Garden Island Rare Species and Invasive Plant Survey

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Cover photos: top left, Houghton's goldenrod (Photo by Phyllis J. Higman), top middle, English sundew (Photo by Bill Parsons); upper right, butterwort (Photo by Phyllis J. Higman); lower left, Hine's Emerald Dragonfly (Photo by Bill Parsons), lower middle, Pitcher's thistle (Photo by Bill Parsons); and lower right, Lake Huron Locust, (Photo by Bill Parsons).

Executive Summary

Garden Island is one of two islands within the Beaver Island Archipelago which are part of the 1855 Little Traverse Bay Bands of Odawa (LTBB) Reservation. This project created a partnership between the Michigan Natural Features Inventory (MNFI) and LTBB to assess the current status of the natural features on the island and educate one another about these and other important island features. Early and late season surveys were conducted for 19 rare plants, 12 rare avian species, two rare invertebrates, and five priority invasive plant species. Target species were selected based upon their known or reported occurrence in the northern Lake Michigan area or the presence of suitable habitat as determined through aerial photo interpretation.

Occurrences of state and federal threatened Houghton's goldenrod and state and special concern butterwort were relocated in Jensen Harbor and their status and spatial extent updated. The last reported surveys for these were 30 and 44 years ago, respectively. A second occurrence of state special concern English sundew was also documented in Jensen Harbor, where it was locally abundant. All three of these species are known primarily from calcareous coastal wetlands in northern Michigan. An occurrence of federal and state threatened dwarf lake iris was reported by other researchers just as this report was nearing completion. Preliminary data for this occurrence are included in this report; however, formal documentation will be accomplished at a later date. An occurrence of the culturally significant sweet grass was also documented along the western coastal zone.

The goldenrod is a globally rare Great Lakes endemic, known from approximately 60 occurrences in Michigan, including four sites within the Beaver Island Archipelago. The Garden Island population represents a potentially important reservoir of genetic diversity. Butterwort is known from 70 sites statewide and English sundew is known from 24. Four sites lie within the Beaver Archipelago, including the two Garden Island sites where they occur together. There are also several disjunct records for the sundew in southeastern Lower Michigan. The dwarf-lake iris occurrence is one of about 80 documented globally. This species is known only from northern Lakes Michigan and Huron shores, where it occurs primarily in boreal forest edges and openings, and alvar and limestone bedrock communities.

None of the targeted bird marsh species were located during the call playback surveys at Indian Harbor or Jensen Harbor. However, both Virginia Rail and Sora responded to playback calls at Indian Harbor marsh and an active Wilson's Snipe nest was observed in the Jensen Harbor coastal fen. These species are primary targets for the Michigan Marsh Bird Survey and are identified as species of greatest conservation need in Michigan's Wildlife Action Plan. An active Sandhill Crane nest was also observed at Indian Harbor marsh. This species is a secondary target of the Michigan Marsh Bird Survey.

Lake Huron locust was observed in Northcutt Bay and Jensen Harbor, representing a single new occurrence with multiple localities for the island and one of only five known Great Lakes island populations. This species is more typical of much larger dune complexes, thus monitoring this population may provide valuable information regarding its ability to persist in less extensive dunes.

A single adult male Hine's emerald dragonfly was found along the southern edge of a large coastal fen at Jensen Harbor, representing the 15th known occurrence for the

state. This species is known primarily from the Great Lakes region and, it has been documented globally from about 50-80 sites in seven U.S. states and one Canadian province. It is believed to be currently extant at less than 50 sites in only five states and provinces (NatureServe 2011).

Invasive species were surprisingly sparse in the coastal zone, providing an opportunity for mounting a highly effective rapid response effort. The treatment of phragmites that has already been initiated should be continued and expanded to include all priority invasive species documented. Dedicated surveys of all trails and other disturbed areas, as well as representative vegetation types are encouraged so that prioritized rapid response efforts can be implemented effectively throughout the island. Primary emphasis should be placed on keeping sites where rare species occur, particularly Jensen Harbor, free of all invasive species, as well as containing source populations and disrupting dispersal pathways.

Further surveys are recommended for all targeted rare species in suitable habitat that was not surveyed in 2011. These include intensive surveys for rare orchids in late May in the northwest boreal forest and the northeast dune and swale complex, revisiting the known Pitcher's thistle and English sundew occurrences on the northwest coastal zone, and conducting surveys for Houghton's goldenrod, Pitcher's thistle, English sundew, and butterwort in the remaining coastal zone. The dwarf lake iris occurrence should be formally documented and its full extent on the island determined. Surveys should also target culturally significant plants such as sweet grass.

Boat surveys for shoreline birds such as the Caspian tern, more intensive raptor surveys in the interior woodlands and on-going surveys for loons are also recommended. Surveys for the Lake Huron locust and Hine's emerald dragonfly should be conducted throughout the entire coastal zone to better document their status and full extent on the island. Suitable habitat for rare snails also appears to be present on the island, particularly in the coastal zone, and future surveys for these species are encouraged.

Surveys to delineate and assess the status of the natural communities on the Island are also highly recommended as they provide essential habitat for rare and vulnerable species. A systematic threat analysis for these communities would be highly beneficial. Maintaining the health and integrity of these underlying communities and their natural processes will allow the diversity of native species, both common and rare, to thrive.

These findings provide important data for consideration when identifying conservation targets for the Island and devising management strategies for their protection.

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Introduction

Garden Island harbors numerous features that contribute to the rich biodiversity and cultural value of the Beaver Island Archipelago. It is one of two islands within the archipelago which are part of the 1855 Little Traverse Bay Bands of Odawa (LTBB) Reservation. Previous surveys by the Michigan Natural Features Inventory (MNFI) identified several natural community and rare species occurrences on the island; however, these data are now outdated and incomplete. Also, few data are available about the status of invasive plants, such as *Phragmites australis* ssp. *australis* (non-native phragmites) and *Centaurea stoebe [Centaurea maculosa]* (spotted knapweed), that pose a significant and imminent threat to natural features. This project created a partnership between MNFI and LTBB designed to accomplish a number of goals, including: 1) gathering current data on previously identified natural features on the island, 2) identifying and filling survey gaps, 3) identifying and mapping priority invasive plant species, and 4) educating LTBB natural resource staff about MNFI's survey methods and the natural features of Garden Island.

MNFI and LTBB staff worked together to accomplish these goals. The LTBB provided state of the art, 2010, digital orthophotos for the interpretation and identification of natural feature inventory targets. They also provided transportation to the island. Because a comprehensive survey of the island for all potential conservation targets and invasive plants was cost-prohibitive, our surveys focused on rare and vulnerable plant and animal taxa and selected invasive plants, while gathering general ecological information to inform future survey work. These data are important for defining conservation targets and developing management strategies for their protection.

Organization of the Report

This report provides overviews of the study area, access and timing of surveys, aerial photo interpretation, and selection of survey targets first, as these are common to the three main components of the project. It is then divided into separate sections for rare plants, rare animals, and invasive species, each with its own methods, results, and discussion sections. The overall findings are summarized in the executive summary. The appendices include plant species lists for selected natural communities, detailed species accounts for rare species documented on Garden Island, and NatureServe element occurrence rank specifications.

Study Area, Access and Timing of Field Surveys

Surveys for this project were conducted on Garden Island, located in northern Lake Michigan, just north of Beaver Island, Charlevoix County, Michigan (Figure 1). The survey crews set up a home base on Beaver Island and accessed the island using an 18 foot Lund boat piloted by LTBB staff. Two survey periods were selected, coinciding with when the majority of targets were most easily detected, e.g., during breeding and flowering periods. Early season field inventories were planned for the week of June 5-11, 2011 and late season surveys for the week of July 31-August 6, 2011. Emphasis was placed on accessing high priority sites identified from the aerial photo interpretation, although to a large extent surveys were ultimately influenced by the ability to access shoreline areas by boat and by the dictates of weather.

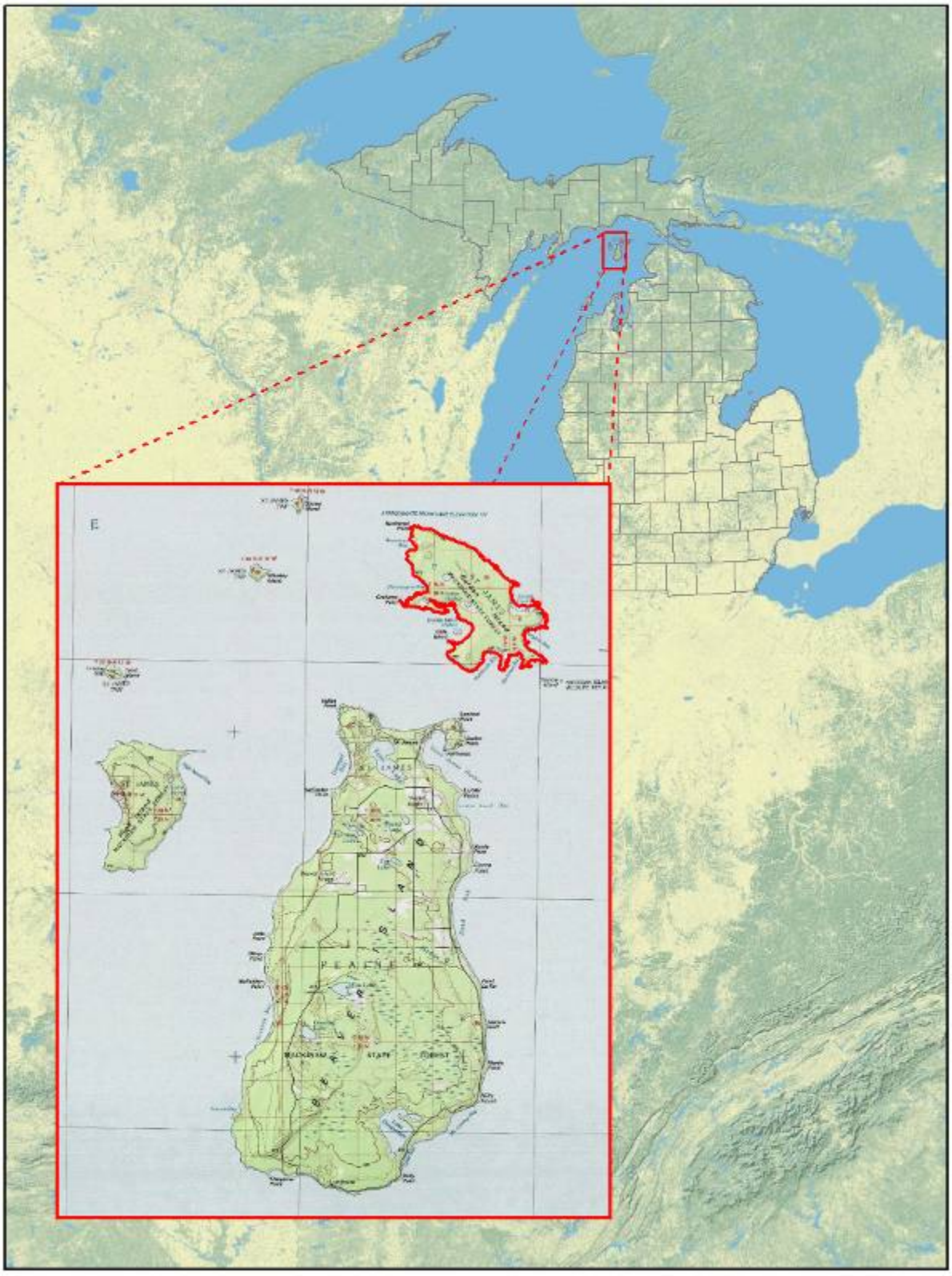

Figure 1. The study area, Garden Island, lies within the Beaver Island Archipelago in northern Lake Michigan.

Using the LTBB aerial imagery and GIS maps, both in digital form using handheld devices and hard copies, surveyors hiked to delineated areas from three principal access points: Indian Harbor, Jensen Harbor, and Northcutt Bay. Access was dependent upon weather conditions that allowed safe passage between Beaver and Garden islands. While there was some flexibility in the survey schedule, some planned surveys were not possible or were restricted in scope, due to the inability to access or stay on the island during the pre-selected survey windows. MNFI and LTBB staff conducted surveys together, learning from one another in the process.

Aerial Photo Interpretation

Prior to the field season, color aerial imagery collected April 11, 2010 by LTBB, was obtained to conduct a methodical interpretation of Garden Island for natural features. The imagery consisted of digital orthophotos with a one-foot GSD (Ground Sample Distance) or 0.3048 meters. The imagery was interpreted in conjunction with data from the MNFI Biotics Database. These data included information and associated shapefiles for all known element occurrences (EOs) of high quality natural communities, rare animals, rare plants, and other tracked features, such as exemplary geological formations or lichens. MDNR aerial imagery was also consulted for comparison, particularly the 1998 CIR (color infrared) photos and additional color imagery from 2005 and 2009.

Interpretation focused on the identification of natural communities, with special attention to those occurring along or in close proximity to the shoreline and most likely to support high priority rare taxa. Priority natural community types included coastal fen, northern fen, rich conifer swamp, boreal forest, mesic northern forest, open dunes, interdunal wetland, wooded dune and swale, and limestone cobble shore. These types guided the selection of priority survey sites for each component of the project.

Figure 2 shows the principle areas highlighted for field survey. They consisted primarily of the coastal habitats of the southern region of the island, from Jensen Harbor in the southeast through the southern end of the island and northwest to approximately Indian Harbor. The large coastal fen and limestone cobble shore complex within Jensen Harbor on the northeastern shoreline was identified as being of particular interest, owing to the large size of the tract and a high potential to support a number of rare plant and animal species. A large wooded dune and swale complex formed in an extensive embayment of Sturgeon Bay was identified on the southeastern shore of the island, grading from ridge and swale topography on the southeast end to a dense cedar swamp at its tip to the northwest. A kettle bog surrounded by what appeared to be rich conifer swamp was identified between the wooded dune and swale complex and the junction of Northcutt Bay and Monatou Bay on the south shore of the island. The marsh extending west from Indian Harbor was identified as potential habitat for marsh birds. An extensive boreal forest along the northwest shore of the island was highlighted based on the potential for rare orchids such as calypso orchid (*Calypso bulbosa*) and ram's head orchid (*Cypripedium arietinum*) and possible colonies of dwarf lake iris (*Iris lacustris*). Numerous, small wetlands within the boreal forest were identified as potential isolated fen pockets, that also merited field surveys. Finally, an occurrence of lowland hardwoods in the northwest interior of the island noted by LTBB staff was targeted for survey as well.

Figure 2. Principle areas highlighted for field survey on Garden Island in 2011.

Selection of Survey Targets

Target species for survey were identified for rare plants, rare animals, and invasive plants prior to the field season to help direct inventories. Species selection was based upon the known, historical or reported occurrence within the Beaver Island Archipelago, other islands within northern Lake Michigan, the Straits region, or the coastal zone of adjacent mainland areas (Penskar et al. 2002a, Penskar et al. 2002b, Penskar et al. 2001, Penskar et al. 2000, Penskar et al. 1999, Penskar et al. 1997, Penskar and Leibfreid 1993). Additional species were included for which suitable habitat appeared to be present on the island as determined by the aerial photo interpretation and experience of the surveyors. Surveys were guided by but not limited to seeking the targeted species. With extensive experience in habitats throughout Michigan, all surveyors were prepared to gather data on any other significant species unknown or unusual for the region.

Rare Plant Inventories
Methods

Target Species

Nineteen rare plant species were targeted for survey including five species previously documented on the Island (Table 1). The latter included records for *Cirsium pitcheri* (Pitcher's thistle, state and federal threatened), *Pinguicula vulgaris* (butterwort, state special concern), *Solidago houghtonii* (Houghton's goldenrod, state and federal threatened), *Drosera anglica* (English sundew, state special concern) and calypso orchid (state threatened).

Field Surveys

Sites were systematically surveyed by conducting methodical meander-searches. Efforts were made to identify previously known rare plant records to determine whether they were extant or not and to update extant occurrences with current, detailed, spatial and population data. When potential habitat for new rare plant taxa was encountered, sites were carefully surveyed to detect any of these species. Plant species lists were compiled for significant natural communities during site surveys and foot travel throughout the island. These lists were compiled using the statewide assessment system provided by Herman et al. (2001), to characterize floristic quality. They were also compiled so that known, high quality natural community occurrences could be subsequently updated by MNFI ecology staff.

Special plant field forms, plant species lists, and representative photographs were compiled as necessary when rare plant populations were identified. Waypoints were recorded via a Garmin 12XL GPS unit to obtain accurate location data for occurrences, in addition to depicting survey areas and routes throughout the island. Where appropriate, voucher specimens were collected and pressed to provide documentation for new plant records, including both rare and more common species. In some cases, voucher specimens were sought to better document known records previously based solely on field observations, or to obtain higher quality, contemporary collections more representative of the population of a site. Specimens were also obtained for the subsequent identification of plants that could not be determined in the field and/or required determination by a specialist.

Table 1. Target species identified for rare plant surveys on Garden Island in 2011.

Species	Common Name	Global, State Rank[1]	State[2], US[3] Status	Associated Natural Community types/habitats
Amerorchis rotundifolia	roundleaf orchid	G5, S1	E	Rich conifer swamp
Asplenium trichomanes-ramosum	green spleenwort	G4, S3	SC	Limestone outcrops
Botrychium campestre	dunewort	G3G4, S2	T	Open dunes, old fields
Bromus pumpellianus	Pumpelly's brome grass	G5T4, S2	T	Open dunes
Calypso bulbosa	Calypso orchid	G5, S2	T	Boreal forest, rich conifer swamp
Carex richardsonii	Richardson's sedge	G4, S3S4	SC	Alvar, limestone bedrock lakeshore, northern fen
Carex scirpoidea	bulrush sedge	G5, S2	T	Coastal fen, limestone bedrock lakeshore, northern fen, alvar
Cirsium pitcheri	Pitcher's thistle	G3, S3	T, LT	Open dunes
Cypripedium arietinum	ram's head orchid	G3, S3	SC	Boreal forest, rich conifer swamp
Drosera anglica	English sundew	G5, S3	SC	Coastal fen, northern fen
Iris lacustris	dwarf lake iris	G3, S3	T, LT	Boreal forest, alvar, limestone bedrock lakeshore
Mimulus michiganensis	Michigan monkey-flower	G5T1, S1	E, LE	Rich conifer swamp
Orobanche fasciculata	fascicled broomrape	G4, S2	T	Open dunes
Panax quinquefolius	ginseng	G3G4, S2S3	T	Mesic northern forest
Pinguicula vulgaris	butterwort	G5, S3	SC	Coastal fen, interdunal wetland, limestone bedrock lakeshore
Pterospora andromedea	pinedrops	G5, S2	T	Boreal forest, dry-mesic northern forest, dry northern forest, wooded dune and swale
Solidago houghtonii	Houghton's goldenrod	G3, S3	T, LT	Alvar, interdunal wetland, limestone cobble shore, coastal fen, northern fen, open dunes
Stellaria longipes	stitchwort	G5, S2	SC	Open dunes
Tanacetum huronense	Lake Huron tansy	G5T4T5, S3	T	Open dunes, limestone cobble shore, wooded dune and swale

[1]NatureServe Global and State Ranks: G1, S1-most imperiled; G5, S5-least imperiled.
[2]State status abbreviation: E, state endangered; T, state threatened; SC, state species of special concern.
[3]US/Federal status abbreviation: LE, legally endangered, LT, legally threatened.

Data Processing

Following field surveys, voucher specimens collected during inventories were examined and identified. Data from field forms, notes, and plant lists were compiled and in conjunction with downloaded GPS data and photographs, element occurrence records were evaluated, transcribed, and processed. Where appropriate, new records were mapped and recorded, and known records were updated and remapped as necessary to more accurately reflect their recently observed spatial distributions.

Rare Plant Inventories
Results

Field Surveys

Overall, most of the coastal areas of the southern portion of the island from Jensen Harbor to Indian Harbor were traversed and surveyed, as well as the coastal areas north through Ninneegoes Bay to Bomways Bay. A portion of the extensive boreal forest area along the northwest shore of the island in the

region of Bomways Bay was surveyed in June for rare orchid species, and the eastern half of the dense wooded dune and swale complex in Sturgeon Bay was also accessed and surveyed during the early season visit. Three rare plant species were collectively identified during these inventories, consisting of a new occurrence of English sundew, an updated occurrence of butterwort, and an updated occurrence of Houghton's goldenrod. All of these were observed within the large coastal fen and limestone cobble shore complex comprising the majority of open habitat within Jensen Harbor (Figure 3).

Dwarf lake iris was reported west of Indian Harbor as this report was being finalized. Complete data for this occurrence will be collected later. A colony of *Hierochloe odorata* (sweet grass) was also identified in a coastal wetland north of Indian Harbor.

The rare species occurrences documented in 2011 and other previously reported occurrences on the island are summarized in Table 2. Plant species lists were compiled for mesic northern forest, coastal fen, and limestone cobble shore and are presented in Appendix A.

Table 2. Previously known and updated rare plant element occurrences for Garden Island, based on the MNFI Natural Heritage Database, 2011.

Scientific Name	Common Name	State, Federal Status	EO Number	Year First Observed	Year Last Observed
Calypso bulbosa	calypso orchid	T	27	1966	1966
Cirsium pitcheri	Pitcher's thistle	T, LT	105	1983	1983
Cirsium pitcheri	Pitcher's thistle	T, LT	128	1998	1998
Cirsium pitcheri	Pitcher's thistle	T, LT	144	1981	1999
Adlumia fungosa	climbing fumitory	SC	13	1966	1966
Drosera anglica	English sundew	SC	16	1998	1998
Drosera anglica	English sundew	SC	25	2011	2011
Iris lacustris	dwarf lake iris	T, LT	tbd	2008	2012
Pinguicula vulgaris	butterwort	SC	46	1967	2011
Pinguicula vulgaris	butterwort	SC	29	1998	1998
Solidago houghtonii	Houghton's goldenrod	T, LT	46	1981	2011
Solidago houghtonii	Houghton's goldenrod	T, LT	66	1999	1999
Tanacetum huronense	Lake Huron tansy	T	70	1981	1999

Rare Plant Inventories
Discussion

Although Garden Island is significantly smaller than Beaver Island, it comprises one of the most important islands within the archipelago. Key natural features include broad areas of boreal forest bordering most of the island's perimeter, mature mesic northern forest areas within the interior in the northern and southern regions of the island, interior bogs and rich conifer swamps, a large wooded dune and swale complex contiguous with Sturgeon Bay, and a pristine coast containing high quality coastal fens as well as extensive stretches of limestone cobble shore. These natural communities provide the high quality context for the rare flora of the island known to date. Although relatively few rare plant species were encountered during the surveys, and included previously known occurrences that were updated, the results comprise important data.

Of the two previously known plant species records, significant field data were collected for an occurrence of butterwort, which had not been updated since it was first observed

Figure 3. Rare and culturally significant plants (red), documented on Garden Island in 2011. Rare plants previously documented on the Island, but not relocated or resurveyed in 2011 are shown in yellow.

in 1967, and an occurrence of Houghton's goldenrod, a federal threatened species that had not been observed since it was documented in 1981. For both of these taxa, which had not been observed in 44 and 30 years, respectively, more detailed data on population size, habitat, and spatial extent were acquired to significantly enhance these records.

Butterwort (Figure 4) is known from about 70 occurrences in Michigan, occurring in the northern Lower Peninsula and the Upper Peninsula, and is primarily a species of northern Great Lakes shorelines, where it is restricted to alkaline, marly shores, coastal and northern fens, and calcareous bedrock communities (Penskar and Hansen 2009, Appendix B). It was observed in two distinct colonies comprising the occurrence in Jensen Harbor, one of only four occurrences in the archipelago.

Houghton's goldenrod (Figure 4) is a Great Lakes endemic known from approximately 60 occurrences in Michigan, where it is restricted to the tip of the Lower Peninsula and the eastern Upper Peninsula. It usually occurs in shoreline habitats such as interdunal wetland, limestone cobble shore, coastal fen, northern fen, alvar, and occasionally associated habitats such as wooded dune and swale complexes (Penskar et al. 1996, Appendix B). Its occurrence in the Beaver Island archipelago, where it is known from four localities, is biologically significant, owing to the global rarity of the species and the potential for this occurrence to represent an important reservoir of genetic diversity as an isolated island population.

The new record discovered for English sundew (Figure 4) is the second Garden Island locality for this species and fourth occurrence for the archipelago, where it was found to be locally abundant in Jensen Harbor, comprising the larger of the two known island populations. English sundew is known statewide from 24 records, occurring principally in the Upper Peninsula and the tip of the Lower Peninsula, with a few disjunct records in southeastern Lower Michigan (Penskar and Higman 1999, Appendix B). It typically occurs in coastal and northern fens, marl flats, cobble shores, and interdunal wetlands, sometimes arising as a result of hybridization between the common *D. rotundifolia* (round-leaved sundew) and *D. linearis* (linear-leaved sundew) as discussed by Penskar and Higman (1999). The dwarf lake iris occurrence is one of around 80, known only from the shores of northern Lakes Michigan and Huron in boreal forest openings and edges, and alvar and limestone bedrock communities.

Sweet grass was found to be locally abundant in a coastal wetland along the northwest shore, where it occurs in a swale-like meadow with water at the surface. Sweet grass, also known as Wiingashk or Wiishkobimashkos, is a culturally significant species with a wide variety of uses such as smudge, medicine, utility, and crafting, such as basketry (Pilette 2011). It is also an important ceremonial plant. Unlike many other grasses, sweet grass produces flowering stems prior to leaf development, emerging in late May to early June. It is difficult to identify after the flowers have past, and is best sought in late spring in calcareous habitats. These include coastal fens, wet meadows, and swales along Great Lakes shores and similar interior habitats including northern fens, northern wet meadows, and communities such as wet prairies, among other types. Additional surveys may result in the identification of additional populations of sweet grass on the island.

With regard to other areas surveyed, a portion of the large, contiguous boreal forest on

the northern end of the island was accessed and meander-searched for calypso orchid, which is known from the east side of the island via a 1966 collection. The brief survey for rare orchids in early June was unsuccessful but far from definitive, due to the difficulty of conducting thorough inventories for very diminutive species in densely populated communities such as boreal forest. Similarly difficult terrain was encountered in the wooded dune and swale complex partially transected near Sturgeon Bay, and thus these sites warrant much more dedicated and comprehensive surveys. Due to the concentration of effort in the shoreline areas, and the often limited time for surveys once the island was accessed, sufficient time was not available to explore any of the interior bogs and swamps. The species lists presented in Appendix A using the Floristic Quality Assessment System, were compiled for characterization purposes, but are representative of the floristic diversity of the natural communities included and indicative of the high quality of these community types. This is demonstrated by the relatively high floristic quality index (FQI) values and high average coefficient of conservatism (COC) scores. Ideally, more comprehensive floristic inventory conducted throughout the growing season is necessary to develop reliable, defensible FQI data, particularly to compare these sites to other examples in the region and state.

Figure 4. Rare plants documented on Garden Island: basal rosettes of butterwort (upper left); flowering heads of Houghton's goldenrod (upper right); English sundew (bottom center) [photos by Bill Parsons]; dwarf lake iris leaves (bottom right) [photo by Beth Leuck].

Rare Animal Inventories
Methods

Target species

Animal inventories focused on surveys for 10 rare avian and two rare invertebrates (Table 3). Avian surveys targeted rare species that had been documented breeding previously on Garden Island, as well as additional rare species that had potential for breeding on the island. These included marsh-dependent species such as the American and least bittern (*Botaurus lentiginosus,* state special concern; *Ixobrychus exilis,* state threatened); rare raptors such as the merlin (*Falco columbarius,* state threatened*),* red-shouldered hawk (*Buteo lineatus,* state threatened), northern goshawk (*Accipiter gentilis,* state special concern), bald eagle (*Haliaeetus leucocephalus,* state special concern*),* and osprey (*Pandion haliaetus,* state special concern); species that typically nest along Great Lakes shorelines or on islands, such as the Caspian and common tern (*Sterna caspia,* state threatened; *Sterna hirundo,* state threatened); and the northern, inland lake species, common loon (*Gavia immer,* state threatened).

Invertebrate targets included the Lake Huron locust (*Trimerotropis huroniana*, state threatened), a dune species, and Hine's emerald dragonfly (*Somatochlora hineana*, state and federal endangered), known from calcareous wetlands. Surveys for the dune cutworm (*Euxoa aurulenta,* state special concern) and piping plover (*Charadrius melodus,* state and federal threatened) were not conducted due to lack of suitable habitat.

Inventories were conducted where previous occurrences were known and at additional suitable sites, during periods when the targeted animals were most active or when adults would be expected to occur. Surveys emphasized both the identification of new occurrences and the review of known or historical occurrences of rare species. Brief descriptions of these species, their habitats, and survey methods are provided below.

Avian Surveys

Marsh-dependant Birds

The American Bittern is a brown, medium-sized heron with a rusty crown, white throat, a heavily streaked brown and white underside, and a long, black patch extending from below the eye down the side of the neck. It has a distinguishing breeding call which consists of a series of deep, gulping, "*BLOONK-Adoonk*" sounds (Gibbs et al. 1992, Sibley 2000). American bitterns most often breed in shallow wetlands dominated by tall emergent vegetation, including cat-tail (*Typha* spp.) marshes, wet meadows, bogs, and shrubby marshes, and occasionally hayfields (Adams 1991). American bitterns may be area-sensitive, occurring more frequently or in greater abundance in larger wetlands (Brown and Dinsmore 1986, Gibbs et al. 1992, Riffell et al. 2001). The least bittern is a small, stout heron with a greenish-black crown, back and tail; brown and white neck, sides, and underparts; chestnut wings with contrasting pale patches; and white lines bordering the scapular feathers on the wings (Gibbs et al. 1992, Evers 1994). Because of its secretive nature and tendency to use dense cover, it is often easier to identify by its low dovelike call which consists of a fast series of three to five "*coo*" notes for males (Gibbs et al. 1992). This species uses a variety of freshwater and brackish marshes with dense, tall growths of aquatic or semi-aquatic vegetation, especially cat-tail, sedge (*Carex* spp.), bulrush (*Schoenoplectus* spp.), and arrowhead (*Sagittaria* spp.), interspersed with clumps of woody vegetation and open water (Gibbs et al. 1992).

Table 3. Target species identified for rare animal surveys on Garden Island.

Scientific Name	Common Name	Global Rank[1]	State Rank[1]	State Status[2]	US Status[3]	Habitats
Haliaeetus leucocephalus	Bald Eagle	G5	S4	SC		Forests near open water
Falco columbarius	Merlin	G5	S1S2	T		Boreal forest near open water/wetlands along lakeshores
Pandion haliaetus	Osprey	G5	S4	SC		Swamp forests, floodplain forest, and open wetlands along open water
Gavia immer	Common Loon	G5	S3S4	T		Inland lakes, Great Lakes
Sterna caspia	Caspian Tern[4]	G5	S2	T		Sand and gravel beach on shorelines and islands
Sterna hirundo	Common Tern[4]	G5	S2	T		Sand and gravel beach on shorelines and islands
Botaurus lentiginosus	American Bittern	G4	S3S4	SC		Shallow wetlands including marshes, wet meadows, wet prairies, bogs, fens
Ixobrychus exilis	Least Bittern	G5	S2	T		Great Lakes marsh, emergent marsh, coastal plain marsh
Accipiter gentilis	Northern Goshawk	G5	S3	SC		Northern forests, swamp forests, floodplain forest, and boreal forest
Buteo lineatus	Red-shouldered Hawk	G5	S3S4	T	LE	Mature northern and southern forests, swamp forests, and floodplain forest
Trimerotropis huroniana	Lake Huron Locust	G2G3	S2S3	T		Dunes
Somatochlora hineana	Hine's Emerald Dragonfly	G2G3	S1	E		Calcareous wetlands, northern fens

[1]NatureServe Global and State Ranks: G1, S1-most imperiled; G5, S5-least imperiled.
[2]State status abbreviation: E, state endangered; T, state threatened; SC, state species of special concern.
[3]US/Federal status abbreviation: LE, legally endangered, LT, legally threatened.
[4]Previously recorded breeding on Garden Island.

Call playback surveys for marsh birds, using the protocol established for the Michigan Marsh Bird Survey (MMBS) (Monfils 2010), were conducted on June 6 and 7, at locations known to support the target species or in wetland types deemed most likely to harbor priority marsh birds (Figure 5). A total of nine point counts were taken in the Great Lakes marsh habitat surrounding Indian Harbor and in the coastal fen community along Jensen Harbor. Marsh birds are typically most vocal in the 2 hours surrounding sunrise and sunset. Morning foot surveys began on Garden Island at 0620 and ended at approximately 0830. A cluster of point counts was chosen based on visual clues taken by the primary observer. Adjacent survey points were no closer than

Figure 5. Avian call stations and locations of rare birds observed in 2011 (pink) and previously documented (red) on Garden Island.

400 (0.25 mi) from their nearest neighbor. Each survey point lasted 10 minutes and consisted of two parts: an initial 5-minute passive listening period and a subsequent 5-minute broadcast period consisting of five 1-minute segments of calls for target wetland species. The broadcast sequence consisted of calls of Least Bittern, Yellow Rail (*Coturnicops noveboracensis*), Sora (*Porzana Carolina*), Virginia Rail (*Rallus limicola*) and American Bittern. Calls were broadcasted using a MP3 player and a portable speaker set. Point count information /data were compiled on MMBS forms.

Merlin, Northern Goshawk, Red-shouldered Hawk

The Merlin is a medium-sized falcon, about the size of a blue jay, characterized by long, pointed wings that beat rapidly, a vertically streaked underside, and a long, heavily-barred tail (MNFI 2007, Cuthrell 2002). Merlins nest near lakeshores or other semi-open areas in boreal forests (Johnson and Coble 1967, Jordan and Shelton 1982, Haas 2010). They do not build their own nests but use those of other birds, most commonly those of corvids (crows, ravens) (Cuthrell 2002). The northern goshawk is a large, gray bird with long, broad wings and a long tail which is rounded on the end (Cooper 1999a). The head has a black cap with a pronounced white eyeline. Adult red-shouldered hawks can be distinguished by the reddish coloration of the upper part of their wings, their underparts and wing linings, and their five to six narrow, white tail bands (Cooper 1999b, MNFI 2007). In flight, they show crescent-shaped translucent patches at the base of their wings (Cooper 1999b, MNFI 2007). Both the red-shouldered hawk and the northern goshawk utilize a wide range of forested habitats including boreal forest and mesic northern hardwoods (Cooper 1999a, Copper 1999b, MNFI 2007, Seefelt 2010).

Call playback surveys were conducted on June 7 and 8. A total of four point counts were taken: three in boreal forest habitat and one along a ridge in a mesic northern forest community (Figure 5). At each calling station, taped playback calls were broadcast with an MP3 player and a portable speaker system. The broadcast sequence consisted of merlin, northern goshawk, and red-shouldered hawk. Each broadcast consisted of three 1-minute call segments followed by a 2-minute silent period for each raptor species. The primary observer rotated the direction of the broadcasts after each segment, playing the first segment at 60 degrees, the second at 180 degrees, and the third at 300 degrees.

Shoreline Birds

Both the Caspian and common tern have historically nested on the sand and gravel beaches and natural jetties and spits of the Beaver Archipelago (Seefelt 2010; Norwood 2010). Terns typically nest on islands to avoid terrestrial predators (MNFI 2007). The Caspian tern is the largest of the terns, with a wing span averaging 1.4 meters (4.5 feet; Hyde 1996). It has a black cap and a red bill similar to other white terns in the state but its large size and lack of a deeply forked tail distinguishes it from these other terns (Hyde 1996). The common tern also has a black head and nape and a red bill, but is smaller than the Caspian tern, with a wingspan averaging 0.8 meter/2.6 feet. It has a slender body, long pointed wings, and a deeply forked tail (Hyde 1997). Common terns were last observed on Garden Island in 1982 just off Little Island in Garden Island Harbor. Another colony of 360 nests was located off the northern tip of Snake Island in Manatou Bay in 1985 (MNFI 2011).

Meandering foot surveys were conducted along the shoreline for both tern species on June 6 and 7, paying particular attention to

adults flying over carrying food in their bill for young.

Common loon, Bald Eagle, Osprey
Casual foot and boat surveys were conducted for the common loon, bald eagle, and osprey. High quality breeding habitat for the common loon in Michigan has been characterized as an inland lake of adequate size (usually >40 acres) with a stable water level; clear, high-alkaline waters; and undeveloped shoreline, small islands, or bog mats for successful nesting (Jung 1987, McIntyre 1988, Robinson et al.1993). Common Loons will also utilize smaller lakes and/or lakes with marginal water quality (Gibson 2007a). Bald eagles will nest in a variety of forested habitats that provide suitable nest sites close to open water (Gehring 2006, MNFI 2007). Osprey also will nest in a variety of forested habitats with suitable nest sites (i.e., trees, snags or cliffs) near open water with an adequate fish supply or prey base (Gibson 2007b, MNFI 2007).

Invertebrate Surveys
Lake Huron locust
The Lake Huron locust is a small ash-gray grasshopper with darker brown and white markings and wings with a prominent dark band. The pronutum (saddle-like structure behind the head) is cut by two narrow grooves (sulci), and a broad (not narrow) black band covers half the inner surface of the hind femora near the body. This species occurs only in sparsely vegetated, high quality Great Lakes sand dunes along northern Lake Michigan, northern Lake Huron, and eastern Lake Superior. Ideal habitat includes at least a mile of shoreline with two or more sets of dunes with blowouts. It primarily feeds on dune grass, beach grass, and wormwood, but will eat other forbs also, including the federal threatened pitcher's thistle (*Cirsium pitcheri*). The Lake Huron locust is most active in late morning, after 9:30 or 10 am. Males crepitate in flight, making a cracking noise.

Surveys were conducted by walking through appropriate habitat and flushing individuals, and counting and recording points with a handheld GPS unit. Close-focusing binoculars and an aerial net were used to confirm identification. Surveys for the Lake Huron locust occurred on August 3 and 5, in two areas with suitable habitat, Northcutt Bay and Jensen Harbor (Figure 6).

Hine's emerald dragonfly
Hine's emerald dragonfly adults, like other members of its family, have brilliant green eyes. *Somatochlora hineana* can be distinguished from all other species of *Somatochlora* by a combination of its dark metallic green thorax with two distinct creamy-yellow lateral lines and its distinctively shaped terminal appendages or genitalia. Adults have a body length of 2.3-2.5 inches (60-65 mm) and a wingspan of 3.5-3.7 inches (90- 95 mm). Important habitat characteristics of Hine's emerald sites include graminoid-dominated wetlands which contain seeps, or slow moving rivulets; cool, shallow water slowly flowing through vegetation; and open areas in close proximity to forest edge. The shallow, flowing, cool water provides important larval habitat and the open areas with adjacent woodland edge provide adult hunting and roosting habitat. Hine's emerald dragonfly sites in Michigan are classified as calcareous wetlands or northern fens with an underlying layer of shallow dolomite.

Adult Hine's emeralds feed over meadows or at forest edges by 7 am on hot days, but are most active from 9:30 am to 1:30 pm, occasionally hanging from twigs. Sometimes they feed in swarms during the day or near sunset. Males patrol territories 1-3 m over rivulets, darting between hovering

Figure 6. Survey sites and documented occurrences of Hine's emerald dragonfly and Lake Huron locust on Garden Island in 2011.

points where they pivot in different directions. The rear half of the abdomen on females looks muddy and two-toned, and their flickering brown wings are visible at some distance. Surveys for the Hine's emerald dragonfly were conducted on August 3 and 5, at three locations on the island; Northcutt Bay, Indian Harbor, and Jensen Harbor (Figure 6). Meander surveys were conducted through appropriate habitat using close-focusing binoculars and aerial nets. Netting individuals and examining them closely or photographing them before releasing them provides the most definitive method for identification in the field.

Data Processing

Following field surveys, data from field forms, notes, and species lists were compiled and examined, and GPS locations and photographs were downloaded. Voucher specimens collected during inventories were examined and identified. Element occurrence records were evaluated, transcribed, and processed. New element occurrence records were mapped and entered into the MNFI Natural Heritage Database, and known element occurrence records were updated and remapped as necessary to more accurately represent their spatial distribution in the database.

Rare Animal Inventories
Results

Avian Surveys

None of the targeted marsh species were located during the call playback surveys at Indian Harbor or Jensen Harbor. However, both Virginia rail and sora responded to taped playback calls in the Indian Harbor marsh and an active Wilson's snipe (*Gallinago delicata*) nest was observed in the coastal fen at Jensen Harbor. These three species are primary target species for the MMBS, and all are identified as species of greatest conservation need in Michigan's Wildlife Action Plan (MDNR 2006). An active sandhill crane (*Grus canadensis*) nest was also observed in the Indian Harbor marsh. This species is a secondary target of the MMBS.

No targeted raptor species were located during the call playback surveys and no tern colonies were documented during coastal surveys. An active bald eagle nest was observed by LTBB staff in the interior of the Island during a reconnaissance survey in 2011, and a single common loon was observed foraging near Little Island in Garden Island Harbor on June 7. No suitable nesting habitat for common loons was located during surveys as they typically nest on large, undeveloped inland lakes (MNFI 2007).

Invertebrate Surveys

Lake Huron locust

The Lake Huron locust was found at both areas surveyed during this project. Over 46 Lake Huron locusts were observed in an area with a small, low sand dune and sandy shoreline along Northcutt Bay on August 3 (Figure 6). A single Lake Huron locust was found on August 5, in a small foredune area with sand and cobbles adjacent to a limestone cobble lakeshore and a coastal fen in Jensen Harbor (Figure 7). Specimens were collected from both locations to provide additional documentation of this population. The often co-occurring Carolina locust (*Dissosteira carolina*) was also found in both these areas.

These observations of the Lake Huron locust comprise a single, newly documented element occurrence for this species (Table 4).

Figure 7. Photo of Lake Huron locust (*Trimerotropis huroniana*) found at Jensen Harbor on Garden Island on August 5, 2011.

Table 4. Previously known and updated rare animal element occurrences for Garden Island, based on MNFI Natural Heritage Database, 2011.

Scientific Name	Common Name	State, Federal Status	EO Number	Year First Observed	Year Last Observed
Birds					
Haliaeetus leucocephalus	Bald Eagle	SC	591	2000	2011
Sterna hirundo	Common Tern	T	33	1962	1985
Sterna hirundo	Common Tern	T	34	1980	1981
Insects					
Trimerotropis huroniana	Lake Huron Locust	T	92	2011	2011
Somatochlora hineana	Hine's Emerald Dragonfly	E, LE	16	2011	2011

Due to the ability of this species to move through and between available suitable habitat on the island, Northcutt Bay and Jensen Harbor are considered multiple locations within a single element occurrence record. Using NatureServe specifications (2011), this population was ranked as having fair viability (C-rank; Schweitzer and Whittaker 2007, Appendix C). The C-rank was based on the observation of between 10 and 50 individuals in less than 100 acres of suitable habitat.

Hine's emerald dragonfly

An adult male Hine's emerald dragonfly was found along the southern edge of a large coastal fen at Jensen Harbor on August 5 (Figure 8). It was observed flying along the trees that border the inland edge of the coastal fen (Figure 9) and was netted and collected as a voucher specimen for verification and documentation. Additional individuals may have been observed during surveys for this species at Jensen Harbor,

Figure 8. Photos of adult male Hine's emerald dragonfly (*Somatochlora hineana*) found in coastal fen at Jensen Harbor on Garden Island on August 5, 2011. Photos taken by Bill Parsons.

Figure 9. Photo of coastal fen habitat where Hine's emerald dragonfly was found at Jensen Harbor, Garden Island, on August 5, 2011.

however, the lack of a successful capture did not allow confirmation of this.

No Hine's emerald dragonflies were observed in suitable wetland habitats along Northcutt Bay and Indian Harbor. Several other dragonfly species were observed and/or collected for specimens during these surveys, including the twelve-spotted skimmer (*Libellula pulchella)*, meadowhawks (*Sympetrum spp.*), four-spotted skimmer (*Libellula quadrimaculata)*, chalk-fronted corporal (*Ladona julia*), common whitetail or long-tailed skimmer (*Plathemis [Libellula] lydia*), calico pennant dragonfly (*Celithemis elisa*), and common green darner (*Anax junius*). Several of these are shown in Figure 10.

The discovery of Hine's emerald dragonfly on Garden Island represents a new element occurrence of this species in the state. The NatureServe specifications require there be some evidence of historical or current presence of single or multiple specimens, ideally with evidence of on-site breeding (teneral adults, mating pairs, territorial males, ovipositing females, larvae, or exuviae), at a

Figure 10. Photos of other dragonfly species encountered during Hine's emerald dragonfly surveys on Garden Island on August 3 or 5, 2011. These include the twelve-spotted skimmer (*Libellula pulchella)* (top left), a meadowhawk (*Sympetrum sp.*) (top right), and common green darner (*Anax junius*) (bottom center).

given location with potential breeding habitat. This population was ranked as having good to fair viability (BC-rank) based on the size, condition, and landscape context of available habitat at this site. The dragonfly is likely to persist at this site for the foreseeable future, at least 20-30 years.

Several, more common amphibians and reptiles were encountered during the Hine's emerald dragonfly surveys. These included the northern water snake (*Nerodia sipedon sipedo*n) on August 3, in the coastal fen along Northcutt Bay, and the eastern American toad (*Anaxyrus [Bufo] americanus americanus*) and spring peeper (*Pseudacris crucifer*) on August 5, in Jensen Harbor. According to LTBB staff, the spring peeper observation may be the first documented record of this species on Garden Island (Parsons pers. comm.).

Rare Animal Inventories
Discussion

Avian Species

Although none of the targeted bird species were observed during the June 2011 surveys, this work added to the understanding of the bird use and diversity on Garden Island. The marsh habitat at Indian Harbor may not be suitable in terms of its size and vegetation type to support the targeted wetland obligates but provides important habitat for other marsh bird species. The marsh is too small for American bitterns, an area-dependent species that typically prefer larger wetlands (Monfils 2004). Least bitterns are less dependent on area, but prefer more extensive cat-tails (*Typha* spp.) and deeper water conditions (Monfils 2003). However, the availability and type of coastal wetlands are directly linked to Great Lakes water levels. Conditions can change quickly and, thus, the species using them. The MMBS survey should continue at the Indian Harbor marsh to gain a greater understanding of Garden Island's marsh bird population.

While the call playback raptor survey conducted in June was unsuccessful in finding raptors, the results are far from definitive. The extensive amount of boreal forest habitat on the island probably supports merlins and possibly northern goshawks. Although suitable habitat for the red-shouldered hawk exists on the island in areas with mesic northern forest, this species is less likely to cross over from the mainland and may require a larger area of suitable habitat than is currently present on Garden Island (Cooper 1999b). Additional survey work is needed to determine the composition and distribution of the Garden Island's raptor populations. Additional aerial and boat surveys are recommended for osprey and bald eagle, and the island's inland lakes should be monitored for common loon breeding evidence.

Due to changing water levels and predation, tern colonies are ephemeral along the Great Lakes, making confirmation of their presence challenging. Terns will abandon natural nesting locations such as sand and gravel beaches for artificial sites when water levels are high (Norwood 2010). Logistical concerns accessing and traversing the island in 2011 made it difficult to conduct tern surveys on foot. It is recommended that future surveys be conducted by boat or aircraft to cover more ground and to be able to access offshore locations. Efforts should be made to minimize disturbance to nesting birds as much as possible during surveys.

Invertebrate Species

Lake Huron locust

The new Lake Huron locust population discovered during this study represents the fifth

population of this species documented on an island in the Great Lakes (MNFI 2011). Its occurrence on Garden Island was rather unexpected given the limited open sand dune habitat, particularly at the Jensen Harbor site. These observations indicate that this species can occur in areas with small open sand dunes or even narrow, open sandy shorelines. As a result, there is potential for it to occur in other dune or open sandy habitats around the island. Additional surveys for this species should be conducted to determine the full extent and size of the population on the island and monitor its status and viability.

The Garden Island Lake Huron locust population is significant from global and state perspectives. This species is a Great Lakes endemic known only from sand dunes in Michigan, Wisconsin, and Ontario (Otte 1984, Ballard 1989, Rabe 1999, NatureServe 2011). It may be extirpated from Ontario and is restricted to only a small number of sites in Wisconsin (NatureServe 2011). Thus, Michigan contains the majority of the global population and range of this species. Additionally, with its fair viability, it is one of only about 51 (57%) of the 89 known sites in Michigan that are ranked as having excellent (A-rank), good (B-rank) or fair viability (MNFI 2011, Appendix C). The remaining sites are ranked as having fair to poor viability (CD-rank) or poor viability (D-rank), or are considered historical sites. Scholtens (1996, 1997) also identified the Lake Michigan islands as one of six major shoreline areas in the state with significant populations of the locust.

Maintaining the Lake Huron locust population on Garden Island is important for the conservation of the species in Michigan and globally. Throughout its range, significant portions of the species' dune habitat have been degraded or destroyed by residential and/or recreational development (Rabe 1999). Protection of the remaining habitat is critical. Shorelines that are one mile or more in length with extensive, wide dunes that contain at least two sets of dunes and blowout areas appear to be ideal habitat for this species (Scholtens 1997, Rabe 1999). These large areas typically sustain the natural processes that maintain and create habitat, particularly areas of bare sand where the locust likely lays its eggs and overwinters. Although the island may not contain ideal or exceptional habitat for the Lake Huron locust, the species can persist in areas with smaller dunes and with low to moderate levels of natural and/or anthropogenic disturbance (Scholtens 1997, Rabe 1999). The species generally occurs in large numbers in high quality sites, and quickly diminishes or disappears when dunes become heavily vegetated or disturbed (Ballard pers. comm.) Because Garden Island appears to provide relatively undisturbed habitat for the species, the Lake Huron locust may continue to persist there into the foreseeable future, e.g., at least 20-30 years. However, the population should be monitored closely.

Further research is needed on the life history and ecology of the Lake Huron locust to provide a stronger basis for management and conservation of this species. Additional information about the species' microhabitat requirements, particularly for different stages of its life history, is needed (Rabe 1999). Information about the species' movement and dispersal patterns and capabilities would also be useful (Rabe 1999).

Hine's emerald dragonfly

Documentation of the Hine's emerald dragonfly on Garden Island was a very exciting and significant discovery. This species is known primarily from the Great Lakes region. Globally, it has been documented from about 50-80 sites in seven U.S.

states and one Canadian province, but is believed to be currently extant at less than 50 sites in only five states and provinces (NatureServe 2011). In Michigan, this species is known from only 15 sites including the new Garden Island site. The Garden Island population is the only known population on an island in Lake Michigan, and the first new population documented in the state since 2007 (MNFI 2011).

Because of the global and state rarity of this species, all known populations should be maintained and protected. The most significant threats to this species across its range have been identified as habitat destruction or alteration and chemical contamination (Cuthrell 1999). These threats do not appear to be an issue at the Garden Island site currently, which highlights the importance of protecting this site. The size of the population and full extent and condition of suitable habitat at Jenson Harbor should be assessed through further survey and monitoring. Maintaining the hydrology at occupied sites is particularly important (Cuthrell 1999).

Due to limited surveys in 2011 and the challenge of finding this species, additional surveys should be conducted at other sites with suitable habitat on the island, such as Northcutt Bay. Surveys should document the size of additional populations discovered, and the extent and condition of suitable habitat to assess population viability. Larval habitats within occupied sites also need to be identified and protected. Additional research to clarify the ecological requirements of Hine's emerald dragonfly adults and larvae is also needed.

Invasive Plant Inventories
Methods

Target Species

Invasive species targeted for survey were selected from the list of invasive species with potential to impact Michigan's native communities, presented in *Meeting the Challenge of Invasive Plants: A Framework for Action* (Higman and Campbell 2009). Species that were already known from, or near, the Beaver Archipelago, that spread quickly and pose significant threats to the natural features of the island were prioritized. Currently known distributions, anticipated threat, and rates of spread were based on data from the Midwest Invasive Species Information Network (MISIN), the University of Michigan Herbarium, local networks of conservation organization staff, the extensive review conducted for developing the *Framework* and personal experience of the project team.

Table 5 lists the invasive species targeted, the natural communities they are most likely to colonize, and the rare species they are most likely to impact. While these species were the primary focus for survey, observations of any species listed in the *Framework* or any other species known to be invasive elsewhere, but not yet documented from the region were also noted.

Field Surveys

Since comprehensive surveys throughout the entire island were beyond the scope of this project, the primary focus was to conduct invasive plant surveys in areas where rare species were known or are likely to occur, thereby identifying threats to the most vulnerable species and their habitats first. The secondary focus was to target disturbed areas, which are often key entry points for invasive species. Surveys were conducted while en route to rare species survey sites and at the survey sites themselves (Figure 2). Additional surveys were conducted along other areas of the coastal zone, trails,

Table 5. Priority invasive species targeted on Garden Island, the natural communities they are likely to colonize and the vulnerable features they are likely to impact.

Invasive Species	Natural Communities	Vulnerable Plants	Vulnerable Animals
hybrid cat-tail non-native phragmites narrow-leaved cat-tail reed canary grass	coastal fen Great Lakes marsh limestone cobble shore northern fen	bulrush sedge (T) butterwort (SC) English sundew (SC) fleshy stitchwort (SC) Houghton's goldenrod (LT, T) Lake huron tansy (LT, T) Pumpelly's brome grass (T) Richardson's sedge (SC)	American bittern (SC) Caspian tern (T) common loon (T) common tern (T) Hine's emerald dragonfly (LE, E) least bittern (T)
spotted knapweed lyme grass baby's-breath	open dune	dunewort dwarf lake iris (LT, T) fascicled broomrape (T) Lake Huron tansy (T) pitcher's thistle (LT, T)	Lake Huron locust (T)
autumn olive common buckhorn Eurasian honeysuckles garlic mustard glossy buckthorn multiflora rose	boreal forest dry-mesic northern forest dry northern forest mesic northern forest rich conifer swamp wooded dune and swale	calypso orchid (T) dwarf-lake iris (LT, T) gensing (T) green spleenwort (SC) pine drops (T) ram's-head orchid (SC) roundleaf orchid (E) Michigan monkeyflower (LE, E)	Lake Huron locust (T) Merlin (T) Northern Goshawk (T) Osprey (SC) Red-shouldered Hawk (T)

and clearings where feasible and as time allowed. Surveyors meandered along the route and through the survey sites, covering as much ground as possible, while deliberately targeting the heterogeneity of the habitat (Goff et al. 1982). Occurrences of invasive plants were documented by marking their location with a GPS point and indicating the area (extent) and abundance of each infestation using standardized drop-down menus. The area and density categories are shown in Table 6 and are based on protocols established by the Michigan Department of Natural Resources (MDNR) Parks Stewardship Program (Clancy 2011). Separate occurrences were marked for infestations that were separated by 100 feet or more of un-infested area.

Table 6. Size and density codes for invasive species occurrences.

Area Code	Area Description	Density Code	Density Description
1	Individual/few/several	1	Sparse (scattered individual stems or very small stands)
2	less than 1,000 square feet	2	Patchy (a mix of sparse and dense areas)
3	1,000 ft^2 to 0.5 acre	3	Dense (greater than 40% of the area)
4	0.5 acre to 1 acre	4	Monoculture (nearly 100% of area)
5	greater than 1 acre		

Data Processing

The invasive species GPS data points were downloaded to a GIS project file and a map depicting the species, location and size of each mapped infestation was created. A close-up map of a portion of the island was also produced where individual occurrences can be more easily discerned. The density of an occurrence was not depicted on these maps, but can be determined using the identify feature in ArcMap, and clicking on a mapped point in the project shapefile.

Invasive Plant Inventories
Results

Five priority invasive plants targeted were documented on Garden Island, including non-native phragmites, reed canary grass, narrow-leaved cat-tail, hybrid cat-tail, and spotted knapweed (Table 7). The grasses and cat-tails were mostly found as widely scattered, small and sparse patches, along the coastal shoreline, primarily in limestone cobble shore and coastal fen. Spotted knapweed was found in occasional patches in coastal foredunes and limestone cobble shore, as well as in disturbed openings inland, where it was sometimes abundant. Notably absent in surveyed areas were garlic mustard, common buckthorn, glossy buckthorn, multiflora rose, baby's-breath and lyme grass. Figure 11 shows the occurrences of these species as well as numerous patches of native phragmites, which was quite common in the coastal zone. Native phragmites was also found inland at the southeast corner of Sorry Burn Lake. Figure 12 shows a close-up view of the priority species infestations in Northcutt Bay. Species are distinguished by color with the size of the icon corresponding to the area description code for each occurrence. Shapefiles with both area and density data for each occurrence were provided separately to LTTB.

Table 7. Priority invasive species documented on Garden Island during 2011 surveys.

Common Name	Scientific Name	Common Name	Scientific Name
hybrid cat-tail	*Typha Xglauca*	reed canary grass	*Phalaris arundinacea*
narrow-leaved cat-tail	*Typha angustifolia*	spotted knapweed	*Centaurea stoebe*
non-native phragmites	*Phragmites australis* ssp. *australis*		

Twelve additional species, noted as invasive in the *Framework,* were also documented on the island (Table 8). These lower threat species occurrences were, for the most part, uncommon and sparse, with the exception of wild parsnip (*Pastinaca sativa,* Figure 13) which was found scattered along many of the trails throughout the island and abundant in several disturbed openings. This species contains a photosensitive chemical that can cause serious skin burns. An isolated occurrence of Japanese hops (*Humulus japonicus,* Figure 14) was documented in the lowland hardwoods in the northeast interior of the island. This species can form dense mats several feet deep, blocking light to plants underneath. It can also twine around shrubs and trees causing them to break or fall over.

Table 8. Lower threat invasive species documented on Garden Island during 2011 surveys.

Common Name	Scientific Name	Scientific Name	Common Name
bird foot trefoil	*Lotus corniculata*	common St. John's-wort	*Hypericum perforatum*
bittersweet nightshade	*Solanum dulcamara*	European marsh thistle	*Cirsium palustre*
bladder campion	*Silene vulgaris*	Japanese hops	*Humulus japonicus*
bull thistle	*Cirsium vulgare*	white sweet clover	*Melilotis alba*
Canada thistle	*Cirsium arvense*	wild parsnip	*Pastinaca sativa*
common mullein	*Verbascum thapsis*	yellow sweet clover	*Melilotis officinale*

Figure 11. Priority invasive species mapped on Garden Island during 2011 surveys.

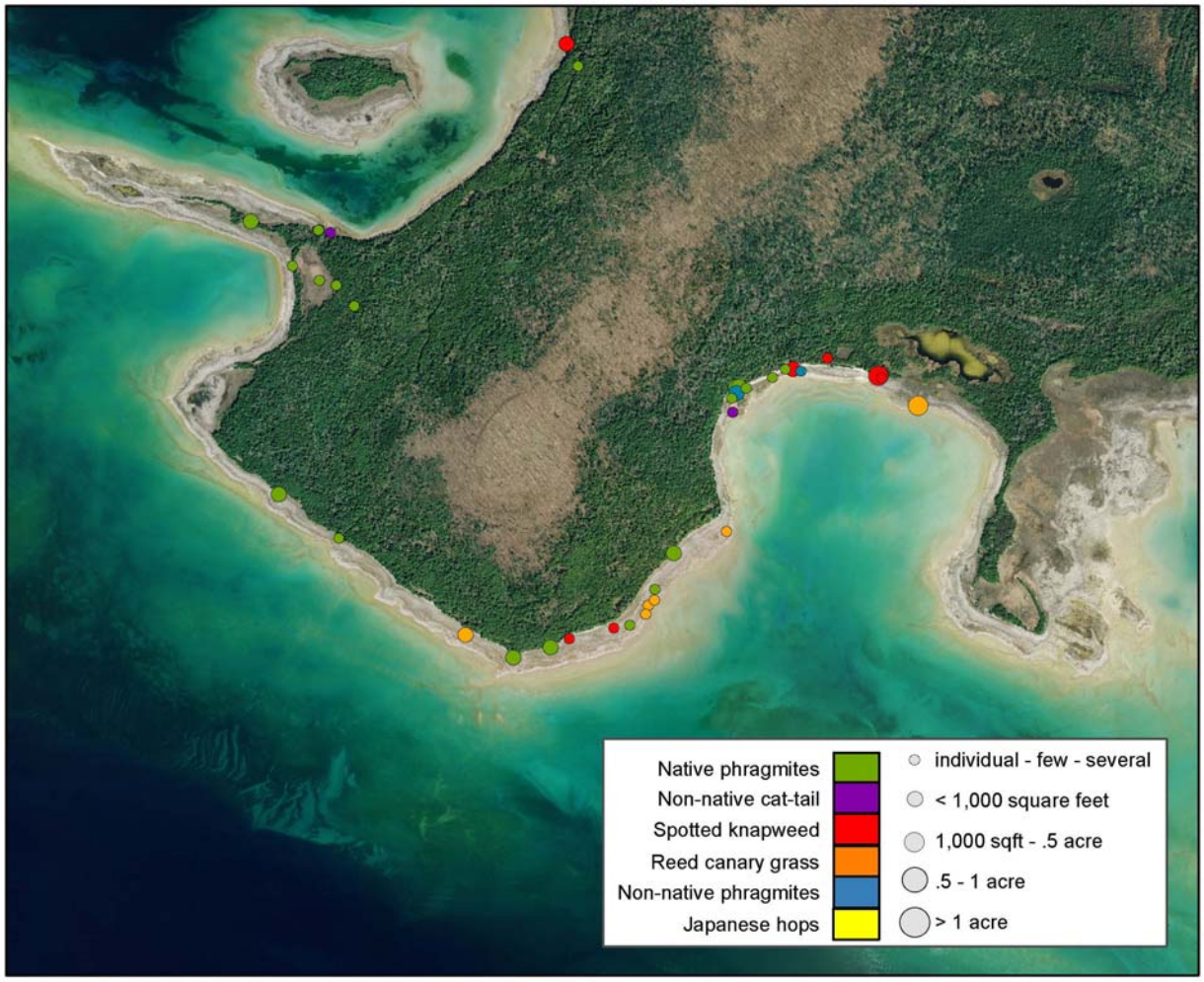

Figure 12. View of Northcutt Bay showing priority invasive species infestations by size.

Figure 13. Wild parsnip (*Pastinaca sativa*).

Figure 14. Japanese hops (*Humulus japonicus*).

Figure 15. Locations of lower threat invasive species mapped on Garden Island during 2011 surveys.

Invasive Plant Inventories
Discussion

The invasive species documented on Garden Island are typical of disturbed areas in northern Michigan, although their relatively low abundance, particularly in areas with rare species, is a significant finding. Coupled with the noted absence of garlic mustard, Eurasian honeysuckles, autumn olive, common buckthorn, glossy buckthorn, multiflora rose and lyme grass, these findings present an opportunity for mounting a highly effective rapid response effort. Due to the currently low abundance of these species, there is a window of opportunity to treat most, if not all, of the currently mapped infestations with high success rates, potentially eradicating some and containing or preventing the spread of others. Figure 16 demonstrates how costs will increase and level of success decline the longer these aggressive invasive species remain unchecked.

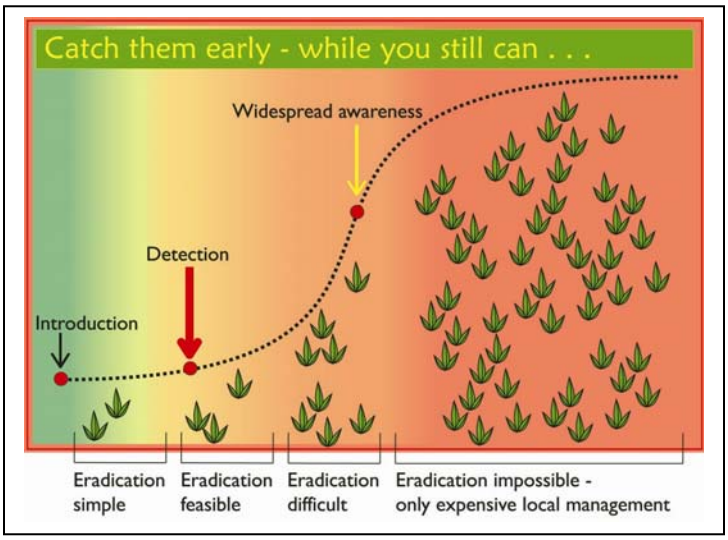

Figure 16. Cost effectiveness of early detection and rapid response.

In general, it is most effective to treat small isolated infestations first and work backwards towards larger source infestations, ultimately eradicating or containing them. Otherwise, the small, isolated occurrences will grow into larger infestations. When sufficient resources to treat every infestation are lacking, this strategy can be focused in areas of highest value first. For rare species, these are the sites with known element occurrences shown in Figures 3, 5 and 6. Other valued sites could be identified to augment these maps and integrated into the prioritization plan.

Since most infestations documented on the Island to date are relatively small, it is recommended that all infestations of priority invasive species shown in Table 7 be treated as quickly as possible. If left unchecked, these species will quickly degrade the coastal communities where most of the rare species on Garden Island are known. Ideally, the isolated lower threat infestations should be treated as well. Because most of these occurrences are quite small and sparse, this could be accomplished at a fairly low cost. They will become harder and more expensive to treat as time passes, however,

since they typically don't spread as quickly, their immediate treatment is not as urgent. The lone occurrence of Japanese hops, however, should be prioritized for further assessment and potential treatment before it spreads to other areas. If the population is not extensive, eradication may be possible.

Since treatment rarely completely eradicates an infestation and new propagules will continue to arrive, rapid response efforts are most cost-effective when complemented by strategic long-term monitoring. This entails periodic monitoring for new infestations near high value sites to keep them out, and in disturbed areas where invasive species are likely to establish first. It is recommended that routine monitoring of the entire coastal zone and all high value sites and pathways be conducted annually, to keep existing invaders at low levels and to detect and eradicate newly colonizing invasive species.

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Appendix A. Plant Species Lists for Selected Natural Communities Using the Floristic Quality Assessment

Coastal Fen

Floristic Quality Data
2011, by Mike Penskar

NATIVE SPECIES	97	Native	97	100.00%	Adventive	0	0.00%
Total Species	97	Tree	7	7.20%	Tree	0	0.00%
NATIVE MEAN C	7.1	Shrub	14	14.40%	Shrub	0	0.00%
W/Adventives	7.1	W-Vine	1	1.00%	W-Vine	0	0.00%
NATIVE FQI	69.6	H-Vine	0	0.00%	H-Vine	0	0.00%
W/Adventives	69.6	P-Forb	37	38.10%	P-Forb	0	0.00%
NATIVE MEAN W	-2.8	B-Forb	1	1.00%	B-Forb	0	0.00%
W/Adventives	-2.8	A-Forb	3	3.10%	A-Forb	0	0.00%
Facultative (-)		P-Grass	4	4.10%	P-Grass	0	0.00%
		A-Grass	0	0.00%	A-Grass	0	0.00%
		P-Sedge	26	26.80%	P-Sedge	0	0.00%
		A-Sedge	1	1.00%	A-Sedge	0	0.00%
		Fern	3	3.10%			

Scientific Name	Common Name	C	W	Wetness	Physiognomy
Agalinis purpurea	purple gerardia	7	-3	FACW	Nt A-Forb
Andropogon scoparius	little bluestem grass	5	3	FACU	Nt P-Grass
Arabis lyrata	sand cress	7	4	FACU-	Nt B-Forb
Arctostaphylos uva-ursi	bearberry	8	5	UPL	Nt Shrub
Asclepias syriaca	common milkweed	1	5	UPL	Nt P-Forb
Aster borealis	northern bog aster	9	-5	OBL	Nt P-Forb
Betula papyrifera	paper birch	2	2	FACU+	Nt Tree
Calamagrostis canadensis	blue joint grass	3	-5	OBL	Nt P-Grass
Calamintha arkansana	low calamint	10	-3	FACW	Nt P-Forb
Campanula aparinoides	marsh bellflower	7	-5	OBL	Nt P-Forb
Carex aquatilis	sedge	7	-5	OBL	Nt P-Sedge
Carex buxbaumii	sedge	10	-5	OBL	Nt P-Sedge
Carex capillaris	sedge	9	-3	FACW	Nt P-Sedge
Carex concinna	beauty sedge	10	2	FACU+	Nt P-Sedge
Carex crawei	sedge	10	-3	FACW	Nt P-Sedge
Carex eburnea	sedge	7	4	FACU-	Nt P-Sedge
Carex echinata	sedge	6	-5	OBL	Nt P-Sedge
Carex flava	sedge	4	-5	OBL	Nt P-Sedge
Carex garberi	sedge	8	-3	FACW	Nt P-Sedge
Carex gynocrates	sedge	10	-5	OBL	Nt P-Sedge
Carex lasiocarpa	sedge	8	-5	OBL	Nt P-Sedge
Carex limosa	bog sedge	10	-5	OBL	Nt P-Sedge
Carex livida	sedge	10	-5	OBL	Nt P-Sedge
Carex stricta	sedge	4	-5	OBL	Nt P-Sedge
Carex viridula	sedge	4	-5	OBL	Nt P-Sedge

Scientific Name	Common Name	C	W	Wetness	Physiognomy
Castilleja coccinea	Indian paintbrush	8	0	FAC	Nt A-Forb
Cladium mariscoides	twig rush	10	-5	OBL	Nt P-Sedge
Comandra umbellata	bastard toadflax	5	3	FACU	Nt P-Forb
Cornus stolonifera	red osier dogwood	2	-3	FACW	Nt Shrub
Cypripedium calceolus var. pubescens	large yellow lady's slipper	5	-1	FAC+	Nt P-Forb
Cypripedium reginae	showy or queen's lady slipper	9	-4	FACW+	Nt P-Forb
Deschampsia cespitosa	hair grass	9	-4	FACW+	Nt P-Grass
Drosera linearis	linear leaved sundew	10	-5	OBL	Nt P-Forb
Drosera rotundifolia	round leaved sundew	6	-5	OBL	Nt P-Forb
Drosera Xanglica	English sundew	10	-5	OBL	Nt P-Forb
Eleocharis elliptica	golden seeded spike rush	6	-3	FACW	Nt P-Sedge
Eleocharis quinqueflora	spike rush	10	-5	OBL	Nt P-Sedge
Eleocharis rostellata	spike rush	10	-5	OBL	Nt P-Sedge
Equisetum variegatum	variegated scouring rush	8	-3	FACW	Nt Fern Ally
Eriophorum viridi-carinatum	green keeled cotton grass	8	-5	OBL	Nt P-Sedge
Euthamia graminifolia	grass leaved goldenrod	3	-2	FACW-	Nt P-Forb
Fraxinus pennsylvanica	red ash	2	-3	FACW	Nt Tree
Gaultheria hispidula	creeping snowberry	8	-3	FACW	Nt Shrub
Hypericum kalmianum	kalm's st. john's-wort	10	-2	FACW-	Nt Shrub
Juncus balticus	rush	4	-5	OBL	Nt P-Forb
Juncus brachycephalus	rush	7	-5	OBL	Nt P-Forb
Juniperus communis	common or ground juniper	4	3	FACU	Nt Shrub
Juniperus horizontalis	creeping juniper	10	1	FAC-	Nt Shrub
Larix laricina	tamarack	5	-3	FACW	Nt Tree
Ledum groenlandicum	labrador tea	8	-5	OBL	Nt Shrub
Lilium philadelphicum	wood lily	10	1	FAC-	Nt P-Forb
Liparis loeselii	loesel's twayblade	5	-4	FACW+	Nt P-Forb
Lobelia kalmii	bog lobelia	10	-5	OBL	Nt P-Forb
Lonicera dioica	red honeysuckle	5	3	FACU	Nt W-Vine
Menyanthes trifoliata	buckbean	8	-5	OBL	Nt P-Forb
Myrica gale	sweet gale	6	-5	OBL	Nt Shrub
Panicum lindheimeri	panic grass	8	-5	OBL	Nt P-Grass
Parnassia glauca	grass of parnassus	8	-5	OBL	Nt P-Forb
Picea glauca	white spruce	3	3	FACU	Nt Tree
Picea mariana	black spruce	6	-3	FACW	Nt Tree
Pinus strobus	white pine	3	3	FACU	Nt Tree
Pogonia ophioglossoides	rose pogonia	10	-5	OBL	Nt P-Forb
Polygala paucifolia	gay wings	7	3	FACU	Nt P-Forb
Potentilla anserina	silverweed	5	-4	FACW+	Nt P-Forb
Potentilla fruticosa	shrubby cinquefoil	10	-3	FACW	Nt Shrub
Primula mistassinica	dwarf Canadian primrose	10	-3	FACW	Nt P-Forb
PRUNELLA VULGARIS	lawn prunella	0	0	FAC	Nt P-Forb
Prunus pumila	sand cherry	8	5	UPL	Nt Shrub
Rhamnus alnifolia	alder leaved buckthorn	8	-5	OBL	Nt Shrub
Rhynchospora alba	beak rush	6	-5	OBL	Nt P-Sedge

Scientific Name	Common Name	C	W	Wetness	Physiognomy
Rhynchospora capillacea	beak rush	10	-5	OBL	Nt P-Sedge
Rudbeckia hirta	black eyed susan	1	3	FACU	Nt P-Forb
Salix myricoides	blueleaf willow	9	-3	FACW	Nt Shrub
Sarracenia purpurea	pitcher plant	10	-5	OBL	Nt P-Forb
Scheuchzeria palustris	arrow grass	10	-5	OBL	Nt P-Forb
Schoenoplectus acutus	hardstem bulrush	5	-5	OBL	Nt P-Sedge
Schoenoplectus pungens	three square	5	-5	OBL	Nt P-Sedge
Scleria verticillata	nut rush	10	-5	OBL	Nt A-Sedge
Selaginella eclipes	selaginella	5	-4	FACW+	Nt Fern Ally
Selaginella selaginoides	spikemoss	10	-4	FACW+	Nt Fern Ally
Senecio pauperculus	balsam ragwort	3	-1	FAC+	Nt P-Forb
Smilacina stellata	starry false solomon seal	5	1	FAC-	Nt P-Forb
Solidago canadensis	canada goldenrod	1	3	FACU	Nt P-Forb
Solidago houghtonii	Houghton’s goldenrod	10	-5	OBL	Nt P-Forb
Solidago ohioensis	Ohio goldenrod	8	-5	OBL	Nt P-Forb
Solidago uliginosa	bog goldenrod	4	-5	OBL	Nt P-Forb
Spiranthes cernua	nodding ladies' tresses	4	-2	FACW-	Nt P-Forb
Thuja occidentalis	arbor vitae	4	-3	FACW	Nt Tree
Tofieldia glutinosa	false asphodel	10	-5	OBL	Nt P-Forb
Trichophorum alpinum	bulrush	10	-5	OBL	Nt P-Sedge
Trichophorum cespitosum	bulrush	10	-5	OBL	Nt P-Sedge
Triglochin maritimum	common bog arrow grass	8	-5	OBL	Nt P-Forb
Triglochin palustris	slender bog arrow grass	8	-5	OBL	Nt P-Forb
Utricularia cornuta	horned bladderwort	10	-5	OBL	Nt A-Forb
Utricularia intermedia	flat leaved bladderwort	10	-5	OBL	Nt P-Forb
Vaccinium macrocarpon	large cranberry	8	-5	OBL	Nt Shrub
Vaccinium oxycoccos	small cranberry	8	-5	OBL	Nt Shrub

Mesic Northern Forest

Floristic Quality Data
2011, by Mike Penskar

NATIVE SPECIES	54	Native	54	100.00%	Adventive	0	0.00%
Total Species	54	Tree	4	7.40%	Tree	0	0.00%
NATIVE MEAN C	4.9	Shrub	5	9.30%	Shrub	0	0.00%
W/Adventives	4.9	W-Vine	1	1.90%	W-Vine	0	0.00%
NATIVE FQI	35.8	H-Vine	0	0.00%	H-Vine	0	0.00%
W/Adventives	35.8	P-Forb	28	51.90%	P-Forb	0	0.00%
NATIVE MEAN W	1.8	B-Forb	0	0.00%	B-Forb	0	0.00%
W/Adventives	1.8	A-Forb	2	3.70%	A-Forb	0	0.00%
Facultative (-)		P-Grass	3	5.60%	P-Grass	0	0.00%
		A-Grass	0	0.00%	A-Grass	0	0.00%
		P-Sedge	6	11.10%	P-Sedge	0	0.00%
		A-Sedge	0	0.00%	A-Sedge	0	0.00%
		Fern	5	9.30%			

Scientific Name	Common Name	C	W	Wetness	Physiognomy
Acer saccharum	sugar maple	3	3	FACU	Nt Tree
Actaea pachypoda	doll's eyes	5	5	UPL	Nt P-Forb
Adiantum pedatum	maidenhair fern	1	1	FAC-	Nt Fern
Allium tricoccum	wild leek	2	2	FACU+	Nt P-Forb
Aquilegia canadensis	wild columbine	1	1	FAC-	Nt P-Forb
Aralia nudicaulis	wild sarsaparilla	3	3	FACU	Nt P-Forb
Athyrium filix-femina	lady fern	0	0	FAC	Nt Fern
Betula papyrifera	paper birch	2	2	FACU+	Nt Tree
Carex albursina	sedge	5	5	UPL	Nt P-Sedge
Carex arctata	sedge	5	5	UPL	Nt P-Sedge
Carex brunnescens	sedge	-3	-3	FACW	Nt P-Sedge
Carex deweyana	sedge	4	4	FACU-	Nt P-Sedge
Carex pedunculata	sedge	5	5	UPL	Nt P-Sedge
Carex sprengelii	sedge	0	0	FAC	Nt P-Sedge
Caulophyllum thalictroides	blue cohosh	5	5	UPL	Nt P-Forb
Cornus rugosa	round leaved dogwood	5	5	UPL	Nt Shrub
Corylus cornuta	beaked hazelnut	5	5	UPL	Nt Shrub
Cypripedium calceolus var. pubescens	large yellow lady's slipper	-1	-1	FAC+	Nt P-Forb
Cystopteris bulbifera	bulblet fern	-2	-2	FACW-	Nt Fern
Dentaria diphylla	two leaved toothwort	5	5	UPL	Nt P-Forb
Dicentra cucullaria	dutchman's breeches	5	5	UPL	Nt P-Forb
Dryopteris carthusiana	spinulose woodfern	-2	-2	FACW-	Nt Fern
Erythronium americanum	yellow trout lily	5	5	UPL	Nt P-Forb
Festuca subverticillata	nodding fescue	2	2	FACU+	Nt P-Grass
Galium triflorum	fragrant bedstraw	2	2	FACU+	Nt P-Forb
Geranium robertianum	herb robert	5	5	UPL	Nt A-Forb
Geum canadense	white avens	0	0	FAC	Nt P-Forb
Hepatica acutiloba	sharp lobed hepatica	5	5	UPL	Nt P-Forb
Heracleum maximum	cow parsnip	-3	-3	FACW	Nt P-Forb
Laportea canadensis	wood nettle	-3	-3	FACW	Nt P-Forb

Scientific Name	Common Name	C	W	Wetness	Physiognomy
Lonicera canadensis	American fly honeysuckle	3	3	FACU	Nt Shrub
Maianthemum canadense	Canada mayflower	0	0	FAC	Nt P-Forb
Matteuccia struthiopteris	ostrich fern	-3	-3	FACW	Nt Fern
Medeola virginiana	Indian cucumber root	5	5	UPL	Nt P-Forb
Milium effusum	wood millet	4	4	FACU-	Nt P-Grass
Pedicularis lanceolata	swamp betony	-4	-4	FACW+	Nt P-Forb
Polygala paucifolia	gay wings	3	3	FACU	Nt P-Forb
Polygonatum pubescens	downy solomon seal	5	5	UPL	Nt P-Forb
Populus balsamifera	balsam poplar	-3	-3	FACW	Nt Tree
Quercus rubra	red oak	3	3	FACU	Nt Tree
Ranunculus recurvatus	hooked crowfoot	-3	-3	FACW	Nt A-Forb
Ribes americanum	wild black currant	-3	-3	FACW	Nt Shrub
Sambucus racemosa	red berried elder	2	2	FACU+	Nt Shrub
Sanguinaria canadensis	bloodroot	4	4	FACU-	Nt P-Forb
Schizachne purpurascens	false melic	2	2	FACU+	Nt P-Grass
Smilacina racemosa	false spikenard	3	3	FACU	Nt P-Forb
Thalictrum dioicum	early meadow rue	2	2	FACU+	Nt P-Forb
Toxicodendron radicans	poison ivy	-1	-1	FAC+	Nt W-Vine
Trientalis borealis	starflower	-1	-1	FAC+	Nt P-Forb
Trillium cernuum	nodding trillium	0	0	FAC	Nt P-Forb
Trillium grandiflorum	common trillium	5	5	UPL	Nt P-Forb
Viola adunca	sand violet	1	1	FAC-	Nt P-Forb
Viola canadensis	Canada violet	5	5	UPL	Nt P-Forb
Viola pubescens	yellow violet	4	4	FACU-	Nt P-Forb

Limestone Cobble/Sand Gravel Beach

Floristic Quality Data
2011, by Mike Penskar

NATIVE SPECIES	54	Native	54	100.00%	Adventive	0	0.00%
Total Species	54	Tree	5	9.30%	Tree	0	0.00%
NATIVE MEAN C	6.5	Shrub	10	18.50%	Shrub	0	0.00%
W/Adventives	6.5	W-Vine	0	0.00%	W-Vine	0	0.00%
NATIVE FQI	47.9	H-Vine	0	0.00%	H-Vine	0	0.00%
W/Adventives	47.9	P-Forb	17	31.50%	P-Forb	0	0.00%
NATIVE MEAN W	-2.9	B-Forb	1	1.90%	B-Forb	0	0.00%
W/Adventives	-2.9	A-Forb	3	5.60%	A-Forb	0	0.00%
Facultative (-)		P-Grass	4	7.40%	P-Grass	0	0.00%
		A-Grass	0	0.00%	A-Grass	0	0.00%
		P-Sedge	13	24.10%	P-Sedge	0	0.00%
		A-Sedge	0	0.00%	A-Sedge	0	0.00%
		Fern	1	1.90%			

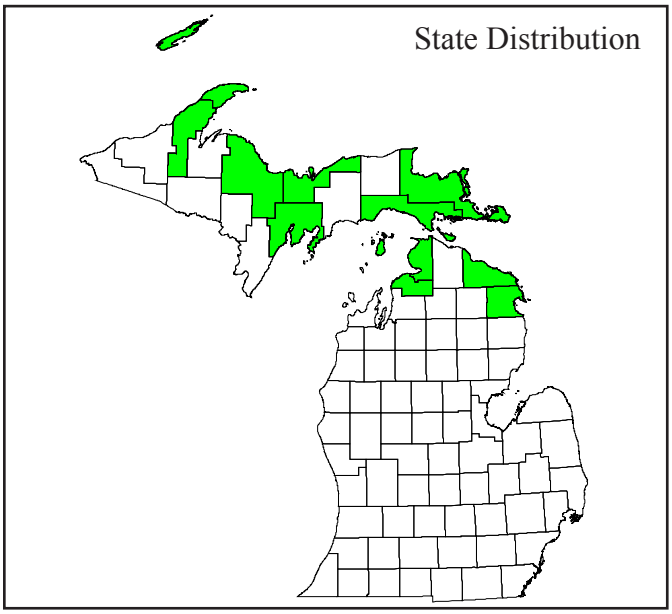
Scientific Name	Common Name	C	W	Wetness	Physiognomy
Andropogon scoparius	little bluestem grass	5	3	FACU	Nt P-Grass
Arctostaphylos uva-ursi	bearberry	8	5	UPL	Nt Shrub
Aster borealis	northern bog aster	9	-5	OBL	Nt P-Forb
Calamagrostis canadensis	blue joint grass	3	-5	OBL	Nt P-Grass
Calamintha arkansana	low calamint	10	-3	FACW	Nt P-Forb
Carex buxbaumii	sedge	10	-5	OBL	Nt P-Sedge
Carex capillaris	sedge	9	-3	FACW	Nt P-Sedge
Carex crawei	sedge	10	-3	FACW	Nt P-Sedge
Carex eburnea	sedge	7	4	FACU-	Nt P-Sedge
Carex echinata	sedge	6	-5	OBL	Nt P-Sedge
Carex garberi	sedge	8	-3	FACW	Nt P-Sedge
Carex hystericina	sedge	2	-5	OBL	Nt P-Sedge
Carex sterilis	sedge	10	-5	OBL	Nt P-Sedge
Castilleja coccinea	Indian paintbrush	8	0	FAC	Nt A-Forb
Cladium mariscoides	twig rush	10	-5	OBL	Nt P-Sedge
Eleocharis elliptica	golden seeded spike rush	6	-3	FACW	Nt P-Sedge
Eleocharis quinqueflora	spike rush	10	-5	OBL	Nt P-Sedge
Gentianopsis procera	small fringed gentian	8	-5	OBL	Nt A-Forb
Hierochloe odorata	sweet grass	9	-3	FACW	Nt P-Grass
Hypericum kalmianum	kalm's st. john's-wort	10	-2	FACW-	Nt Shrub
Juncus balticus	rush	4	-5	OBL	Nt P-Forb
Juncus brachycephalus	rush	7	-5	OBL	Nt P-Forb
Juncus nodosus	joint rush	5	-5	OBL	Nt P-Forb
Larix laricina	tamarack	5	-3	FACW	Nt Tree
Lobelia kalmii	bog lobelia	10	-5	OBL	Nt P-Forb
Lycopus americanus	common water horehound	2	-5	OBL	Nt P-Forb
Oenothera biennis	common evening primrose	2	3	FACU	Nt B-Forb
Parnassia glauca	grass of parnassus	8	-5	OBL	Nt P-Forb
Phragmites australis	reed	0	-4	FACW+	Nt P-Grass
Picea glauca	white spruce	3	3	FACU	Nt Tree
Polygala paucifolia	gay wings	7	3	FACU	Nt P-Forb

Scientific Name	Common Name	C	W	Wetness	Physiognomy
Populus balsamifera	balsam poplar	2	-3	FACW	Nt Tree
Populus tremuloides	quaking aspen	1	0	FAC	Nt Tree
Potentilla anserina	silverweed	5	-4	FACW+	Nt P-Forb
Potentilla fruticosa	shrubby cinquefoil	10	-3	FACW	Nt Shrub
Primula mistassinica	dwarf Canadian primrose	10	-3	FACW	Nt P-Forb
Rhynchospora capillacea	beak rush	10	-5	OBL	Nt P-Sedge
Salix bebbiana	Bebb's willow	1	-4	FACW+	Nt Shrub
Salix candida	hoary willow	9	-5	OBL	Nt Shrub
Salix discolor	pussy willow	1	-3	FACW	Nt Shrub
Salix lucida	shining willow	3	-4	FACW+	Nt Shrub
Salix myricoides	blueleaf willow	9	-3	FACW	Nt Shrub
Schoenoplectus pungens	three square	5	-5	OBL	Nt P-Sedge
Selaginella eclipes	selaginella	5	-4	FACW+	Nt Fern Ally
Shepherdia canadensis	soapberry	7	5	UPL	Nt Shrub
Solidago ohioensis	Ohio goldenrod	8	-5	OBL	Nt P-Forb
Solidago uliginosa	bog goldenrod	4	-5	OBL	Nt P-Forb
Spiranthes cernua	nodding ladies' tresses	4	-2	FACW-	Nt P-Forb
Taxus canadensis	Canadian yew	5	3	FACU	Nt Shrub
Thuja occidentalis	arbor vitae	4	-3	FACW	Nt Tree
Tofieldia glutinosa	false asphodel	10	-5	OBL	Nt P-Forb
Triglochin maritimum	common bog arrow grass	8	-5	OBL	Nt P-Forb
Utricularia cornuta	horned bladderwort	10	-5	OBL	Nt A-Forb
Utricularia intermedia	flat leaved bladderwort	10	-5	OBL	Nt P-Forb

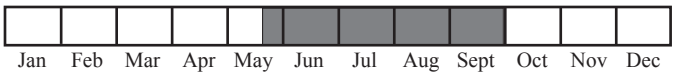
Appendix B. Rare Species Abstracts

Pinguicula vulgaris L. butterwort

Photo by Susan R. Crispin



Best Survey Period



Status: State special concern

Global and state rank: G5/S3

Other common names: common butterwort, bog-violet, violet butterwort

Family: Lentibulariaceae (bladderwort family)

Range: Butterwort is a circumpolar species ranging around the world in temperate and boreal regions. It is of widespread occurrence from Europe through Siberia. Elsewhere this species occurs in the Arctic from Alaska to Canada and East Greenland, extending southward in North America to northeast Minnesota, northwest Wisconsin, and through the Lake Superior region east to New York and New England. It is considered rare in Alberta, Maine, Minnesota, New Brunswick, New Hampshire, New York, Nova Scotia, Saskatchewan, Vermont, and Wisconsin (NatureServe 2006).

State distribution: Michigan localities for *P. vulgaris* are widely distributed, occurring from Isle Royale through the Upper Peninsula to the tip of the Lower Peninsula. It is known from just over 70 sites, most of which (50+ localities) occur in Keweenaw, Mackinac, and Alger counties, with four or fewer sites known for Delta, Houghton, Marquette, Alpena, Charlevoix, Chippewa, Emmet, and Presque Isle counties.

Recognition: *Pinguicula vulgaris* is a small, herbaceous, insectivorous perennial with **rosettes of 3-6 distinctly yellowish-green leaves**. The blunt, oblong-ovate to elliptic leaves, which narrow to the base, range to ca. 8 cm in length, curling slightly inward along their upper margins. The **upper leaf surface is covered with numerous enzyme-secreting glands** that aid in the breakdown and digestion of small insects, and give the leaves a **sticky-greasy feel when touched**. This slimy, watery surface also serves to attract and capture insect prey. The **spurred purple flowers are solitary on 1.5-12 cm long, leafless peduncles (**stalks) and have **a white spot at the mouth**. In addition to a well developed basal spur, the flowers have a 3-lobed upper lip and 2-lobed lower lip, thus superficially resembling a violet. A single rosette may have produce up to three or more flowering stalks. The fruit is a small capsule with tiny seeds that lack endosperm.

Best survey time/phenology: Butterwort is best sought in spring when in flower, from about early June to early July. However, the distinct bright yellowish-green basal rosettes can be easily recognized throughout the growing season, from approximately late May through September.

FQI Coefficient and Wetland Category: 10, OBL

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Habitat: *Pinguicula vulgaris* is a well-known calciphile (favoring alkaline or lime-rich habitats) and as with most insectivorous plants, prefers wet substrates. It is found in moist alkaline rock crevices and outcrops; rocky or gravelly shores, sandy, interdunal shoreline flats; marshy soils near bogs, wet alvars, and the marly, calcareous soils of coastal and northern fens. It also occurs in Lake Superior coastal areas where it inhabits volcanic bedrock lakeshore areas, favoring basalts and conglomerate bedrock types. Most Michigan locations are along Great Lakes shores, particularly on rocky, wet beaches and nearshore wetlands and interdunal areas. *Primula mistassinica* (birds-eye primrose) is a common associate as are numerous other herbs such as *Drosera rotundifolia* (round-leaved sundew), *D. linearis* (linear-leaved sundew), *Sarracenia purpurea* (pitcher-plant), *Utricularia intermedia* (flat-leaved bladderwort), *U. cornuta* (horned bladderwort), *Castilleja coccinea (*Indian paintbrush), *Parnassia glauca* grass-of-Parnassus), *Tofieldia glutinosa* (false asphodel), and *Gentianopsis procera* (small fringed gentian). The rare *Solidago houghtonii* (Houghton's goldenrod) is an expected associate in the Straits region, as might be *Empetrum nigrum* (black crowberry) and other rarities such as the similarly boreal *Erigeron hyssopifolius* (hyssop-leaved fleabane) and *Carex scirpoidea* (bulrush sedge). These associates are similar to those found with butterwort in shoreline limestone pavement or wet alvar sites.

In bedrock shoreline communities in the more northern portion of its Michigan range, butterwort occurs on alkaline basalts, volcanic conglomerates, and occasionally wet sandstones, where associates include such species as *Campanula rotundifolia* (harebell), *Deschampsia cespitosa* (hair grass), *Festuca saximontana* (fescue), *Artemisia campestris* (wormwood), *Carex viridula* (sedge), and *Solidago simplex* (Gillman's goldenrod).

Biology: *Pinguicula vulgaris* is an insectivorous, perennial herb that secretes mucilaginous fluids and digestive enzymes through two types of leaf glands. Small insects first adhere to the mucilaginous fluids secreted by the stalked 'sticky' glands. Their struggling movements, which stimulate increased production of the mucilaginous fluids, then cause the secretion of enzyme-containing fluids from the 'sessile' glands. It is the latter secretion that is primarily responsible for insect digestion and nutrient absorption by the plant. Upon stimulation, the leaves also roll inward from their margins; this is thought to minimize the loss of prey and also aid in enzymatic degradation by increasing the leaf surface area in contact with the prey. This in-rolling may also reduce the loss of enzymes and nutrients through seepage or by preventing exposure to rainfall.

Flowering plants can be found in late May through June and into early July, followed by the formation of a capsule containing several seeds, typically from early July through August. During winter, butterwort persists as a winter resting bud known as a hibernaculum that begins to form in the center of the rosette by late summer. This bud is entirely without roots and therefore may be dispersed by water movement, wind, or possibly animal activity. The small scale-leaves of the hibernaculum contain starches that nurture the enclosed seedling during spring emergence when new leaves and roots are forming.

Biologists have long been interested in carnivorous plants, particularly with regard to the topics of resource allocation, reproduction, plant demography (the structure and dynamics of populations), and the evolution of carnivory as an adaptation to low nutrient availability. Owing to the extensive nature of this literature, which cannot be adequately summarized here, the reader is referred to the following references for further information on these topics: Méndez and Karlsson (2005), Méndez and Karlsson (2004), Eckstein and Karlsson (2001), Worley and Harder (1999), Thorén and Karlsson (1998), Thorén et al. (1996), Lesica and Steele (1996), Worley and Harder (1996), Svensson et al. (1993), Kull and Zobel (1991), Karlsson et al. (1990), Karlsson 1988), Karlsson and Carlsson (1984), and Aldenius et al. (1983).

Conservation/management: Several large butterwort populations are protected on public lands, including several sites within Isle Royale National Park, and also via a number of private nature preserves, including large exemplary areas managed by the Michigan Nature Conservancy in the Straits region. Habitat loss through shoreline development and recreation is the most critical threat to butterwort populations, and as for many coastal areas, the prevalence and widespread use of off-road-vehicles (ORVs) remains a constant and ever present threat to sites. Conservation strategies should focus on the identification and preservation of shoreline ecosystems that encompass known and potential

habitat. Equally important is the education of private landowners as well as federal, state, and local land managers to provide guidance on how to identify and steward important coastal systems and their associated rare species.

Comments: The word *Pinguicula* is derived from the Latin word *pinguis*, meaning 'fat', and refers to the leaves being 'greasy' or 'buttery' to the touch. It is reported that the leaves were once used by farmers to coagulate milk.

Research needs: The principal need at present, given the extensive research that has been conducted to date, is perhaps the identification of viable colonies and conducting monitoring to determine population dynamics, trends, changes in status, and the presence of natural and artificial threats.

Related abstracts: Coastal fen, northern fen, interdunal wetland, sand and gravel shore, limestone bedrock lakeshore, limestone cobble shore, volcanic bedrock lakeshore, cherrystone drop, Eastern massasauga, Hine's emerald, incurvate emerald, crested vertigo, six-whorl vertigo, tapered vertigo, alpine bluegrass, calypso, English sundew, Franklin's Phacelia, Hill's thistle, Houghton's goldenrod, prairie Indian plantain, ram's head orchid, Richardson's sedge, rock whitlow-grass, and numerous additional animal and plant species.

Selected references:

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Abstract citation:

Penskar, M.R. and J.A. Hansen. 2009. Special Plant Abstract for *Pinguicula vulgaris* (butterwort). Michigan Natural Features Inventory, Lansing, MI. 4 pp.

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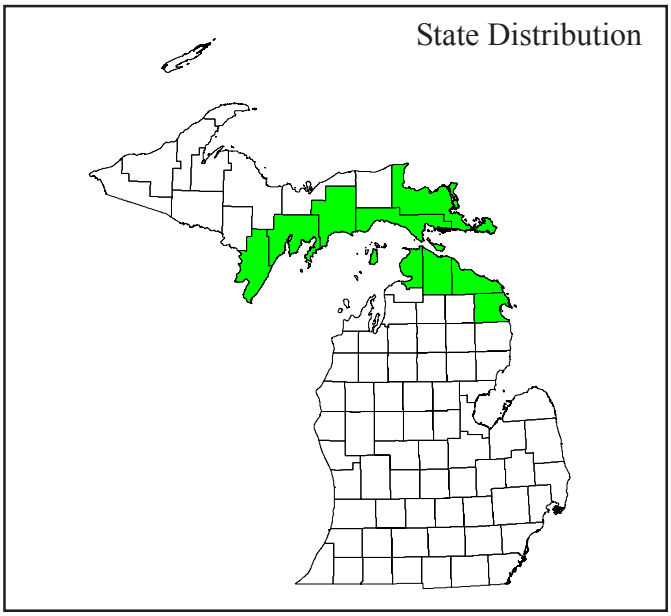
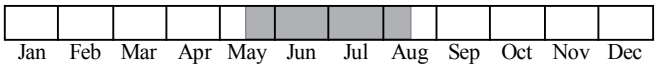
Iris lacustris Nutt. dwarf lake iris


Photo by Thomas Arter



Best Survey Period



Legal status: State threatened, federal threatened

Global and state rank: G3/S3

Other common names: baby iris

Family: Iridaceae (iris family)

Synonyms: *Iris cristata* Ait. ssp. *lacustris* (Nutt.) Iltis; *Iris cristata* Ait. var. *lacustris* (Nutt.) Dykes.

Taxonomy: Though the dwarf lake iris was treated as a variety of the southern *Iris cristata* by Dykes in 1913 (see also Mason and Iltis 1965), it has since come to be widely recognized, including by Dykes (1924), as a distinct species based on consistent differences in morphology, habitat, range, and chromosome number and configuration (Foster 1937).

Total range: *Iris lacustris* is endemic to the northern shores of Lakes Michigan and Huron, growing nowhere else in the world. Its distribution centers around the Mackinac Straits region, with outliers extending to Wisconsin's Door Peninsula and Ontario's Bruce Peninsula. The distribution in the Great Lakes follows the geological feature known as the Niagara Escarpment, a limestone formation extending from the Door Peninsula through Michigan and Ontario to New York.

State distribution: The majority of the world's *Iris lacustris* population lies within Michigan's boundaries, z where it is known from more than 80 locations. Its coastal range in Michigan extends from the Stonington Peninsula (Delta County) to Drummond Island (Chippewa County) and south to Wilderness State Park (Emmet County), Beaver Island (Charlevoix County), and Alpena (Alpena County). Atypical inland stations, which are probably relicts of former post-glacial lake stages, are known from Delta and Menominee counties. The abundance of dwarf lake iris is greatest in three general areas--the Garden Peninsula, southeastern Presque Isle and adjacent Alpena counties, and Cheboygan/Emmet counties--where it occurs almost continuously for many miles along the lakeshores and then densely to discontinuously over a few square miles inland. Colonies range in size from the extensive population clusters covering several hundred acres, such as in southern Presque Isle County, to those consisting of a few straggly stems persisting in isolated inland localities or forming small colonies on Great Lakes islands.

Recognition: This miniature iris is distinctive among the Michigan flora. Its **slender, yellowish**, **finely ribbed rhizomes have enlarged nodes** that give rise to fans of **flattened, slender leaves that range to ca. 15 cm in length and are about 1-2 cm wide**. The **showy, deep blue flowers** are of the typical iris type, with three arching, petal-like sepals (ca. 2 cm long) whose **orange, bearded crests lie partly beneath the smaller petal-like style branches**. The three petals are similar to the three sepals, and alternate with them. *Iris lacustris* can be recognized vegetatively by

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its relatively diminutive leaves and slender rhizomes, the latter of which are useful in distinguishing dwarf lake iris from small individuals and juvenile plants of the widespread *Iris versicolor* (common blue-flag). *Iris lacustris* is notable for its somewhat sparse production of fruit, which when present consists of small, oblong, green capsules on short stalks. The seeds have been shown, in part, to be ant-dispersed (Planisek 1983).

Dwarf lake iris is most likely to be confused with *Tofieldia glutinosa* (false asphodel), a member of the lily family with extremely similar leaves that very commonly occurs in the same northern shoreline habitats. *Tofieldia*, which produces small **clusters of white flowers that develop clumps of reddish capsules**, can be distinguished from dwarf lake iris by its **much narrower, firmer-textured leaves and long, sticky flower stalks**. Moreover, quick observation will show that *Tofieldia* **lacks a rhizome and does not grow in dense clumps or patches** as dwarf lake iris does.

Best survey time/phenology: The leaves and rhizomes of dwarf lake iris can be identified throughout the growing season, and in combination with habitat information can be used fairly reliably to detect this species. It is easiest to detect, however, during the flowering period from mid-May through early June.

Habitat: Dwarf lake iris usually occurs in close proximity to Great Lakes shores on sand or in thin soils over calcareous gravel or bedrock (alvar). It tolerates full sun to nearly complete shade, but appears to flower best in semi-open edge or ecotonal habitats, typically amongst scattered trees or on shozreline forest margins where it usually occurs with northern white cedar (*Thuja occidentalis*) and balsam fir (*Abies balsamea*). Dwarf lake iris is almost invariably associated with northern white cedar, though spruce (principally *Picea glauca*), balsam fir, and trembling aspen (*Populus tremuloides*) are also frequently present in the overstory. Groundcover associates commonly include *Arctostaphylos uva-ursi* (bearberry), *Primula mistassinica* (bird's-eye primrose), *Cypripedium calceolus* (yellow lady-slipper), *Polygala paucifolia* (gay-wings), *Smilacina stellata* (false Solomon-seal), *Castilleja coccinea* (Indian paintbrush), *Tofieldia glutinosa* (false asphodel), *Carex capillaris* (sedge), *C. castanea* (sedge), and especially *C. eburnea* (sedge). Frequent shrub associates are *Shepherdia canadensis* (soapberry), *Juniperus communis* (common juniper), *J. horizontalis (ground juniper),Cornus stolonifera* (red-osier dogwood), and *Potentilla fruticosa* (shrubby cinquefoil).

Other rarities that may be found in association with dwarf lake iris include state and federal threatened *Solidago houghtonii* (Houghton's goldenrod), state threatened *Calypso bulbosa* (calypso orchid), *Carex scirpoides* (bulrush sedge), and *Pterospora andromedea* (pine-drops), and state special concern *Cypripedium arietinum* (ram's-head orchid), *Pinguicula vulgaris* (butterwort), and *Carex richardsonii* (Richardson's sedge). Occasionally, this species extends out into open dune ridges in association with state and federal threatened *Cirsium pitcheri* (Pitcher's thistle) and state threatened *Tanacetum huronense* (Lake Huron tansy). On Drummond Island it is found in alvar habitat associated wtih state special concern *Sporobolus heterolepis* (prairie dropseed).

In many instances, the historical distribution of this iris seems to be as important as habitat in determining where it now grows. For example, many stations, likely consisting of relict colonies, lie along abandoned shores, especially former beach ridges of the ancient Great Lakes, sometimes in habitats that are now obviously unfavorable due to succession and other factors. This species has demonstrated that under certain conditions it can readily spread into artificially cleared areas with dryish, calcareous substrates, where it may advance aggressively.

Biology: Dwarf lake iris usually flowers from about mid-May through early June, depending on site exposure and annual weather variations. Each flower remains open about three days (Planisek 1983). Fruiting capsules ripen from mid-July to mid-August and release seeds that bear a white accessory appendage attractive to ants, which appear to play a role in dispersal (Planisek 1983). Observations show that fertility in this species is low due to: 1) sparse flower production, 2) low fruit-set (only 3% of growing tips develop fruits), and 3) low seed-set (an average of 21 seeds per capsule) (Planisek 1983). The flowers are self-compatible. No pollen vectors have been observed, though other irises are known to be bee- or fly-pollinated. Plants of *Iris lacustris* reproduce readily by rhizome forking and elongation, and plants can be aged by counting the enlarged nodes which mark the locations of past years' growing tips. Extensive clones often form, with tens or possibly hundreds of shoots possibly representing only one or a few genetically distinct individuals. Isozyme analysis of nine populations of dwarf lake iris found this species to be genetically depauperate as a whole (Hannan 2000.) There was a lack of detectable isozyme variation at any locus, and all isozymes found exhibited electrophoretic mobilities similar to those of *I.*

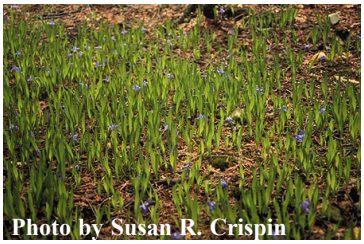
Photo by Susan R. Crispin

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cristata, a similar species found south of the Wisconsonian glacial maximum. These findings support the hypothesis that dwarf lake iris is of geologically recent origin from a single, genetically depauperate *I. cristata* gene pool.

Conservation/management: Since *Iris lacustris* is largely restricted to the Great Lakes shores, it is highly vulnerable to ongoing shoreline development and intensive recreation. Fortunately, this species is a persistent and rather ecologically resilient plant, and can often withstand less-than-catastrophic disturbances (e.g. overstory removal, occasional trampling, shading). It is clearly sensitive to mechanical disturbance or removal of its substrate, but can often recolonize small disturbed areas if it flourishes nearby. At least seven large, thriving colonies of iris lie partly or wholly on state lands, as do numerous other healthy but smaller ones. The Nature Conservancy and Michigan Nature Association each have good colonies of this iris within their preserve systems. Thriving colonies are probably best maintained without active management, though experimental techniques to determine the effects of disturbance, such as the removal of maturing canopy trees, are desirable to learn if this type of management may be necessary to perpetuate dwarf lake iris in some habitats. Colonies which appear to be suffering from shading might be rejuvenated by removing some canopy trees, which is likely to stimulate flowering. Historically, fire may have played a role locally by reducing canopy closure.


Photo by Susan R. Crispin

Comments: Form *albiflora*, bearing white flowers, occurs sporadically among the typical blue-flowered plants at several locations in Emmet, Presque Isle, and Schoolcraft counties, and perhaps elsewhere. Dwarf lake iris was designated Michigan's state wildflower in 1998.

Research needs: Breeding system studies, including investigations of pollination biology, are desirable for this species. Due to the increasing amount of development occurring where the iris occurs, research on experimental management techniques such as canopy removal, to determine the role of disturbance in the natural history of this species, is of high priority.

Related abstracts: Limestone pavement lakeshore, wooded dune and swale, American dune wild-rye, butterwort, calypso orchid, fascicled broom-rape, Houghton's goldenrod, Lake Huron tansy, pine-drops, Pitcher's thistle, prairie dropseed, Pumpelly's brome grass, ram's-head orchid, black tern, Caspian tern, common tern, Hine's emerald, Lake Huron locust, massasauga, piping plover.

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Abstract Citation:

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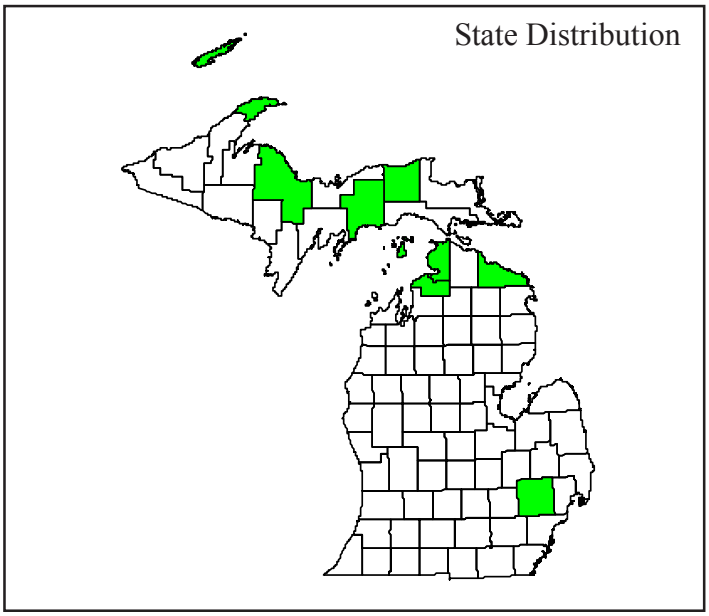
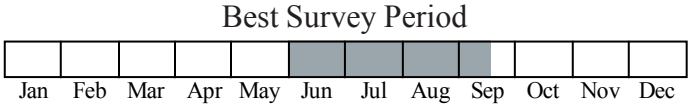
Drosera anglica Hudson — English sundew

Photo by J. Freudenstein





Status: State special concern

Global and state rank: G5/S3

Other common names: sundew

Family: Droseraceae (sundew)

Synonyms: *Drosera* X*anglica* Hudson

Taxonomy: *Drosera anglica* exists in two forms, occurring as a sterile, diploid hybrid (*D.* X*anglica*) between the common *D. rotundifolia* (round-leaved sundew) and *D. linearis* (linear-leaved sundew), and also as a fertile tetraploid (i.e. having four sets of chromosomes). The presence of filled seed capsules is evidence of the fertile form of this plant, which otherwise is indistinguishable from the diploid hybrids.

Total range: English sundew is a circumboreal species, ranging south in North America to Quebec, northern Maine, and southern Ontario, in the Midwest occurring south primarily to the northern regions of Michigan, Wisconsin, and Minnesota, and in the West, ranging south to California (Gleason & Cronquist 1991).

State distribution: *Drosera anglica* occurs primarily in the Upper Peninsula and northern Lower Michigan, ranging from Isle Royale and the Keweenaw Peninsula to Luce and Mackinac counties. In northern Lower Michigan, this species ranges through Charlevoix, Emmet, Cheboygan, and Presque Isle counties. Somewhat disjunct occurrences have been documented in marl fens in southern Lower Michigan, where this species has been in Oakland and Livingston counties.

Recognition: English sundew is a diminutive plant similar to other species of *Drosera*, forming small clumps or rosettes of leaves covered with numerous sticky, red, glandular hairs. The rosettes, which are approximately 5-10 cm or more in diameter, are composed of **long-petioled, glandular leaves that become broadened and narrowly paddle-shaped (spatulate) toward the tip**. The **leaves**, which are somewhat **erect to ascending**, are covered with long, reddish, hairs, each tipped with a small droplet of sticky fluid. **Tiny, white, five-petaled flowers** are borne toward the end of a slender stem that arises from the center of the rosette.

There are only four species of sundew known in Michigan, and these taxa may rarely occur in close proximity within the same site, such as in patterned peatlands in eastern Upper Peninsula. English sundew, however, is most likely to be confused with *D. intermedia*, a species that usually occurs in bogs and other acid substrates. ***D. intermedia* is a markedly smaller, more delicate plant with leaf blades that range only from 2-4 mm wide versus 3-8 mm wide in *D. anglica***. Aadditional differences include **smooth petioles in *D. intermedia* versus at least slightly glandular petioles in *D. anglica* and the laterally borne flowering stem in *D. intermedia* in contrast to the centrally arising flowering stem in *D. anglica*** (Voss 1985). *Drosera rotundifolia* (round-leaved sundew), which often occurs with English sundew, is generally a smaller and distinctly prostrate plant with shorter petioles that terminate abruptly in very roundish, orbicular leaf blades.

Best survey time/phenology: English sundew is observable by the latter part of May, and is probably best sought

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from late spring through early summer, though it will persist through August and perhaps later in recognizable form. Flowering occurs approximately in late June through July.

Habitat: English sundew typically occurs in northern fens, including marl flats, cobble shores, and other calcareous habitats such as interdunal wetlands along the northern shores of Lake Huron and Lake Michigan. It also occurs in rock pools on Isle Royale (Voss 1985). In these sites, typical associates include such species as *Drosera linearis*, *D. rotundifolia*, *Thuja occidentalis* (northern white cedar), *Larix laricina* (Eastern larch), *Triglochin* spp. (arrow-grasses), *Sarracenia purpurea* (pitcher-plant), *Tofieldia glutinosa* (false asphodel), *Primula mistassinica* (bird's-eye primrose), *Lobelia kalmii* (Kalm's lobelia), *Scirpus cespitosus* (bulrush), *Pogonia ophioglossoides* (rose pogonia), *Calopogon tuberosus* (marsh-pink), as well as several *Sphagnum* species and brown mosses such as *Scorpidium scorpioides* (scorpidium). Elsewhere, English sundew also occurs in interior areas on floating peat mats and in wet depressions (termed "flarks") of patterned peatland complexes in the eastern Upper Peninsula. In southern Lower Michigan, this species is very rare, being restricted to the wet, marly zones of a few prairie fens, where it occurs with many of the aforementioned plant associates.

Biology: Similar to *Sarracenia purpurea* (pitcher-plant) and *Pinguicula vulgaris* (butterwort), sundews are carnivorous plants, capturing insects (primarily) with their nectar-like, mucilaginous secretions to supplement nutrients, such as nitrogen, that are otherwise in low availability in their habitats. Sundew leaves curl around their insect prey, when captured, to digest it.

Conservation/management: The primary conservation need for this species is simply the protection of its habitat, including the maintenance of local hydrological and natural disturbance regimes to sustain wetland function and the generally open, non-forested habitat required for perpetuation.

Research needs: There are relatively few published studies concerning the biology and ecology of this species, although there is widespread interest in insectivorous and carnivorous plants. Research likely to be of the greatest benefit to conservation would include studies of population dynamics, demography, and virtually any aspect of life history, especially if such investigations incorporate habitat information.

Related abstracts: prairie fen, small white lady's-slipper, mat muhly, prairie dropseed, Eastern massasauga, Mitchell's satyr

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Abstract citation

Penskar, M.R. and P.J. Higman. 1999. Special plant abstract for *Drosera anglica* (English sundew). Michigan Natural Features Inventory, Lansing, MI. 2 pp.

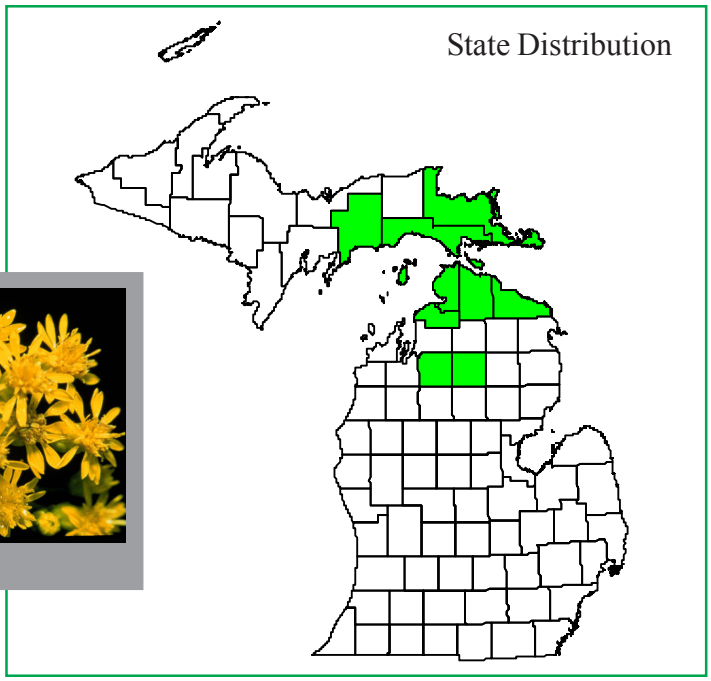
Funding for abstract provided by Michigan Department of Natural Resources - Wildlife Division and Wildlife Division, Non-Game Program.

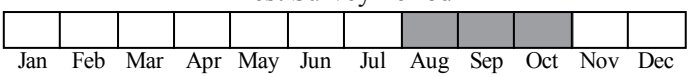
2-00/mrp

Solidago houghtonii A. Gray — Houghton's goldenrod

Photo by Phyllis J. Higman

Photo by Doug Moore





Status: State threatened**,** federal threatened

Global and state rank: G3/S2S3

Family: Asteraceae (Aster family)

Taxonomy: Although *Solidago houghtonii* is widely accepted as a distinctive species, its origin and affinities are disputed. Morton (1979) theorizes that a hybrid of *S. ptarmicoides* (Nees) Boivin (long known as *Aster ptarmicoides* (Nees) T. & G.) and *S. ohioensis* Riddell backcrossed with *S. ohioensis* to form a sterile triploid (three sets of chromosomes); a subsequent doubling of chromosomes resulted in the fertile hexaploid (6x = 54) known as *S. houghtonii*. Semple & Ringius (1983), among others, disagree, concluding that *S. riddellii* Frank, not *S. ptarmicoides*, is the second parent. Most anomalous in the *S. houghtonii* "complex" is a population identified in Crawford County within Camp Grayling. These plants are reportedly octoploids, apparently the only such ploidy level known for a *Solidago* species, and differ somewhat from shoreline populations, thus possibly representing a different taxon. A reported disjunct station in Genesee County, New York (Bergen Swamp), is now believed to represent hybrids between *S. ptarmicoides* and *S. uliginosa.*

Total range: Houghton's goldenrod occurs primarily along the northernmost shores of Lakes Michigan and Huron, ranging east to the Bruce Peninsula in Ontario. Isolated inland stations of what some authors believe to be this species occur in Crawford and Kalkaska counties, Michigan, more than 100 km south of the Mackinac Straits region. A second disjunct station of what is currently considered to be this species occurs in western New York.

State distribution: The greatest concentrations of *S. houghtonii* lie in Chippewa, western Mackinac, northern Emmet, Cheboygan, and northern Presque Isle counties. Each of these areas has large populations extending over at least a mile of shoreline, as well as several scattered smaller populations. About 60 occurrences are known overall.

Recognition: Houghton's goldenrod has smooth, slender, often somewhat reddish stems that reach 3-6 dm in height. The well-scattered, pointed **leaves are long (to 1.3 dm), narrow (less than 1 cm), and often folded along the midrib** (conduplicate), **tapering to a slightly clasping base**. Terminating the stem is a more or less **flat-topped, branched inflorescence consisting of relatively few, showy, large flower-heads** that may number from 5-30 and not uncommonly more (standard manuals, basing their description on the wrong nomenclatural type, incorrectly state the number of flower-heads to be only 5-15). **The branches and pedicels** (flower stalks) of the inflorescence are **finely hairy**, at least sparsely so, with **fine upcurving hairs**, and the achenes are smooth and ribbed.

This species is most likely to be confused with the

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widespread *Euthamia graminifolia* (grass-leaved goldenrod) and *S. ohioensis* (Ohio goldenrod*). Euthamia graminifolia* can be distinguished by its more leafy stem lacking basal leaves when in flower. It also has narrower 3-5 nerved leaves, and an inflorescence composed of distinctly smaller flower heads with short ray flowers and hairy achenes. *Solidago ohioensis*, the goldenrod most similar to *S. houghtonii* in northern Michigan, is a more robust species with leafier stems. It usually has broader, more flattened, ovate-lanceolate leaves and a dense, many-headed inflorescence. Other features include **smooth branches and pedicels, smaller ray flowers,** and smooth, unribbed achenes.

Best survey time/phenology: *Solidago houghtonii* is best identifed during peak flowering, when it is most easily distinguished from the extremely similar *Solidago ohioensis*. Flowering occurs from about early August through early September, with plants often blooming into October.

Habitat: *Solidago houghtonii* occurs primarily along the northern shores of Lakes Huron and Michigan, restricted to calcareous beach sands, rocky and cobbly shores, beach flats, and most commonly the shallow, trough-like interdunal wetlands that parallel shoreline areas. This species also occurs on seasonally wet limestone pavement, its more typical habitat in the eastern portion of its range, primarily in Ontario (Morton 1979; Semple and Ringius 1983). Common plant associates include *Parnassia glauca* (grass-of-Parnassus), *Lobelia kalmii* (Kalm's lobelia), *Calamintha arkansana* (Arkansas mint), *Tofieldia glutinosa* (false asphodel), *Potentilla fruticosa* (shrubby cinquefoil), *Gentiana procera* (fringed gentian), *Carex crawei* (sedge), *C. garberi* (sedge), *Eleocharis pauciflora* (spikerush), *Euthamia graminifolia* (grass-leaved goldenrod), *Solidago ohioensis* (Ohio goldenrod), and *Myrica gale* (sweet gale). In the Crawford and Kalkaska county localities, Houghton's goldenrod occurs in an unusual northern wet prairie habitat within the jack pine barrens. There it occupies seasonally indundated areas and old interdunal depressions in a sandy glacial outwash landscape, where it occurs with such species as *Pinus banksiana* (jack pine), *Andropogon gerardii* (big bluestem), *Lobelia spicata* (lobelia), *Castilleja coccinea* (Indian paintbrush), *Eleocharis elliptica* (spikerush), *Potentilla fruticosa*, *Carex conoidea* and *C. flava* (sedges), and several other rare plant species, including *Juncus vaseyi* (Vasey's rush), *Scirpus clintonii* (Clinton's bulrush), and *Viola novae-angliae* (New England violet).

Biology: Houghton's goldenrod is a perennial, frequently forming small clumps (clones) produced vegetatively by means of relatively short rhizomes (underground stem). Flowering occurs primarily in August and early September, but some plants may flower well until October.

Conservation/management: The shoreline habitat of *S. houghtonii* is strongly threatened by residential development and heavy recreational use. Recreational vehicles pose an ever present and increasing threat, as do heavy foot traffic and wetland alterations during the course of shoreline development. Four populations thought to be the largest in existence are currently under protective ownership, one on a Nature Conservancy preserve and three on state land. About fifteen other substantial populations lie on State Forest, National Forest, and State Park lands, receiving some form of protection. Several populations occur partly within Michigan Department of Transportation rights-of-way, in designated and signed protected areas.

Comments: This species is named in honor of Douglass Houghton, Michigan's first State Geologist, whose survey team discovered this Great Lakes endemic on the north shore of Lake Michigan during an 1839 expedition.

Research needs: Investigation of nearly all aspects of the biology and ecology of *Solidago houghtonii* is desirable to determine the smallest colony necessary to maintain a viable population. This includes research on demography, reproductive biology, genetic variability, and basic life-history strategies. Biosystematic and genetic research is also needed to determine the true origin of this taxon and its closest affinities. An understanding of colonization requirements and population dynamics is vital to the conservation of this rare Great Lakes endemic.

Related abstracts: Limestone pavement, open dunes, pine barrens, English sundew, Lake Huron tansy, Pitcher's thistle, Pumpelly's brome grass, zig-zag bladderwort, Caspian tern, dune cutworm, eastern massasauga, Hine's emerald dragonfly, Lake Huron locust, piping plover.

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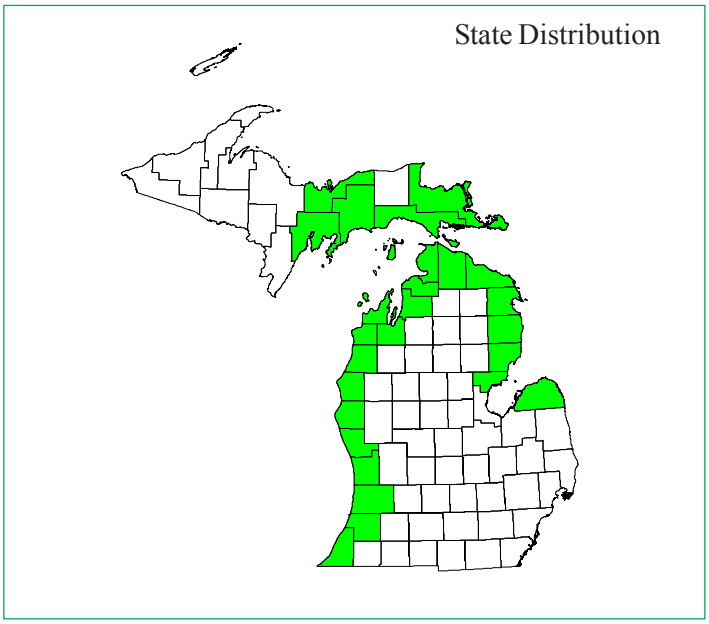
Cirsium pitcheri (Torrey and Gray) Pitcher's thistle

Photos by Sue Crispin



Status: State threatened, Federal threatened

Global and state rank: G3/S3

Other common names: Dune thistle

Family: Asteraceae (aster family)

Total range: The range of this Great Lakes endemic falls primarily within Michigan's borders, occuring along the entire shoreline of Lake Michigan, with localities along the more limited dunes of Lake Huron and a few sites along the extensive Grand Sable dunes of the Lake Superior shore. In Canada this species occurs in northern Lake Huron and at least one site on the north shore of Lake Superior. Several scattered sites occur along Lake Michigan in Wisconsin, and populations remain extant in Indiana within Indiana Dunes National Lakeshore. Historically, Pitcher's thistle was known from several localities in Illinois, where it was subsequently extirpated, but is now being reintroduced as part of the Federal Recovery Plan for the species.

State distribution: *Cirsium pitcheri* is most common in Michigan along the extensive dune systems on the northern and northeastern shores of Lake Michigan. It is scattered along the perimeters of southeastern Lake Michigan and northern Lake Huron. One major population and several relatively small occurrences are known along the southeastern shore of Lake Superior. The bulk of the occurrences, and those with the largest populations, are concentrated in the major dune landscapes in the northern Lake Michigan basin, especially in the Lower Peninsula counties of Emmet, Charlevoix, Leelanau, Benzie, Manistee, Mason, and Oceana.

Recognition: This stout, prickly, dune species may grow to ca. 1 m or more in height, though stunted individuals as small as 10 cm may flower. **The leaves and entire plant are blue-green in color and densely covered with white-woolly hairs.** The mature leaves are deeply divided into narrow, spine-tipped segments. **The prickly, spine-tipped flower heads are relatively large and strikingly cream-colored, though they may occasionally have a slightly pinkish tint,** yielding seeds with feathery bristles. Pitcher's thistle is unlikely to be easily confused with any other thistle species in Michigan, including both native and non-native species, all of which can be distinguished by their deep pink flower heads (with the rare exception of occasional albino flowers in other species). Although other thistles, particularly non-native ones, may inhabitat disturbed areas in dunes, they are unlikely to co-occur with Pitcher's thistle or persist in good quality, open dunes habitat. Vegetatively, all other thistles in Michigan lack the deep blue-green color of Pitcher's thistle and its usually dense covering of white woolly hairs.

Best survey time/phenology: *Cirsium pitcheri* is fairly easy to recognize as a seedling, but becomes more easily recognizable as it matures. Until one becomes familiar with the plant at all stages, it is best to survey for it during the principal flowering and fruiting period from late-June to early September.

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Habitat: Pitcher's thistle typically grows on open sand dunes and occasionally on lag gravel associated with shoreline dunes. All of its habitats are along the Great Lakes shores, or in very close proximity. Associated plants include such common dune species as *Ammophila breviligulata* (beach grass), *Andropogon scoparius* (little bluestem), *Elymus canadensis* (wild rye), *Arabis lyrata* (lyre-leaved sand cress), *Arctostaphylos uva-ursi* (bearberry), *Calamovilfa longifolia* (sand reed grass), *Agropyron dasystachyum* (dune wheat grass), *Asclepias syriaca* (common milkweed), *Salix cordata* and *S. myricoides* (dune willows), *Hudsonia tomentosa* (beach heath; false heather), *Lithospermum caroliniense* (hairy puccoon), and many other characteristic species of the open dunes, including other rare taxa such as *Stellaria longipes* (stitchwort), *Orobanche fasciculata* (fascicled broomrape), and *Botrychium campestre* (prairie moonwort). Pitcher's thistle often occurs in association with the Great Lakes endemic *Solidago houghtonii* (Houghton's goldenrod) when interdunal wetlands are present within the dunes landscape.

Biology: This monocarpic (once-flowering) plant produces a vigorous rosette that may mature for ca. 5-8 years or more before it flowers. Pitcher's thistle blooms from approximately late June to early September and is protandrous (the pollen maturing before stigmas are receptive on individual flowers), and at least partially self-compatible. Insect pollinators are relatively diverse, including halictid bees, bumblebees, megachilid bees, anthophorid bees, and skippers and butterflies (*Vanessa cardui, Daneus peleyippus*). Moths may well be nocturnal pollinators (Loveless 1984). Microlepidopteran larvae, especially the artichoke plume moth (*Platyptilia carduidactyla*), are responsible for varying amounts of seed predation by eating developing ovules. Loveless (1984) found that seed set declines throughout the flowering season. Seeds are dispersed individually by wind or as entire flower heads blown across the sand, or possibly transported by water.

American goldfinches were observed by Loveless (1984) to consume as much as 50% of the seeds in a flower head. Thirteen-lined ground squirrels also prey upon undispersed seed, and other birds, especially sparrows, forage on unburied dispersed seeds. The fundamental dispersal unit is often the entire head of mature achenes, which remains attached to the withered stem of the mother plant. Seeds germinate in June, and most seedlings appear within 1-3 meters of parent plants (Loveless 1984; Keddy & Keddy 1984). Spittlebugs contribute to mortality of adult plants by ovipositing on the apical meristem and deforming embryonic leaves. The taproot of this thistle, which can reach up to 2 m in length, enhances its ability to survive the dessicating conditions of the dune habitat (Loveless 1984; Johnson and Iltis 1963). High rates of sand movement probably stresses plants through erosion and burial of growing stems, though sand movement is absolutely essential for maintaining the open dune habitat of this species. Extreme drought can also be a major stress, especially for seedlings and juvenile plants with poorly developed, shallow tap roots.

Conservation/management: Though Pitcher's thistle can be locally extirpated by destruction or major disturbance of its habitat (e.g. by shoreline development or intensive recreation), it is somewhat tolerant of disturbance from pedestrians and limited ORV traffic. This is especially true in the heart of its range where it is more abundant and seed sources are present to assist in replenishment. However, vehicular traffic and regular foot traffic tend to unduly destabilize dune sands by mechanically destroying vegetation; this increases erosion and stresses Pitcher's thistle plants, which also are often severely affected by direct impacts. An indirect effect of artificial disturbance is that it enables non-native species such as the invasive spotted knapweed (*Centaurea maculosa*) to invade dune habitats and displace native vegetation, resulting in further habitat degradation.

Because of the extreme development pressure along the Great Lakes shoreline, the potential cumulative impacts to Pitcher's thistle populations is high. Efforts should be made to create active dune zones where development is limited.

Two of the world's largest populations of *Cirsium pitcheri* lie within Sleeping Bear National Lakeshore and Ludington State Park/Manistee National Forest (Nordhouse Dunes). The species also occurs in at least two Michigan Nature Association Sanctuaries, several Nature Conservancy preserves, five state natural areas, and in Pictured Rocks National Lakeshore, as well as in severally informally protected public and private tracts.

Comments: Loveless (1984) found *Cirsium pitcheri* to be very low in genetic diversity. She also discovered that populations around the Straits of Mackinac differed genetically from more northern and southern populations, suggesting that the former may have been genetically isolated at some point and have had gene flow primarily among themselves. Due to the genetic similarity between *C. pitcheri* and the Great Plains species *C. canescens*, Loveless postulates that they descended from a common parent in the west, which migrated east to the Great Lakes shores during the abrupt warming occurring during the hypsithermal period (ca. 11,000-8000 years B.P.) by colonizing local, transient dune systems created by glacial outwash and proglacial lakes. The genetically depleted and homogeneous founder population which reached and colonized the dunes along the Great Lakes was then isolated from its western counterpart by climatic changes, resulting in postglacial reforestation and the extinction of possible linking populations.

Research needs: The response of this species to disturbance would provide useful management information, as Pitcher's thistle occurs in many areas heavily used by recreationists.

Related abstracts: Open duens, dune cutworm, Lake Huron locust, piping plover, dunewort, fascicled broomrape, Houghton's goldenrod, Lake Huron tansy.

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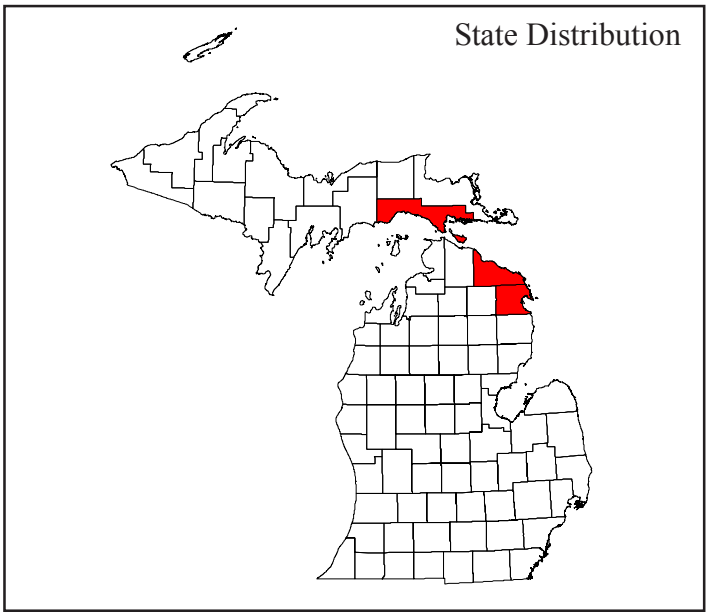
Somatochlora hineana Williamson — Hine's emerald dragonfly



Best Survey Period

Status: Federal and State endangered

Global and state rank: G1/S1

Family: Corduliidae (emerald dragonfly family)

Range: The Hine's emerald is currently known from northern Michigan, northeastern Illinois, Door County, Wisconsin, and from several sites in Missouri. Historically the species was known to occur in three areas of Ohio, and at one site in Indiana. In addition, one specimen had been collected in northern Alabama. Since 1961, Hine's emerald has not been seen in Ohio or Indiana, and it is believed to be extirpated from these states.

State distribution: The Hine's emerald is currently known from thirteen sites in Michigan. Eleven sites are in Mackinac County in the eastern upper peninsula, with one site each in Alpena and Presque Isle counties in the northern lower peninsula. Although not confirmed from Michigan until 1997 a specimen was housed in the Michigan State University insect collection and remained undiscovered until 1998. This adult male specimen had been misidentified as *Somatochlora tenebrosa* (O'Brien 1997).

Recognition: Hine's emerald adults, like other members of its family, have **brilliant green eyes**. *Somatochlora hineana* can be distinguished from all other species of *Somatochlora* by a combination of its **dark metallic green thorax with two distinct creamy-yellow lateral lines** and its **distinctively shaped terminal appendages** or genitalia (Williamson 1931). Adults have a body length of 2.3-2.5 inches (60-65 mm) and a wingspan of 3.5-3.7 inches (90-95 mm) (Zercher 1999). Other species of *Somatochlora* in Michigan which may be confused with Hine's emerald include *Somatochlora elongata*, *S. forcipata*, *S. francklini*, *S. incurvata*, *S. kennedyi*, *S. minor*, *S. walshi*, and *S. williamsoni*. Distinctively shaped male terminal appendages, and female ovipositors separate adults of *S. hineana* from all others. For positive identification adult specimens need to be netted and verified by an expert. No one character will easily or reliably differentiate larvae of Hine's emerald from the species listed above (Zercher 1999). Researchers are currently working on devising keys to differentiate *Somatochlora* larvae.

Best survey time: Adult flight records in Michigan range from late-June through mid-August and adults are best sampled during this period. Larvae can be sampled for at any time during the growing season but seem to be less active during the cooler water temperatures of late fall and early spring (Soluk et al. 1998).

Habitat: Important habitat characteristics of Hine's emerald sites include graminoid dominated wetlands which contain seeps, or slow moving rivulets; cool, shallow water slowly flowing through vegetation; and open areas in close proximity to forest edge (Zercher 1999). The shallow, flowing, cool water provides important larval habitat and the open areas with adjacent woodland edge provide adult hunting and roosting habitat. Michigan Hine's emerald dragonfly sites could be classified as calcareous wetlands or northern fens with an underlining layer of shallow dolomite. One site in Mackinac County has been described as thinly treed, alkaline peatlands (Penskar and Albert 1988). Dominant vegetation in northern fens include sedges (*Carex aquatilis*, *C. lasiocarpa*, *C. limosa*, etc.),

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shrubby cinquefoil (*Potentilla fruticosa*), bulrushes (*Scirpus* spp.), rushes (*Eleocharis* spp.), and twig-rush (*Cladium mariscoide*). White cedar (*Thuja occidentalis*) commonly surrounds and invades northern fens. Other communities in and around Hine's emerald observation locations include: rich conifer swamps, marl fens, coastal fens with seeps, marl pools, hummocks, shallow pools, and small creeks.

Biology: The Hine's emerald exhibits a typical dragonfly life cycle with an aquatic egg, aquatic larva, and a terrestrial/aerial adult (Zercher 1999). The larval stage may last from between 2 to 4 years as they continue to forage and grow within small streamlets (Soluk et al 1998). Hine's emerald larvae are assumed to be a sit-and-wait predator. Analysis of larval behavior in the lab indicates that the larvae are more active at night than during the day (Pintor and Soluk, INHS, unpublished data). Other workers (Mierzwa et al. 1998) have also reported larval movement during the night in the field. It is very likely that the larvae are opportunistic predators feeding on a wide range of invertebrates including but not limited to mayfly, caddisfly, oligochaete larvae, isopods, smaller larvae of other dragonflies, mosquito larvae, worms, and snails (Zercher 1999). An interesting and possible important aspect of larval ecology is the ability to withstand low water or even drought conditions. Hine's emerald larvae have been found beneath discarded railroad timbers in a dried stream channel in Illinois and from crayfish burrows in Illinois and Wisconsin (Soluk 1998). The presumed larval habitat at sites in Michigan has been completely dried up during certain times of the year. Little is currently know on how the larvae survive these conditions in Michigan.

When the larva matures it climbs upon a cattail, rush, or other vertical structure and sheds its exoskeleton (skin) and transforms into a winged adult. This emergence takes place in Michigan from late June through July with adults on the wing until mid-August in most years. As an adult it feeds, establishes a territory, mates, and females lay eggs. Most adult dragonflies are general predators feeding primarily on insects in which they snare while flying (Corbet 1962).

Conservation/management: The most significant threats to the existence of this species have been identified as habitat destruction or alteration, and contamination. Types of direct habitat loss include commercial and residential development, quarrying, creating landfills, constructing pipelines, and filling of wetlands (Zercher 1999). Alteration of habitats include changing the hydrology of sites. This may include building roads, railways, pipelines, and ditches; flooding areas; pulling surface water from nearby areas for irrigation purposes; or pumping groundwater, which could lower groundwater levels (Zercher 1999). Roads and railroads which bisect suitable habitat are especially problematic. Wetland hydrology and quality should also be mantained by preventing improper off-road vehicle use and controlling invasive weeds in these areas. Contamination is a concern due to chemicals and their slow movement through these habitats and the long aquatic stage of this dragonfly (2-4 years). Chemicals in muck sediments can persist and remain toxic for long periods of time and may be difficult if not impossible to treat. Other concerns identified by researchers include environmental extremes, road kills, disease or predation, and fragmentation of habitat leading to genetic stochasticity (Zercher 1999). Further research is needed before more specific management guidelines can be developed. Education and outreach, as well as landowner contact, are important tools for Hine's emerald recovery in Michigan.

Research needs: Additional surveys are needed throughout its range to locate new Hine's emerald populations. In Michigan, larval habitats within occupied wetland complexes need to be identified and protected. Surveys to determine population sizes need to be undertaken at all Michigan sites. Research should focus on the ecological requirements of both adults and larvae.

Related abstracts: incurvate emerald dragonfly

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Abstract citation

Cuthrell, D.L. 1999. Special animal abstract for *Somatochlora hineana* (Hine's emerald dragonfly). Michigan Natural Features Inventory, Lansing, MI. 3 pp.

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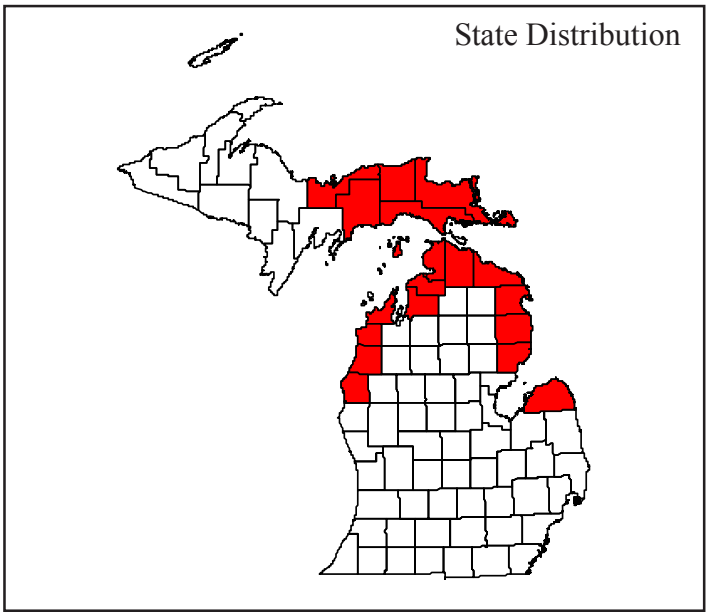
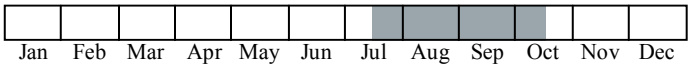
7-05/dlc

Trimerotropis huroniana (Walker) Lake Huron locust



Best Survey Period



Status: State threatened

Global and state rank: G2G3/S2S3

Family: Acrididae (short-horned grasshopper)

Range: The Lake Huron locust is restricted to Great Lakes sand dunes in northeastern Wisconsin (Ballard 1989), the eastern Upper Peninsula and northern Lower Peninsula of Michigan, and the central Lake Huron shoreline of Ontario (Otte 1984).

State distribution: The Lake Huron locust occurs along the Lake Michigan shoreline, including the offshore islands, from Mason to Emmet and Mackinac to Schoolcraft counties; the Lake Huron shoreline from Iosco to Cheyboygan and Mackinac to Chippewa counties; and the Lake Superior shoreline from Chippewa to Alger County. Altogether, it is known from 18 counties, although it has not been observed in Huron County since the 1960s.

Recognition: The Lake Huron locust is a **small** band-winged grasshopper. The length to end of its folded forewings for males is 1-1.24 inches (24-30 mm), and for females is 1.1-1.6 inches (29-40 mm). The **body** is usually **silvery to ash gray, with darker brown and white markings**. Brick red, burnt orange, and ocher color morphs occur occasionally, especially among females. The tegmina (toughened **forewings)** of the adults **have darker bands that may be weakly or strongly expressed**. The **hindwings** are **light yellow near the body with a smoky patch near the tip**. Sexes can be easily distinguished by the males' stronger mottling, their noisy (crepitating) flight, and, as in other Orthoptera, their significantly smaller size. The Lake Huron locust is one of four species in the Great Lakes Region with the pronotum (**the saddlelike structure behind the head) cut across by two well-defined grooves** called sulci. The other three species occur predominately along shorelines farther south than the Lake Huron locust. The range of one of these, the similar-looking seaside locust (*Trimerotropis maritima*), overlaps with the Lake Huron locust along the Lake Michigan shoreline. It can be distinguished from the Lake Huron locust by the two narrow, blackish bands on the inner surface of the hind femora near the distal end. The Lake Huron locust has a **broad band covering half of the inner surface of the hind femora near the body and a narrow band near the distal end**. Other grasshoppers that occur with the Lake Huron locust have one or no sulcus cutting across the pronotum.

Best survey time: Nymphs can be found before mid-July. Adults are present from early to mid-July into October until the time of frequent heavy frosts and snow. Individuals become active between 9:30 and 10:00 a.m., after the sun had risen far enough to warm the foredune shoreline.

Habitat: In Michigan, the Lake Huron locust is restricted to sparsely vegetated, high-quality coastal sand dunes. A similar habitat affinity has been reported from Wisconsin (Ballard 1989). In these areas, it typically occurs in high numbers and is usually the dominant species. Where the open dunes grade into heavily vegetated or disturbed areas, their numbers quickly decline.

Biology: The seaside locust, *Trimerotropis maritima*, apparently replaces the Lake Huron locust as an ecological equivalent along the southern shores of Lake Huron and

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Lake Michigan (Hubbell 1929). On the west side of the state the northward range of the seaside locust, extends at least as far as Manistee, Manistee County, while the southward range of the Lake Huron locust extends at least as far as Ludington State Park, Mason County (Scholtens 1996). Currently, it is not known whether a similar overlap occurs along the Lake Huron shoreline. Scholtens (1996) also documented a third very similar sand-colored, yellow-banded Oedipodinae grasshopper, *Spharagemon collare*, as far north as Presque Isle County along the Lake Huron shoreline. Although it occurred in habitats that are typical for *T. huroniana*, only one of the sites he surveyed contained both species. *Spharagemon collare* was not found on any shoreline sites in good to excellent condition. All localities where it occurred were heavily disturbed with high numbers of invasive weeds.

Little on the life history of the Lake Huron locust has been published. Its courtship behaviors are thought to be similar to that of the pallid-winged locust, *T. pallidipennis* (Otte 1970). Egg masses for the single generation per year are laid in the soft soil where they overwinter. Nymphs hatch in late spring and mature by mid-July. Adults may be found in large numbers through the fall, most likely succumbing to the first hard frosts.

Adults communicate through visual and auditory signals (Otte 1970). Only males crepitate in flight by flashing and snapping their wings, making a cracking noise with each snap. Crepitation occurs during a hovering courtship flight in which the males snap their wings two or three times while hovering; this display typically occurs on sunny days when temperatures reach 80^{o}F. Crepitation also occurs during flight elicited by a disturbance. On the ground, courting males stridulate by rubbing the femora against the forewings, producing a trill in busts of two to three pulses (Otte 1970). Females are cryptically colored against the light sand of the back dunes, whereas the males are virtually invisible on the gravel-dominated upper beaches of the foredunes.

The Lake Huron locust is strictly ground dwelling, essentially never climbing on foliage or other supports (Ballard 1989). On sunny, windless days, locusts are most common on sparsely vegetated sands, where they are evenly distributed with territories of several feet in diameter. In windy, overcast weather, individuals are densely distributed within the heavy dune grass cover, apparently seeking shelter.

Host plant use in the Lake Huron locust is not restricted to grasses, although these probably make up a large portion of the diet. Scholtens (1996) reports that abundant dune grasses are among the most preferred species, but several dune forbs apparently are included in the diet. Three plant species were common to all sites with Lake Huron locusts, dune grass (*Calamovilfa longifolia*), beach grass (*Ammophila breviligulata*) and wild wormwood (*Artemisia campestris*). Other plant species may be important to the locust if it employs diet mixing as a nutritional strategy as do many other locusts (Mulkern et al. 1969). Scholtens (1997) analyzed frass (fecal) pellets to confirm that Lake Huron locust nymphs were feeding on four vascular plant species, including beach grass, wild wormwood, dune grass, and wheatgrass (*Agropyron dasystachyum*). Significant among the acceptable forbs is Pitcher's thistle (*Cirsium pitcheri*), a federally protected species restricted to the dunes. Unacceptable species were generally woody species, but also included the state-threatened Lake Huron tansy (*Tanacetum huronense*). Limited observations in the field indicate that locusts feed by clipping off vegetation near the base of plants. Parts of insect exoskeletons were found in 28% and 44% of pellet samples from two sites (Scholtens 1997). It is thought that locust nymphs scavenge dead insects to supplement the nitrogen intake in their diet. Nitrogen is widely recognized as the most common limiting nutrient for herbivorous insects (Mattson 1980). Scholtens (1997) concluded that the locust appear to be fairly randomly distributed in dune habitat with respect to plant species and seemed to eat most acceptable host plants, virtually at random, although some preference was shown for beach grass. Host plant specialization is not thought to be a factor limiting this species to shoreline dune habitats at this time.

Lake Huron locusts do show significant preference for dry, loose sand substrates characteristic of shoreline dune habitats and not stabilized, wooded dunes or most inland habitats (Scholtens 1997). The biological reason for this preference is not known. The largest, apparently most stable populations of the locust are associated with areas of extensive, wide dunes. Shorelines that are one mile or more in length with at least two sets of dunes containing blowout areas are ideal.

Explaining the presence or absence of the locust from particular dune systems requires evaluation of a variety of factors including geological processes, biological interactions, and human influence. Interactions between changes in lake levels, availability of suitable habitat, and the locust' ability to colonize and recolonize could have significant influence on the species' distribution patterns at any one point in time.

Conservation/management: Unfortunately, significant parts of the locust's high-quality dune habitat have been degraded or destroyed by shoreline home and recreational development throughout the Great Lakes Region. Protection of the remaining habitat is the most significant action that could be taken for the conservation of this species in Michigan. Although a dune-obligate species, the Lake Huron locust apparently can persist with low to medium levels of human-related disturbance. The extent of the dunes protected at a site should be large enough to allow natural processes to locally change the character of the dunes through blowouts, which create more habitat, or stabilization by plants, which reduces habitat. When disturbance changes the character of the habitat away from a typical dune system to one with a large number of invasive weeds, or lack of sand movement, the Lake Huron

locust seems to drop significantly in numbers. Healthy locust populations have been maintained on private lands in several places on Lake Michigan and Lake Huron, as long as the basic dune system is kept intact. The housing developments most destructive to the locust seem to be those older developments along Lake Huron, where the dune system was quite narrow and construction of houses and swimming beaches has essentially removed the dune and its vegetation. Severe destruction of dunes on public lands has had the same effect where the dunes have been essentially denuded of native vegetation and mechanically flattened to create swimming and volleyball areas.

Scholtens (1996, 1997) identified several major shoreline areas with significant populations of the locust:

1. the northwestern segment of Emmet County along Lake Michigan at Sturgeon Bay, an area of at least 10 miles;
2. the Sleeping Bear Dunes National Lakeshore in Benzie and Leelanau counties;
3. the Ludington State Park area in Mason County which includes at least six miles of good beach front;
4. the Pt. Aux Chenes dunes in Mackinac County with at least two to three miles of dunes;
5. much of the Lake Superior shoreline, where long stretches of high dunes exist from Whitefish Point to the Grand Marais area in Chippewa County; and
6. the Lake Michigan islands.

Research needs: Additional surveys should be conducted to verify the current ranges of the Lake Huron locust, the seaside locust and *S. collare*. Examination of the ecological relationships between these species would be helpful. Additional information on the ecology and life history of the Lake Huron locust also is needed to provide a stronger basis for management planning and conservation activities. The exact microhabitat requirements of the locust over the course of its lifespan should be determined. Long-term monitoring of populations spanning a geographic range of disturbance types and levels would provide crucial information necessary to make recommendations about best management practices for this species. Information about normal movement and dispersal patterns, as well as about the locusts' recolonization capabilities, also would be useful.

Related abstracts: open dunes, Pitcher's thistle, Houghton's goldenrod, Lake Huron tansy, piping plover, prairie warbler, dune cutworm

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Abstract citation

Rabe, M.L. 1999. Special animal abstract for *Trimerotropis huroniana* (Lake Huron locust). Michigan Natural Features Inventory, Lansing, MI. 3 pp.

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11-99/mlr

Appendix C. NatureServe Element Occurrence Rank Specifications

Lake Huron Locust

Population or element occurrence (EO) viability rank specifications for the Lake Huron locust, as defined by NatureServe (Schweitzer and Whittaker 2007)

A- Rank: If the B-criteria are accepted as reasonable, then perhaps 1000 adults estimated in 3000 acres would be a reasonable basis for an A. An A ranked occurrence should be among the best all time and should contain substantially more than the minimum required for persistence in present or better condition--including maintaining genetic diversity.

B- Rank: A persistent population estimated after a survey of 1 hour to be greater than 300 individuals in greater than 1000 acres (approx. 405 ha) of suitable habitat. Threats are manageable.

C- Rank: A persistent population estimated after a survey of 1 hour to be between 10 and 50 individuals in less than 100 acres (approx. 40.5 ha) of required habitat. Threats are typically more serious.

D- Rank: A non-persistent population, or an apparently persistent estimated after a survey of 1 hour to be less than 10 individuals in a habitat strip less than 10 m wide, even if it is a long (> 1 km) stretch of habitat. Threats are greater and more difficult to control.

EO Rank Specs Justifications:
The present B-criteria are modified (e.g. 150 estimated changed to 300) from 1994 A-criteria which presumably would define a very good occurrence but are too low to be reasonable as an A for an insect or other animal with a one year or less generation time. Since this would be a good occurrence in the opinion of Whittaker, such is accepted as a reasonable basis for a B. The A-criteria are derived from inflating the B, and it is not certain and current A quality occurrences exist. All criteria are lower than usual for an insect.