*	Exotic	Unconfirmed
Euphorbiaceae	*Euphorbia corollata*	Dunes	Unconfirmed
Euphorbiaceae	*Euphorbia marginata*	Exotic	Unconfirmed
Fabaceae	*Amphicarpaea bracteata*	Woodland	Unconfirmed
Fabaceae	*Apios americana*	Woodland	Unconfirmed
Fabaceae	*Coronilla varia*	Exotic	Unconfirmed

Family	Species	Habitat	Park Status
Fabaceae	*Desmodium glutinosum*	Woodland	Unconfirmed
Fabaceae	*Gleditsia triacanthos*	Exotic	Unconfirmed
Fabaceae	*Lathyrus ochroleucus*	Woodland	Unconfirmed
Fabaceae	*Lathyrus tuberosus*	Exotic	Unconfirmed
Fabaceae	*Lespedeza cuneata*		Unconfirmed
Fabaceae	*Robinia hispida*	Exotic	Unconfirmed
Fabaceae	*Vicia americana*	Woodland	Present in Park
Fabaceae	*Vicia cracca*	Exotic	Present in Park
Fagaceae	*Quercus macrocarpa*	Woodland	Unconfirmed
Gentianaceae	*Gentianopsis crinita*	Wetland	Unconfirmed
Geraniaceae	*Geranium bicknellii*	Woodland	
Geraniaceae	*Geranium maculatum*	Mesic Forest	Present in Park
Geraniaceae	*Geranium pusillum*	Exotic	
Geraniaceae	*Geranium pyrenaicum*		Unconfirmed
Geraniaceae	*Geranium sanguineum*		Unconfirmed
Grossulariaceae	*Ribes lacustre*	Conifer swamp	Unconfirmed
Grossulariaceae	*Ribes rubrum*	Exotic	Unconfirmed
Haloragaceae	*Myriophyllum spicatum*	Exotic	Present in Park
Haloragaceae	*Myriophyllum verticillatum*	Aquatic	Unconfirmed
Hydrangeaceae	*Philadelphus coronarius*	Exotic	Unconfirmed
Hydrophyllaceae	*Hydrophyllum canadense*	Mesic Forest	Unconfirmed
Iridaceae	*Iris germanica*	Exotic	Probably Present
Iridaceae	*Sisyrinchium albidum*	Dunes	Probably Present
Juglandaceae	*Carya ovata*	Woodland	Unconfirmed
Juncaceae	*Juncus articulatus*	Wetland	Probably Present
Juncaceae	*Juncus bufonius*	Wetland	Probably Present
Juncaginaceae	*Triglochin maritima*	Wetland	Probably Present
Lamiaceae	*Ajuga reptans*	Exotic	Unconfirmed
Lamiaceae	*Clinopodium arkansanum*	Bedrock shores	Unconfirmed
Lamiaceae	*Lamium amplexicaule*	Exotic	Unconfirmed
Lamiaceae	*Lamium maculatum*	Exotic	Unconfirmed
Lamiaceae	*Marrubium vulgare*	Exotic	Present in Park
Lamiaceae	*Mentha* X *villosa*	Exotic	Unconfirmed
Lamiaceae	*Physostegia virginiana* ssp. *virginiana*	Wetland	Unconfirmed
Lamiaceae	*Pycnanthemum tenuifolium*	Wetland	Unconfirmed
Lamiaceae	*Salvia pratensis*	Exotic	Unconfirmed
Lamiaceae	*Thymus pulegioides*	Exotic	Unconfirmed
Lauraceae	*Lindera benzoin*	Mesic Forest	Unconfirmed
Lauraceae	*Sassafras albidum*	Mesic Forest	Unconfirmed
Liliaceae	*Allium cepa*	Exotic	Unconfirmed
Liliaceae	*Allium schoenoprasum*	Exotic	Unconfirmed
Liliaceae	*Allium vineale*	Exotic	Probably Present
Liliaceae	*Lilium lancifolium*	Exotic	Probably Present
Liliaceae	*Muscari botryoides*	Exotic	Probably Present
Liliaceae	*Muscari neglectum*	Exotic	Unconfirmed
Liliaceae	*Ornithogalum umbellatum*	Exotic	Unconfirmed
Liliaceae	*Streptopus amplexifolius*	Conifer swamp	Probably Present

Family	Species	Habitat	Park Status
Linaceae	*Linum perenne*	Exotic	Unconfirmed
Linaceae	*Linum sulcatum*	Dunes	Unconfirmed
Linaceae	*Linum usitatissimum*	Exotic	Unconfirmed
Lythraceae	*Lythrum alatum*	Wetland	Unconfirmed
Malvaceae	*Alcea rosea*	Exotic	Unconfirmed
Malvaceae	*Hibiscus trionum*	Exotic	Unconfirmed
Molluginaceae	*Mollugo verticillata*	Exotic	Unconfirmed
Moraceae	*Morus alba*	Exotic	Unconfirmed
Moraceae	*Morus rubra*	Exotic	Unconfirmed
Myricaceae	*Comptonia peregrina*	Dunes	Unconfirmed
Oleaceae	*Ligustrum obtusifolium*	Exotic	Unconfirmed
Onagraceae	*Epilobium hirsutum*	Exotic	Unconfirmed
Onagraceae	*Epilobium palustre*	Wetland	Unconfirmed
Onagraceae	*Epilobium strictum*	Wetland	Unconfirmed
Onagraceae	*Oenothera perennis*	Woodland	Unconfirmed
Onagraceae	*Oenothera pilosella*	Dunes	Unconfirmed
Orchidaceae	*Listera cordata*	Conifer swamp	Probably Present
Orchidaceae	*Malaxis unifolia*	Conifer swamp	Probably Present
Orchidaceae	*Platanthera flava* var. *herbiola*	Wetland	Probably Present
Papaveraceae	*Macleaya cordata*	Exotic	Unconfirmed
Papaveraceae	*Papaver orientale*	Exotic	Unconfirmed
Papaveraceae	*Papaver rhoeas*	Exotic	Unconfirmed
Papaveraceae	*Papaver somniferum*	Exotic	Unconfirmed
Papaveraceae	*Stylophorum diphyllum*	Mesic Forest	Unconfirmed
Pinaceae	*Picea abies*	Exotic	Present in Park
Pinaceae	*Pinus sylvestris*	Exotic	Present in Park
Plantaginaceae	*Plantago aristata*	Dunes	Unconfirmed
Poaceae	*Agropyron smithii*	Dunes	Present in Park
Poaceae	*Aristida basiramea*	Dunes	Probably Present
Poaceae	*Brachyelytrum erectum* var. *septentrionale*	Mesic Forest	Probably Present
Poaceae	*Bromus squarrosus*	Exotic	Probably Present
Poaceae	*Cenchrus longispinus*	Exotic	Probably Present
Poaceae	*Digitaria ischaemum*	Exotic	Probably Present
Poaceae	*Eragrostis minor*	Exotic	Unconfirmed
Poaceae	*Eragrostis pectinacea*	Dunes	Probably Present
Poaceae	*Festuca trachyphylla*		Unconfirmed
Poaceae	*Holcus lanatus*	Exotic	Probably Present
Poaceae	*Muhlenbergia mexicana*	Woodland	Present in Park
Poaceae	*Panicum columbianum*	Dunes	Present in Park
Poaceae	*Panicum lindheimeri*		Probably Present
Poaceae	*Poa annua*	Exotic	Probably Present
Poaceae	*Sorghastrum nutans*	Dunes	Present in Park
Poaceae	*Zizania aquatica*	Aquatic	Probably Present
Polemoniaceae	*Phlox paniculata*	Exotic	Unconfirmed
Polygalaceae	*Polygala polygama*	Dunes	Unconfirmed
Polygonaceae	*Fagopyrum esculentum*	Exotic	Unconfirmed
Polygonaceae	*Polygonum cuspidatum*	Exotic	Unconfirmed

Family	Species	Habitat	Park Status
Polygonaceae	*Polygonum douglasii*	Dunes	Unconfirmed
Polygonaceae	*Polygonum lapathifolium*	Wetland	Unconfirmed
Polygonaceae	*Polygonum pensylvanicum*	Wetland	Unconfirmed
Polygonaceae	*Polygonum scandens*	Woodland	Unconfirmed
Polygonaceae	*Rheum rhabarbarum*	Exotic	Unconfirmed
Portulacaceae	*Claytonia virginica*	Mesic Forest	Probably Present
Potamogetonaceae	*Potamogeton alpinus*	Aquatic	Probably Present
Potamogetonaceae	*Potamogeton epihydrus*	Aquatic	Probably Present
Potamogetonaceae	*Potamogeton perfoliatus*	Aquatic	Present in Park
Potamogetonaceae	*Potamogeton pusillus* var. *tenuissimus*	Aquatic	Unconfirmed
Potamogetonaceae	*Potamogeton vaginatus*	Aquatic	Probably Present
Primulaceae	*Lysimachia nummularia*	Exotic	Unconfirmed
Primulaceae	*Lysimachia punctata*	Exotic	Unconfirmed
Ranunculaceae	*Ranunculus flabellaris*	Aquatic	Unconfirmed
Ranunculaceae	*Ranunculus hispidus*	Wetland	Unconfirmed
Ranunculaceae	*Ranunculus repens*	Exotic	Unconfirmed
Rhamnaceae	*Frangula alnus*	Exotic	Unconfirmed
Rhamnaceae	*Rhamnus alnifolia*	Conifer swamp	Unconfirmed
Rhamnaceae	*Rhamnus carthartica*	Exotic	
Rosaceae	*Agrimonia striata*	Woodland	Unconfirmed
Rosaceae	*Amelanchier stolonifera*		Unconfirmed
Rosaceae	*Chaenomeles speciosa*	Exotic	Unconfirmed
Rosaceae	*Crataegus flabellata*	Woodland	Unconfirmed
Rosaceae	*Crataegus intricata*	Woodland	Unconfirmed
Rosaceae	*Crataegus pedicellata*	Woodland	Unconfirmed
Rosaceae	*Filipendula rubra*	Exotic	Unconfirmed
Rosaceae	*Geum macrophyllum*	Exotic	Present in Park
Rosaceae	*Malus sylvestris*	Exotic	Unconfirmed
Rosaceae	*Physocarpus opulifolius*	Wetland	Unconfirmed
Rosaceae	*Potentilla arguta*	Dunes	Present in Park
Rosaceae	*Potentilla inclinata*	Exotic	Unconfirmed
Rosaceae	*Prunus armeniaca*	Exotic	Unconfirmed
Rosaceae	*Prunus avium*	Exotic	Unconfirmed
Rosaceae	*Prunus cerasifera*	Exotic	Unconfirmed
Rosaceae	*Prunus domestica*	Exotic	Unconfirmed
Rosaceae	*Prunus persica*	Exotic	Unconfirmed
Rosaceae	*Pyrus communis*	Exotic	Unconfirmed
Rosaceae	*Rosa centifolia*	Exotic	Unconfirmed
Rosaceae	*Rosa gallica*	Exotic	Unconfirmed
Rosaceae	*Rosa multiflora*	Exotic	Present in Park
Rosaceae	*Rosa rugosa*	Exotic	Present in Park
Rosaceae	*Rosa spinosissima*	Exotic	Unconfirmed
Rosaceae	*Rubus setosus*	Woodland	Unconfirmed
Rosaceae	*Sorbus americana*	Conifer swamp	Present in Park
Rosaceae	*Spiraea* X *vanhouttei*	Exotic	Unconfirmed
Rubiaceae	*Galium asprellum*	Wetland	Unconfirmed
Rubiaceae	*Galium circaezans*	Woodland	Unconfirmed

Family	Species	Habitat	Park Status
Rubiaceae	*Galium labradoricum*	Wetland	Unconfirmed
Rubiaceae	*Galium trifidum*	Wetland	Unconfirmed
Rutaceae	*Zanthoxylum americanum*	Mesic Forest	Unconfirmed
Salicaceae	*Salix fragilis*	Exotic	Unconfirmed
Salicaceae	*Salix purpurea*	Exotic	Unconfirmed
Scrophulariaceae	*Castilleja coccinea*	Woodland	Unconfirmed
Scrophulariaceae	*Cymbalaria muralis*	Exotic	Unconfirmed
Scrophulariaceae	*Digitalis purpurea*	Exotic	Unconfirmed
Scrophulariaceae	*Linaria dalmatica*	Exotic	Unconfirmed
Scrophulariaceae	*Lindernia dubia*	Wetland	Unconfirmed
Scrophulariaceae	*Mimulus moschatus*	Springs	Unconfirmed
Scrophulariaceae	*Penstemon digitalis*	Exotic	Unconfirmed
Scrophulariaceae	*Penstemon pallidus*	Exotic	Unconfirmed
Scrophulariaceae	*Veronica beccabunga*	Exotic	Unconfirmed
Scrophulariaceae	*Veronica verna*	Exotic	Unconfirmed
Smilacaceae	*Smilax tamnoides*	Mesic Forest	Probably Present
Solanaceae	*Lycium barbarum*	Exotic	Unconfirmed
Solanaceae	*Solanum tuberosum*	Exotic	Unconfirmed
Sparganiaceae	*Sparganium angustifolium*	Aquatic	Unconfirmed
Thelypteridaceae	*Thelypteris noveboracensis*	Mesic Forest	Unconfirmed
Ulmaceae	*Ulmus pumila*	Exotic	Unconfirmed
Ulmaceae	*Ulmus thomasii*	Mesic Forest	Unconfirmed
Urticaceae	*Pilea fontana*	Wetland	Unconfirmed
Valerianaceae	*Valeriana officinalis*	Exotic	Unconfirmed
Verbenaceae	*Verbena urticifolia*	Mesic Forest	Unconfirmed
Violaceae	*Viola lanceolata*	Wetland	Unconfirmed
Violaceae	*Viola tricolor*	Exotic	Unconfirmed
Vitaceae	*Vitis aestivalis*	Woodland	Unconfirmed
Zannichelliaceae	*Zannichellia palustris*	Aquatic	Probably Present

Appendix 4. Proposed target alien plants that were to be mapped by park. Only *Phragmites australis* was mapped at SLBE since the Exotic Plant Management Team (EPMT) mapped exotics. At INDU, the technician worked closely with the EPMT program to coordinate and assist both projects.

Park	Species	Common Name	Notes	Season
INDU	*Alliaria petiolata* (M. Bieb.) Cavers & Grande	Garlic mustard	West Unit first	May
	Celastrus orbiculatus Thunb.	Oriental bittersweet	West Unit first	
	Centaurea biebersteinii DC. (= *C. maculosa*)	Spotted knapweed	CSX Railroad Tracks	August
	Hesperis matronalis L.	Dame's rocket	Throughout	May
	Lythrum salicaria L.	Purple loosestrife	Miller Woods and East Unit	July
	Phragmites australis (Cav.) Steud.	Common reed	Throughout	Throughout
	Polygonum cuspidatum Sieb. & Zucc.	Japanese knotweed	Throughout	Throughout
SLBE	*Centaurea biebersteinii* DC.	Spotted knapweed	Dunes only	August
	Gypsophila paniculata L.	Baby's breath	Dunes only	July-August
	Hesperis matronalis L.	Dame's rocket	Throughout	May
	Phragmites australis (Cav.) Steud.	Common reed	Throughout	Throughout

Appendix 5. Cross comparison of the data fields in the North American Weed Mapping Association (NAWMA) Mapping Standard, the Michigan Natural Features Inventory (MNFI) Special Plant Population Data Form, and the National Park Service Natural Resource (NPS-NR) Data Template.

Category	NAWMA Required Fields	NAWMA Optional Fields	MNFI Fields	NPS-NR Data Template Required Fields	NPS-NR Data Template Optional Fields	Office Variables	Field Variables
General	Park Weed Contact					X	
	Contact phone		Phone #			X	
	Region					X	
	I&M Network					X	
	State					X	
	County		County			X	
	Survey Unit					X	
				ParkCode		X	
				Project (tblLocations)		X	
	Ownership					X	
	Recorders		Surveyor			X	X
	Date		Date	StartDate			X
					EndDate		X
					StartTime		X
					EndTime		X
					TripReport		X
					Protocol		X
				EventID (tblEvents)			X
				Project (tblEvents)			X
	Survey Type						X
	Units						X
	Area Surveyed						X
Category	NAWMA Required Fields	NAWMA Optional Fields	MNFI Fields	NPS-NR Data Template Required Fields	NPS-NR Data Template Optional Fields	Office Variables	Field Variables

Location: Survey Unit		Quad Number				X	
		Quad Name				X	
		Survey Location				X	
Location: Weed Populations		Quad Number				X	
		Quad Name				X	
		Survey Location	Township, range, section			X	
	Hydrological Unit Code#					X	
Plant Information		Site number	Source code	LocationID		**X**	X
				RecordID			X
					Shape	X	
					Area	X	
					Name	X	
	Genus/Species		Species				X
		Intraspecific name	Species				X
	Authority		Species			X	
		Common name				X	X
	Plant code					X	
	Infested area		Habitat extent				X
		Gross area	Proportion of habitat occupied by species				X
	Canopy cover						X
	Density of stems		Total number of individuals				X
		Life form				X	
Category	NAWMA Required Fields	NAWMA Optional Fields	MNFI Fields	NPS-NR Data Template Required Fields	NPS-NR Data Template Optional Fields	Office Variables	Field Variables
		Species status				X	

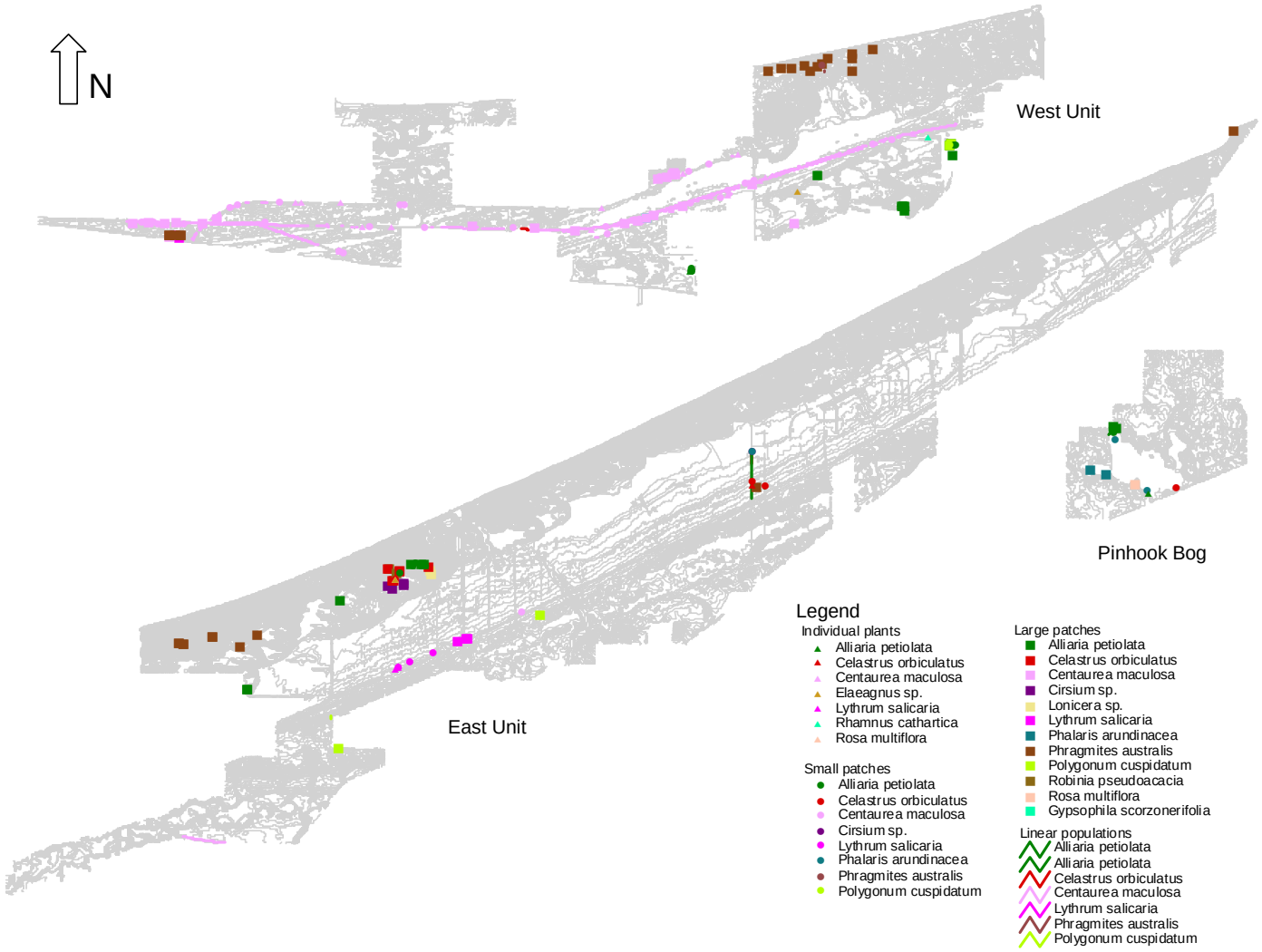
		Priority Species for Management				X	
	Ecological Status of Site						X
		Weed Distribution Throughout Site					X
		Weed Phenology	%flowering, %fruiting, vigor				X
		Management Actions Taken				X	
		Management?				X	
		Distance of Weed Population to Water				X	
	Values at Risk						X
			Threats				X
				StartUTMX			X
				StartUTMY			X
					StopUTMX		X
					StopUTMY		X
				StartLat			X
				UTMZone			X
				StartLon			X
					StopLat		X
					StopLon		X
				Datum			X
					DataType		X
Category	NAWMA Required Fields	NAWMA Optional Fields	MNFI Fields	NPS-NR Data Template Required Fields	NPS-NR Data Template Optional Fields	Office Variables	Field Variables
				EstHError		X	X
					EstVError	X	X

					AccNotes		X
					Elevation		X
					Aspect		X
					Slope		X
					Notes		X
Site Environment	Vegetation Classification	Optional				X	X
					Description		X
	Dominant Associated Vegetation	Optional					X
			Associates				X
	Habitat type	Optional					X
			Microhabitat				X
	Seral stage	Optional					X
	Disturbance	Optional	Disturbance				X
	Elevation	Optional					X
	Aspect	Optional					X
	Slope	Optional					X
	% slope	Optional					X
	Soil type	Optional	Soil type				X
			pH				X
			Litter depth				X
			Organic content				X
			Light				X
			Moisture				X
	Landform	Optional					X
Category	NAWMA Required Fields	NAWMA Optional Fields	MNFI Fields	NPS-NR Data Template Required Fields	NPS-NR Data Template Optional Fields	Office Variables	Field Variables
	Geologic substate	Optional					X
	Climate	Optional				X	

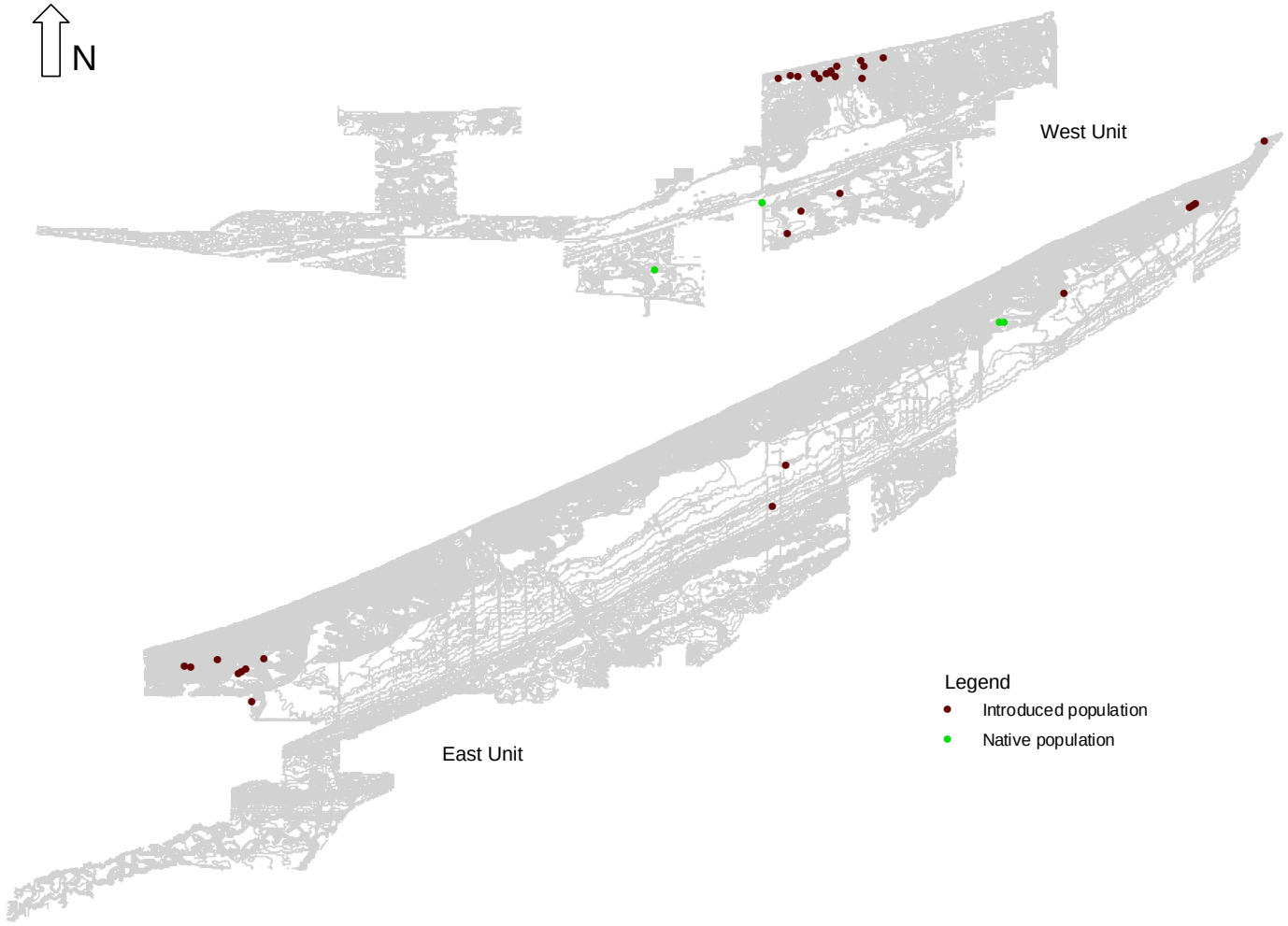
				EventID (tbl*project*Events)			X
					ObsInits		X
					TempC		X
					Wind		X
					Rain		X
					Clouds		X
					Noise		X

Appendix 6. Maps

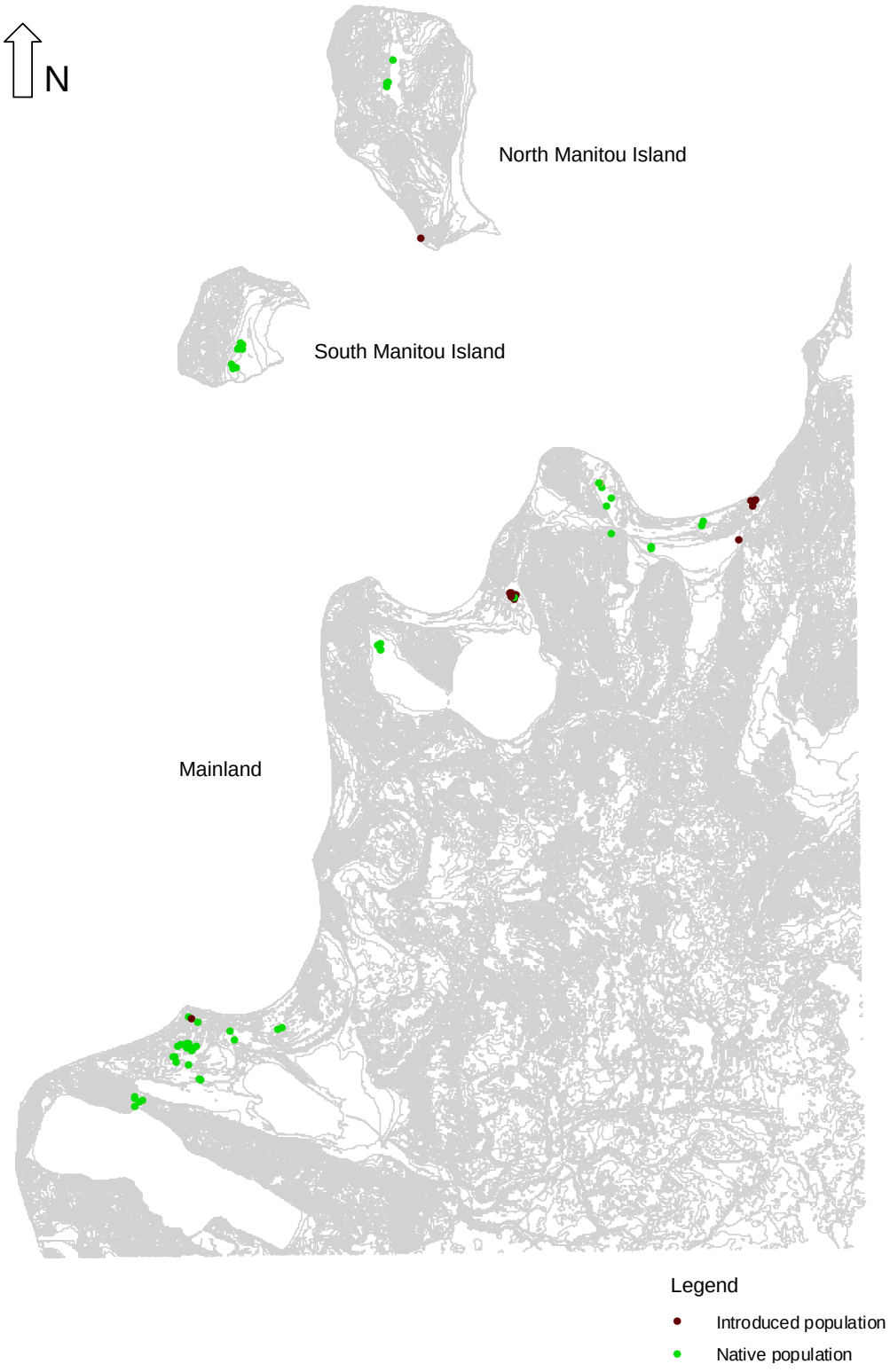
Appendix 6-4. Exotic plant populations mapped in 2003 at Indiana Dunes National Lakeshore.



Appendix 6-5. Introduced and native Phragmites populations mapped in 2003 at Indiana Dunes National Lakeshore.



Appendix 6-6. Introduced and native *Phragmites* populations mapped in 2003 at Sleeping Bear Dunes National Lakeshore.



Appendix 7. Voucher photographs for new ferns to SLBE.

Dryopteris goldiana (Hook. Ex Goldie) A. Gray – Goldie's woodfern

Phegopteris connectilis (Michx.) Watt – long beechfern

Thelypteris noveboracensis (L.) Nieuwl. – New York fern

Appendix 8. Voucher photographs for new exotic populations found at SLBE.

Datura stramonium L. – Jimson weed

Lamium galeobdolon