Natural Community, Rare Species and Invasive Plant Surveys of Garden and High Island

An Addendum to 2013 Surveys

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For:
Little Traverse Bay Bands of Odawa Indians
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ODAWA NATURAL RESOURCE DEPARTMENT

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Cover Photos: Front - A long day on Garden Island. Photo by Phyllis J. Higman. Back - Coastal Fen, Monatou Bay, Garden Island. Photo by Joshua G. Cohen.

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Acknowledgements

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Executive Summary

Natural features surveys conducted on Garden and High Island in 2009 resulted in significant new findings, expanded occurrence information, and identification of survey gaps and invasive species threats. Additional surveys were conducted in 2015 to update and document natural community occurrences, and expand rare species and invasive species surveys. Pilot surveys were also conducted for bats and snails to begin to document their diversity in the Islands and evaluate the potential presence of rare species.

Seventeen natural communities were surveyed, including ten previously documented occurrences and seven new occurrences. Three new occurrences were documented on High Island including dry-mesic northern forest, Great Lakes barrens, and mesic northern forest. Previously documented occurrences of boreal forest, open dune, limestone cobble shore, and two sand and gravel beaches were updated. Five new occurrences were documented on Garden Island including Great Lakes marsh, mesic northern forest, wooded dune and swale complex, and two limestone cobble shore communities. Previously documented occurrences of boreal forest and three coastal fens were updated.

A scoring matrix was developed using indices of ecological integrity, rarity, and threat severity, and these were tallied for each natural community occurrence to provide a stewardship prioritization table. The highest priority sites for stewardship are the two Great Lakes marshes on Garden Island. Medium priority sites include coastal fens, limestone cobble shore, open dunes, Great Lakes barrens, and sand and gravel beach. Lowest priority sites include boreal forest, mesic northern forest, dry-mesic northern forest, wooded dune and swale complex, and northern wet meadow. The stewardship prioritization in conjunction with detailed baseline data for each natural community occurrence provides a flexible framework for determining and prioritizing site-specific management and monitoring actions. This framework can be refined to meet local or broader scale needs.

On Garden Island, two Pitcher's thistle occurrences were updated and the occurrence rank of one population of butterwort was upgraded. One new occurrence of Lake Huron tansy was documented. Previous records of climbing fumitory and calypso orchid and a report of Houghton's goldenrod from the southern shoreline were not reconfirmed. A new species, male fern, was documented on High Island and two pitcher's thistle occurrences and an occurrence of Lake Huron tansy and fascicled broomrape were updated. The tansy occurrence rank was upgraded. A previously documented population of dune stitchwort was not relocated in spite of several targeted surveys.

The occurrence of Lake Huron locust on Garden Island was confirmed in at least one location on the island, however only six individuals were observed in 2015 compared to over 46 individuals in 2011. Over 800 Lake Huron locusts were observed on High Island extending its known distribution from open dunes into low foredunes, sand and gravel beach and Great Lakes barrens. This represents a substantial expansion of this occurrence beyond it's' already substantial expansion in 2011. Its occurrence rank was upgraded to excellent to good viability.

Hine's emerald dragonfly was not reconfirmed on Garden Island in 2015, where it was newly discovered in 2011, however extensive, apparently suitable and

little disturbed habitat was documented. Several individuals have been observed in the intervening years by LTTB scientists and it is likely that it persists there. Timing of surveys is tricky and the species is inherently challenging to survey for. Hine's emerald dragonfly was not observed on High Island nor was suitable habitat. Other dragonfly species observed on Garden Island included twelve-spotted skimmers, four-spotted skimmers rusty snaketails, common green darners, other darners (*Aeshna* spp.), saffron-winged meadowhawks, other red-colored meadow-hawks, and several Williamson's emerald dragonflies. On High Island, additional dragonflies observed included widow skimmers, common green darners, meadowhawks, and rusty snaketail dragonflies. Other species observed included a merlin, bald eagles, northern water snake, eastern garter snake, eastern newt, and monarch butterflies.

Eight of the nine species of bats known to occur in Michigan were detected at each of two acoustic monitoring stations on each Island. Eastern red bat, hoary bat, silver-haired bat, and little brown were most commonly detected. Less commonly detected were big brown bat, northern long eared bat, Indiana bat, and tricolored bat. These represent notable exceptions to previous reports for the archipelago. The detection of big brown bat, hoary bat, and silver-haired bat likely confirms the presence of these species, also detected by Seefelt on High Island in 2013. The detection of Indiana bat, northern long-eared bat, and tricolored bat are the first reported occurrences, based on acoustic detections, for the archipelago. These detections, particularly the Indiana bat, must be viewed with caution as differentiating some bat species with Wildlife Acoustics Kaleidoscope software can be extremely difficult. Results from acoustic sampling should be used in conjunction with live capture techniques for confirmation. This is critical in cases where rare or legally protected species are involved and important or controversial decisions can be made. The USFWS has listed the long-eared bat as a threatened species and the Indian bat as an endangered species.

Fifteen snail species were documented on High Island including an updated record for the Great Lakes physa which was originally documented circa 1920. The non-native species, Mud Bithynia, was documented at one site and empty zebra mussels were seen at the same site. Twenty-four snail species were collected on Garden Island, including a new occurrence of Tapered vertigo, a special concern species. This is the first record of any of the rare vertigo species in the Beaver Island archipelago. Although not currently listed, the two collections of the Iroquois vallonia at two sites on Garden Island may represent important populations for this species.

Six priority invasive plants were documented on the islands, including invasive phragmites, narrow-leaf and hybrid cat-tail, reed canary grass, European marsh thistle, spotted knapweed, and wild parsnip. Nine lower priority species were also documented, including mossy stonecrop which was not noted in 2011. While the high quality natural communities are relatively free of invasive species, this is a critical time to keep them so. The species noted above, are well established in many lower quality areas on the islands and will expand rapidly without proactive and systematic efforts to control them. Many are in areas where Pitcher's thistle, Lake Huron tansy, and Lake Huron locust are holding on. Implementing recommended priorities now will minimize future impacts and treatment costs.

Introduction

Garden and High Islands within the Little Traverse Bay Bands of Odawa Indians' (LTBB) Reservation, harbor significant natural features contributing to the rich biodiversity and cultural value of the Beaver Island archipelago. In 2011, Michigan Natural Features Inventory (MNFI) began systematic surveys with the LTBB scientists to assess new and previously known occurrences of rare plants and insects, as well as priority invasive species that could impact them. Significant extant populations of English sundew, butterwort, Houghton's goldenrod, Pitcher's thistle, Lake Huron tansy, fascicled broomrape, Lake Huron locust, and Hine's emerald dragonfly, were documented, expanding their known extent on the islands. In addition, Lake Huron locust and Hine's emerald sightings were documented for the first time on Garden Island. These findings warranted additional survey effort on the Islands.

Surveys were conducted to update, document and delineate significant natural communities and expand surveys for rare plants, invertebrates and invasive species. In addition pilot surveys were conducted for rare bats and snails. Another element of this project was the reciprocal training between LTBB and MNFI scientists. Surveys were conducted together to share back-and-forth, hands-on, field-based methods and experiences with the unique features of these Islands.

Data gathered from this project will supplement the 2013 surveys data and are intended to inform the identification of conservation targets and development of strategies for their protection on Garden and High Islands. These data will also inform conservation planning for the entire Beaver archipelago and will help identify future survey needs.

Organization of the Report

This addendum report presents each component of the project separately, including sections for natural community, rare plant, rare invertebrate, bat, snail, and invasive species surveys. Detailed site summaries for each natural community surveyed are provided in the Natural Community section. This section also provides a biodiversity stewardship framework that ranks stewardship priorities based on combined indices of ecological integrity, rarity, and threat severity. The overall findings from 2015 are recapped in the executive summary.

Natural Community Surveys
Introduction

The Michigan Natural Features Inventory (MNFI) database of high-quality occurrences of natural communities is a critical source of information on Michigan's terrestrial ecosystems (MNFI 2016). Natural communities are defined as assemblages of interacting plants, animals, and other organisms that repeatedly occur under similar environmental conditions across the landscape and are predominantly structured by natural processes rather than modern anthropogenic disturbances (Kost et al. 2007). Protecting and managing representative natural communities is critical to biodiversity conservation, since native organisms are best adapted to environmental and biotic forces with which they have survived and evolved over the millennia (Kost et al. 2007). Prior to the implementtation of this project, 12 high-quality occurrences of natural communities had been documented on Garden and High Islands. These natural community occurrences represent eight of the 77 natural community types described for Michigan by Cohen et al. (2014). Among these 12 natural community occurrences, four are represented by natural communities that are considered critically imperiled or imperiled at the global scale, including high-quality occurrences of coastal fen and Great Lakes marsh (NatureServe 2010).

Prior to this project, many of the natural community occurrences on these islands had not been surveyed in close to two decades, including six sites that had not been visited since 1986 or earlier. Many of the natural community element occurrences that were previously documented on the islands were in need of more thorough on-the-ground surveys informed by better aerial imagery to refine their mapped boundaries. In addition, air photo interpretation of high-resolution imagery identified the potential for new occurrences of natural communities throughout both islands. A critical goal of this project was to collect updated and new data for natural communities to provide natural resource managers with accurate, detailed information on the current status of ecosystems on these islands that can help guide biodiversity management and restoration and ongoing planning efforts. Our project objectives were to assist resource agencies with land use planning and resource management by (1) updating known high-quality occurrences of natural communities on Garden and High Islands, (2) conducting surveys for new occurrences of natural communities on Garden and High Islands, (3) synthesizing survey results and information in MNFI's conservation database, and (4) proposing biodiversity stewardship and monitoring priorities on Garden and High Islands.

Surveys were conducted during the 2015 field season. MNFI conducted surveys of ten previously known element occurrences and documented seven new natural community element occurrences. Ten different natural community types are represented in the 17 element occurrences surveyed (Table 1). Surveys assessed the element occurrence ranking, classification, and delineation of these occurrences and detailed the vegetative structure and composition, ecological boundaries, landscape and abiotic context, threats, management needs, and restoration opportunities associated with each site. The primary goal of this survey effort is to provide resource managers and planners with standardized, baseline information on each natural community element occurrence. This baseline information is critical for facilitating site-level decisions about biodiversity

stewardship, prioritizing protection, management and restoration, monitoring the success of management and restoration, and informing landscape-level biodiversity planning efforts. This report summarizes the findings of MNFI's ecological surveys and also presents a prioritization of stewardship and monitoring of the natural community element occurrences found on Garden and High Islands.

Table 1. Summary of natural community surveys.

Community Type	EO ID	Survey Site	EO RANK	Prior EO RANK	Year First Observed	Year Last Observed	Island
Boreal Forest	4856	High Island	AB	BC	1986	2015	High Island
Boreal Forest	7487	Garden Island Boreal Forest	A	A	1998	2015	Garden Island
Coastal Fen	7888	Jensen Harbor	A	A	1999	2015	Garden Island
Coastal Fen	9513	Sweat Lodge Swale	B	B	1998	2015	Garden Island
Coastal Fen	10574	Northcutt and Monatou Bays	AB	BC	1999	2015	Garden Island
Dry-Mesic Northern Forest	20453	High Island	B	NA	2015	2015	High Island
Great Lakes Barrens	20454	Nezewabegon Barrens	AB	NA	2015	2015	High Island
Great Lakes Marsh	20450	Taganing Marsh	A	NA	2015	2015	Garden Island
Limestone Cobble Shore	6527	High Island	AB	C	1986	2015	High Island
Limestone Cobble Shore	20448	Monatou Bay	A	NA	2015	2015	Garden Island
Limestone Cobble Shore	20449	Taganing Shore	B	NA	2015	2015	Garden Island
Mesic Northern Forest	10496	Red Oak Garden	C	C	1996	2015	Garden Island
Mesic Northern Forest	20452	Nezewabegon Forest	AB	NA	2015	2015	High Island
Open Dunes	10698	High Island	A	B	1981	2015	High Island
Sand and Gravel Beach	10977	High Island Bay	A	A	1986	2015	High Island
Sand and Gravel Beach	13026	High Island	A	A	1986	2015	High Island
Wooded Dune and Swale Complex	20451	Taganing Dune and Swale	C	NA	2015	2015	Garden Island

Figure 1. Open dunes, High Island. (Photo by Joshua G. Cohen.)

Methods

Field Survey Prioritization

Sites for survey were prioritized by evaluating their date since last survey (with higher priority for older records), state and global ranking (with higher priority for rarer natural communities), and element occurrence ranking (with higher priority for higher quality sites). Targets for de novo survey were identified using aerial photographic interpretation focusing on rare ecosystems, and through site leads and recommendations from scientists with the Little Traverse Bay Bands of Odawa Indians Natural Resources Department.

Field Survey

A total of 17 high-quality natural communities were surveyed in 2015 on Garden and High Islands (Table 1). Each natural community was evaluated employing Natural Heritage and MNFI methodology, which considers three factors to assess a natural community's ecological integrity or quality: size, landscape context, and condition (Faber-Langendoen et al. 2008). If a site meets defined requirements for these three criteria (MNFI 1988) it is categorized as a high-quality example of that specific natural community type, entered into MNFI's database as an element occurrence, and given a rank based on the consideration of its size, landscape context, and condition. Ecological field surveys were conducted during the 2015 growing season to evaluate the condition and classification of the sites. To assess natural community size and landscape context, a combination of field surveys, aerial photographic interpretation, and graphic Information System (GIS) analysis was employed. Typically, a minimum of a half day was dedicated to each site, depending on the size and complexity of the site.

The ecological field surveys involved:

a) compiling comprehensive plant species lists and noting dominant and representative species
b) describing site-specific structural attributes and ecological processes
c) measuring tree diameter at breast height (DBH) of representative canopy trees and aging canopy dominants (where appropriate)
d) analyzing soils and hydrology
e) noting current and historical anthropogenic disturbances
f) evaluating potential threats
g) ground-truthing aerial photographic interpretation using GPS (Garmin units were utilized)
h) taking digital photos and GPS points at significant locations
i) surveying adjacent lands when possible to assess landscape context
j) evaluating the natural community classification and mapped ecological boundaries
k) assigning or updating element occurrence ranks
l) noting management needs and restoration opportunities or evaluating past and current restoration activities and noting additional management needs and restoration opportunities

Following completion of the field surveys, the collected data were analyzed and transcribed to update or create element occurrence records in MNFI's statewide biodiversity conservation database (MNFI 2016). Natural community boundaries were mapped or re-mapped. Information from these surveys and prior surveys, if available, was used to produce site descriptions, threat assessments, and management recommendations for each natural community occurrence, which appear within the following Survey Results section.

Natural Community Stewardship Prioritization

Following the 2015 field season, we conducted an intersection of the natural community element occurrences and the coastal zone as defined by Department of Environmental Quality. A total of 645 natural community element occurrences are found within the coastal zone as of December 2015. We developed a scoring matrix for all of these natural community element occurrences to provide a framework for the prioritization of stewardship. For this scoring matrix, we developed the following three indices: an ecological integrity index, a rarity index, and a threat severity index. We used the element occurrence rank to develop the ecological integrity rank, with higher scores for higher-ranked EOs. The rarity index was developed by assigning a score for each natural community type's state rank and global rank and averaging the two scores. For both state and global ranks, higher scores were assigned to rarer types.

The threat severity index was developed using knowledge of general threats to natural community types and information gained during surveys on specific regional threats to natural community types. Since 2006, MNFI scientists have surveyed or resurveyed 409 natural community element occurrences in the coastal zone, constituting 63% of the total number of occurrences. These surveys included threat assessments that were used to inform the assigning of threat severity scores for individual sites and for inferring the likely threat to sites not recently surveyed by community type and region. For each natural community element occurrence, the sum of the scores for the ecological integrity index, rarity index, and threat severity index was calculated to sort the natural community element occurrences by their stewardship prioritization score. The stewardship prioritization for the natural community element occurrences found on Garden and High Islands is presented in the Stewardship Prioritization Results section.

Figure 2. High water inundating limestone cobble shore, High Island. (Photo by Joshua G. Cohen.)

Results

Survey Results

Seventeen occurrences of high-quality natural communities were surveyed during the 2015 field season with nine sites occurring on Garden Island and eight sites occurring on High Island. A total of 10 different natural community types were visited including: boreal forest (2 element occurrences or EOs), coastal fen (3 EOs), dry-mesic northern forest (1 EO), Great Lakes barrens (1 EO), Great Lakes marsh (1 EO), limestone cobble shore (3 EOs), mesic northern forest (2 EOs), open dunes (1 EO), sand and gravel beach (2 EOs), and wooded dune and swale complex (1 EO). Table 1 lists the visited sites, their element occurrence ranks, and their previous element occurrence ranks if applicable. Two previously documented sites, Indian Harbor Great Lakes marsh (EO ID 13020) and Garden Island Harbor northern wet meadow (EO ID 11804), were not re-visited due to time constraints. Of the 12 natural community element occurrences on Garden and High Islands, these two sites were determined to be the lowest priority for resurvey since they had been surveyed prior to this project most recently (in 1999). As a result, 10 of the 12 previously documented natural community element occurrences were surveyed in 2015 and seven new natural community element occurrences were documented.

The following site summaries summarize threats and management recommendations for each of the 17 natural community EOs visited in 2015 organized alphabetically by community type and then by element occurrence. Each grouping of communities begins with an overview of the natural community type, which was adapted from MNFI's natural community classification (Kost et al. 2007, Cohen et al. 2014). In addition, an ecoregional distribution map is provided for each natural community type (Albert et al. 2008). For each site summary, we indicate if the site is an update of a previously identified EO or a new EO and provide the following information:

a) site name
b) natural community type
c) global and state rank (see Appendix 3 for ranking criteria)
d) current element occurrence rank
e) size
f) locational information
g) digital photograph(s)
h) site description
i) threat assessment
j) management recommendations

Figure 3. Due to the remote location of Garden and High Islands, current threats are primarily limited to localized patches of non-native plants occurring along the shoreline. The primary stewardship priorities are to control pockets of non-native plants and continue monitoring coastal ecosystems for invasives. (Photo by Joshua G. Cohen.)

Table 2. Stewardship prioritization for natural community element occurrences on Garden and High Islands. Element occurrences are sorted by their stewardship prioritization scores and assigned a high (red), medium (yellow), or low (blue) stewardship priority.

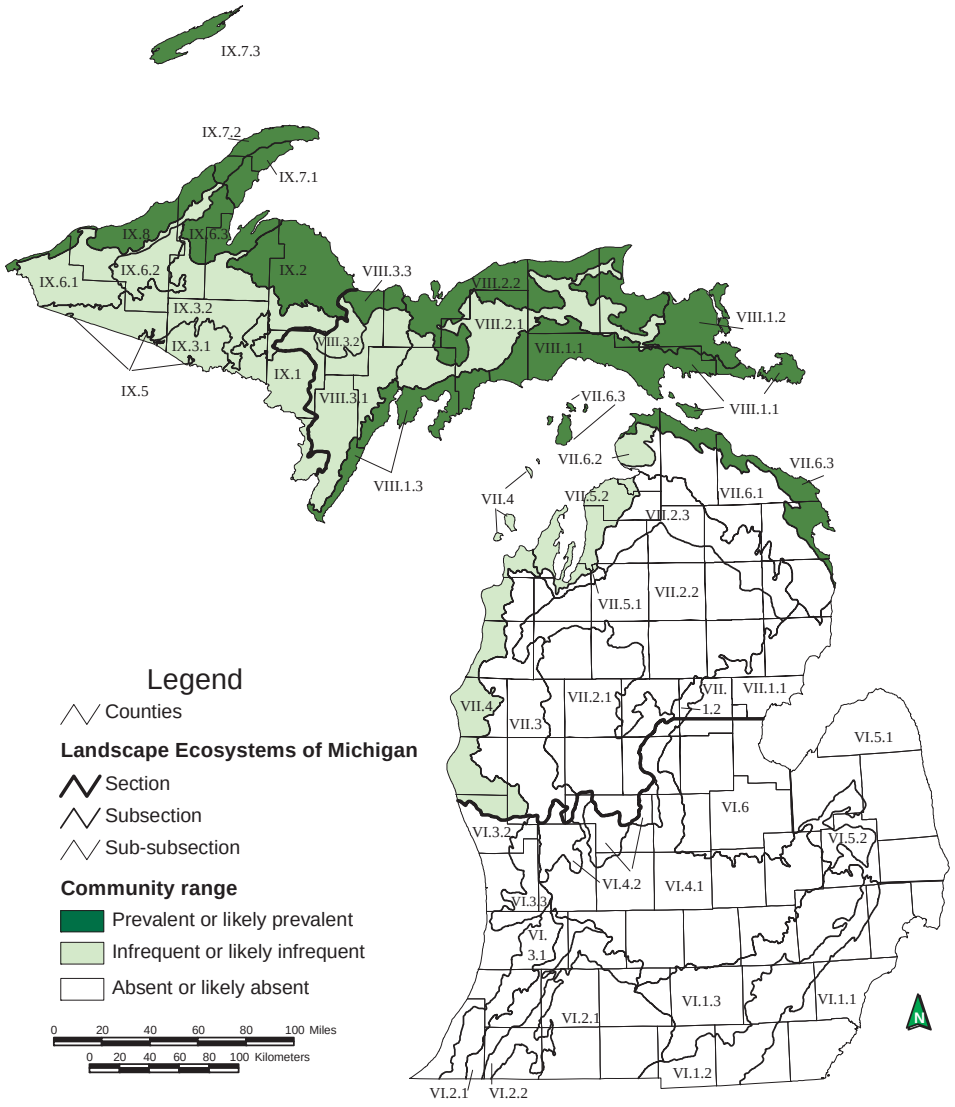
EO ID	Natural Community Type	Surveysite	Island	EO Rank	Global Rank	Global Rank Score	State Rank	State Rank Score	Rarity Index	Ecological Integrity Index	Threat Severity Index	Stewardship Score
13020	Great Lakes Marsh	Indian Harbor	Garden Island	AB	G2	4.00	S3	3.00	3.50	4.50	6.00	14.00
20450	Great Lakes Marsh	Taganing Marsh	Garden Island	A	G2	4.00	S3	3.00	3.50	5.00	5.00	13.50
7888	Coastal Fen	Jensen Harbor	Garden Island	A	G1G2	4.50	S2	4.00	4.25	5.00	1.00	10.25
20449	Limestone Cobble Shore	Taganing Shore	Garden Island	B	G2G3	3.50	S3	3.00	3.25	4.00	3.00	10.25
20448	Limestone Cobble Shore	Monatou Bay	Garden Island	A	G2G3	3.50	S3	3.00	3.25	5.00	2.00	10.25
10698	Open Dunes	High Island	High Island	A	G3	3.00	S3	3.00	3.00	5.00	2.00	10.00
10977	Sand and Gravel Beach	High Island Bay	High Island	A	G3?	3.00	S3	3.00	3.00	5.00	2.00	10.00
13026	Sand and Gravel Beach	High Island	High Island	A	G3?	3.00	S3	3.00	3.00	5.00	2.00	10.00
20454	Great Lakes Barrens	Nezewabegon Barrens	High Island	AB	G3	3.00	S2	4.00	3.50	4.50	2.00	10.00
10574	Coastal Fen	Northcutt Bay	Garden Island	AB	G1G2	4.50	S2	4.00	4.25	4.50	1.00	9.75
6527	Limestone Cobble Shore	High Island	High Island	AB	G2G3	3.50	S3	3.00	3.25	4.50	2.00	9.75
9513	Coastal Fen	Sweat Lodge Swale	Garden Island	B	G1G2	4.50	S2	4.00	4.25	4.00	1.00	9.25
7487	Boreal Forest	Garden Island Boreal Forest	Garden Island	A	GU	3.00	S3	3.00	3.00	5.00	1.00	9.00
4856	Boreal Forest	High Island	High Island	AB	GU	3.00	S3	3.00	3.00	4.50	1.00	8.50
20452	Mesic Northern Forest	Nezewabegon Forest	High Island	AB	G4	2.00	S3	3.00	2.50	4.50	1.00	8.00
11804	Northern Wet Meadow	Garden Island Harbor	Garden Island	A	G4G5	1.50	S4	2.00	1.75	5.00	1.00	7.75
20453	Dry-mesic Northern Forest	High Island	High Island	B	G4	2.00	S3	3.00	2.50	4.00	1.00	7.50
20451	Wooded Dune and Swale Complex	Taganing Dune and Swale	Garden Island	C	G3	3.00	S3	3.00	3.00	3.00	1.00	7.00
10496	Mesic Northern Forest	Red Oak Garden	Garden Island	C	G4	2.00	S3	3.00	2.50	3.00	1.00	6.50

Figure 4. Taganing Marsh, Great Lakes marsh, Garden Island. Preventing the establishment and spread of invasive plants in the Great Lakes marshes of Garden Island is a high stewardship priority for the Beaver Island Archipelago. (Photo by Joshua G. Cohen.)

SITE SUMMARIES

BOREAL FOREST

Overview: Boreal forest is a conifer or conifer-hardwood forest type occurring on moist to dry sites characterized by species dominant in the Canadian boreal forest. It typically occupies upland sites along shores of the Great Lakes, on islands in the Great Lakes, and locally inland. The community occurs north of the climatic tension zone primarily on sand dunes, glacial lakeplains, and thin soil over bedrock or cobble. Soils of sand and sandy loam are typically moderately acid to neutral, but heavier soils and more acid conditions are common. Proximity to the Great Lakes results in high levels of windthrow and climatic conditions characterized by low summer temperatures and high levels of humidity, snowfall, and summer fog and mist. Additional important forms of natural disturbance include fire and insect epidemics (Kost et al. 2007, Cohen et al. 2014).



Map 1. Distribution of boreal forest in Michigan (Albert et al. 2008).

1. Garden Island Boreal Forest
Natural Community Type: Boreal Forest
Rank: GU S3, globally unrankable and vulnerable within the state
Element Occurrence Rank: A
Size: 906 acres
Location: Garden Island
Element Occurrence Identification Number: 7487 (EO update)

Site Description: The Garden Island Boreal Forest is composed of three polygons of uneven-aged boreal forest occurring along the shoreline margin of Garden Island in the southern, northwestern, and northern portion of the island. Garden Island Boreal Forest is one of three A-ranked boreal forests in the state. Surveys in 2015 expanded the existing element occurrence. The boreal forest, which contains inclusions of rich conifer swamp and northern hardwoods, occurs on rolling topography of former cobble shore. Windthrow is prevalent throughout the forest, and as a result, the boreal forest is characterized by high levels of coarse woody debris. The coarse woody debris load is primarily composed of early-successional species, primarily balsam fir (*Abies balsamea*), paper birch (*Betula papyrifera*), and trembling aspen (*Populus tremuloides*). Estimated tree ages ranged from 135 to 165 years old: a 32.7 cm northern white-cedar (*Thuja occidentalis*) was cored and estimated to be over 145 years old; a 37.1 cm northern white-cedar was cored and estimated to be over 165 years old; and a 52.7 cm white pine (*Pinus strobus*) was cored and estimated to be over 135 years old. The soils within the boreal forest are characterized by shallow (1-4 cm), alkaline (pH 7.5-8.0) loams and loamy organics overlying limestone cobble.

Northern white-cedar dominates the canopy with overstory associates including balsam fir, paper birch, white spruce (*Picea glauca*), trembling aspen, and white pine. Canopy trees typically range in diameter at breast height (DBH) from 30 to 50 cm. Canopy closure ranges widely from 50% to 90% with areas of more open canopy (50-65%) occurring following large windthrow events. The understory is characterized by balsam fir, round-leaved dogwood (*Cornus rugosa*), mountain maple (*Acer spicatum*), red elderberry (*Sambucus racemosa*), beaked hazelnut (*Corylus cornuta*), trembling aspen, and sugar maple (*Acer saccharum*). Prevalent species in the low shrub layer include Canadian fly honeysuckle (*Lonicera canadensis*), bush honeysuckle (*Diervella lonicera*), yew (*Taxus canadensis*), wild red raspberry (*Rubus strigosus*), balsam fir, white ash (*Fraxinus americana*), and sugar maple. Characteristic ground cover species include starflower (*Trientalis borealis*), Canada mayflower (*Maianthemum canadense*), twinflower (*Linnaea borealis*), wild sarsaparilla (*Aralia nudicaulis*), woodferns (*Dryopteris* spp.), sedge (*Carex pedunculata*), oak fern (*Gymnocarpium dryopteris*), big-leaved aster (*Aster maculata*), poison ivy (*Toxicodendron radicans*), gay-wings (*Polygala paucifolia*), false spikenard (*Maianthemum racemosum*), and herb Robert (*Geranium robertianum*).

Threats: Species composition and vegetative structure are patterned by natural processes. No threats were observed during the course of the survey. Scattered non-natives observed in the ground cover include bittersweet nightshade (*Solanum dulcamara*) (locally common) and helleborine (*Epipactis helleborine*).

Management Recommendations: The main management recommendations are to allow natural processes to operate unhindered and to retain an intact buffer of natural communities surrounding the boreal forest. The forest should be periodically monitored for invasive species and deer herbivory.

Garden Island Boreal Forest. Photo by Joshua G. Cohen.

Aerial Photograph of Garden Island Boreal Forest.

Garden Island Boreal Forest. Photo by Joshua G. Cohen.

2. High Island
Natural Community Type: Boreal Forest
Rank: GU S3, globally unrankable and vulnerable within the state
Element Occurrence Rank: AB
Size: 784 acres
Location: High Island
Element Occurrence Identification Number: 4856 (EO update)

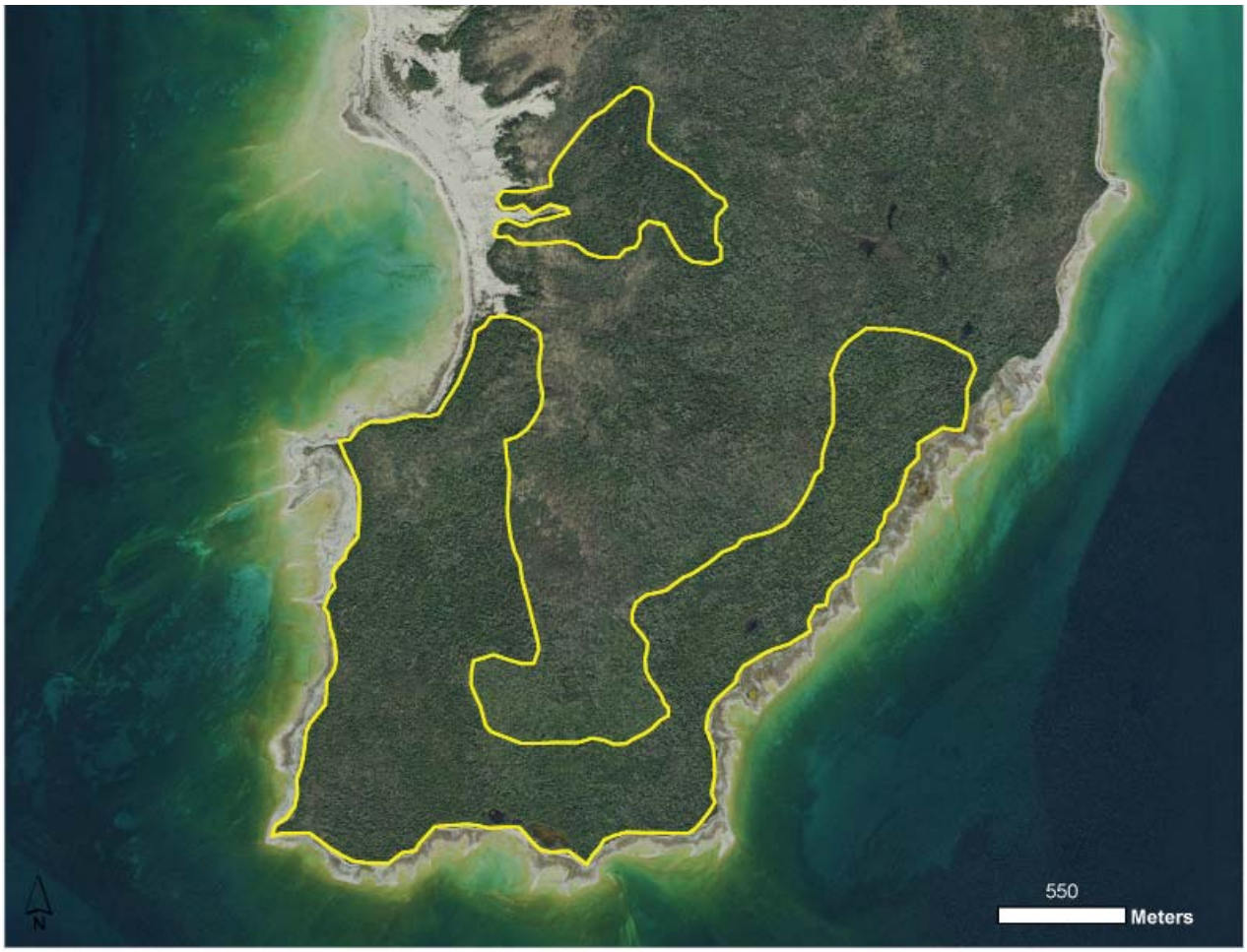
Site Description: The High Island boreal forest is composed of two polygons occurring along the southern portion and central-western portion of High Island. Surveys in 2015 expanded the existing element occurrence. The southern polygon of boreal forest occurs inland from limestone cobble shore on former cobble shore and the central-western polygon occurs inland from open dunes on former sand dunes. The mapped area of boreal forest contains inclusions of rich conifer swamp, mesic northern forest, and dry-mesic northern forest. Prevalence of yew (*Taxus canadensis*) in the understory and fine- scale gradients in hydrology and soils make precisely mapping this boreal forest very difficult. Where yew is an overwhelming dominant in the understory, this species is likely impacting species diversity and regeneration through competition for light resources. Topography ranges from rolling in areas where boreal forest occurs on former cobble shore to rugged where boreal forest occurs on former sand dune. Windthrow is prevalent throughout the forest and as a result, the boreal forest is characterized by high levels of coarse woody debris. A 50.5 cm white spruce (*Picea glauca*) was cored and estimated to be over 100 years old. The alkaline (pH 7.5-7.8) soils of the boreal forest are variable with sands, gravelly sands, and clayey sands and a shallow (10-20cm), acidic (pH 4.5-4.8) organic layer.

Northern white-cedar (*Thuja occidentalis*) dominates the canopy with overstory associates including white spruce, paper birch (*Betula papyrifera*), red maple (*Acer rubrum*), red pine (*Pinus resinosa*), red oak (*Quercus rubra*), American mountain-ash (*Sorbus americana*), and white pine (*Pinus strobus*). Canopy trees typically range in DBH from 30 to 50 cm with wind-protected areas behind the dunes supporting larger trees (60-100cm). Canopy closure ranges widely from 50% to 90% with areas of more open canopy (50-70%) occurring following large windthrow events. The understory is overwhelmingly dominated by robust and dense yew. Understory associates include balsam fir (*Abies balsamea*), mountain maple (*Acer spicatum*), choke cherry (*Prunus virginiana*), red maple, and northern white-cedar. Yew is also dominat in the low shrub layer with associates including Canadian fly honeysuckle (*Lonicera canadensis*), mountain maple, balsam fir, and beaked hazelnut (*Corylus cornuta*). Where yew is an overwhelming dominant in the understory, it is likely impacting species diversity and regeneration through competition for light resources. Characteristic ground cover species include starflower (*Trientalis borealis*), Canada mayflower (*Maianthemum canadense*), twinflower (*Linnaea borealis*), wild sarsaparilla (*Aralia nudicaulis*), bunchberry (*Cornus canadensis*), gay-wings (*Polygala paucifolia*), Jack-in-the-pulpit (*Arisaema triphyllum*), and rattlesnake plantains (*Goodyera* spp.)

Threats: Species composition and vegetative structure are patterned by natural processes. No threats were observed during the course of the survey.

Management Recommendations: The main management recommendations are to allow natural processes to operate unhindered and to retain an intact buffer of natural communities surrounding the boreal forest. The forest should be periodically monitored for invasive species and deer herbivory.

The High Island boreal forest is characterized by dense understory yew (*Taxus canadensis*). Photo by Joshua G. Cohen.

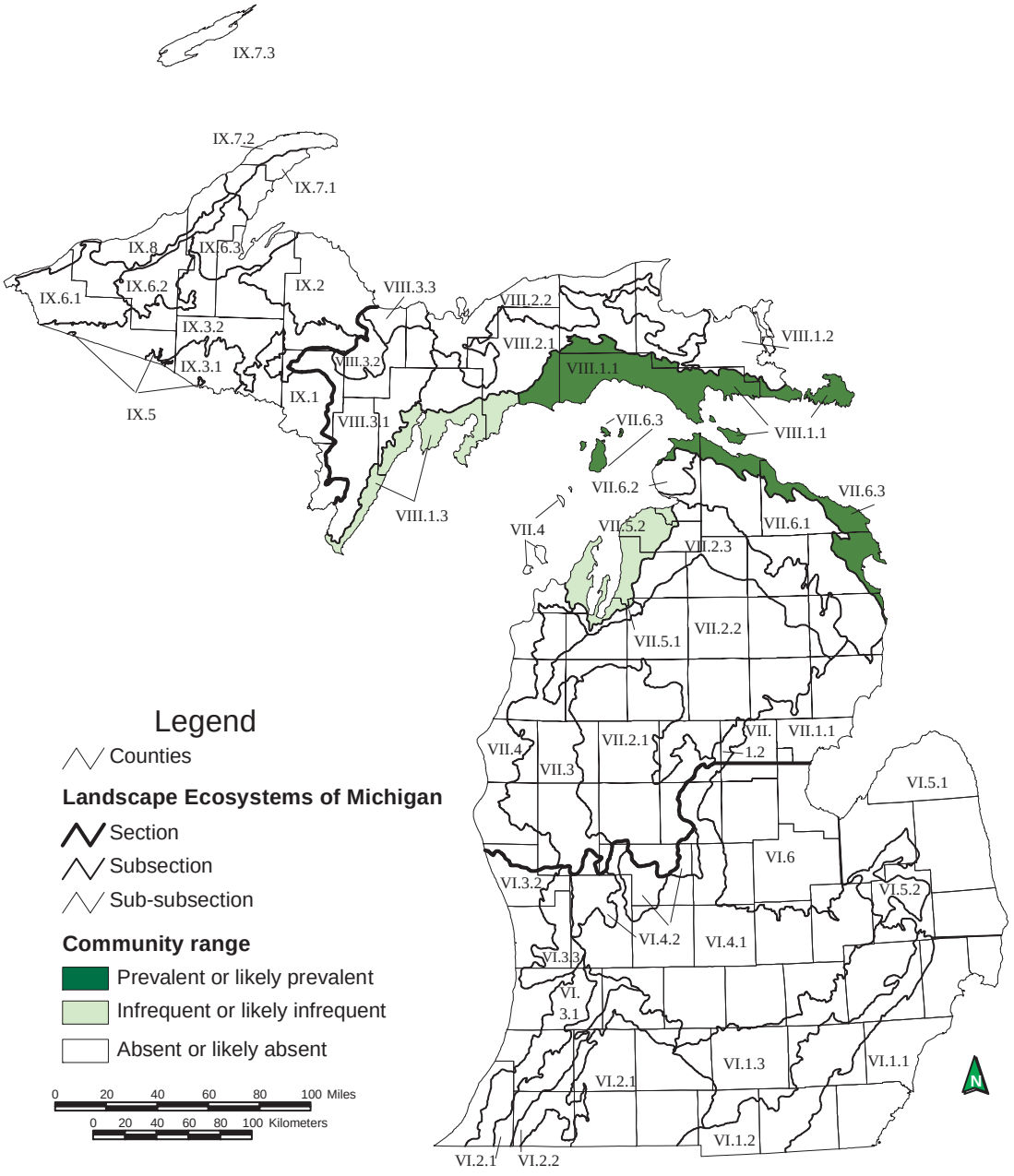


Aerial Photograph of High Island boreal forest.

High Island boreal forest. Photo by Joshua G. Cohen.

COASTAL FEN

Overview: Coastal fen is a sedge- and rush-dominated wetland that occurs on calcareous substrates along Lake Huron and Lake Michigan north of the climatic tension zone. The community occurs where marl and organic soils accumulate in protected coves and abandoned coastal embayments and grade to moderately alkaline glacial tills and lacustrine sediments lakeward. Sediments along the lakeshore are typically fine-textured and rich in calcium and magnesium carbonates. Vegetation is comprised primarily of calcicolous species capable of growing on wet alkaline substrates (Kost et al. 2007, Cohen et al. 2014).



Map 2. Distribution of coastal fen in Michigan (Albert et al. 2008).

3. Jensen Harbor
Natural Community Type: Coastal Fen
Rank: G1G2 S2, globally critically imperiled to imperiled and imperiled within the state
Element Occurrence Rank: A
Size: 59 acres
Location: Garden Island
Element Occurrence Identification Number: 7888 (EO update)

Site Description: The Jensen Harbor coastal fen occurs on Garden Island in Jensen Harbor and also along the shoreline to the northwest of Jensen Harbor. This coastal fen is one of five A-ranked coastal fens in the state. The coastal fen grades to Great Lakes marsh lakeward and the margin between these communities shifts from year to year with fluctuations of the Great Lakes. Following surveys in 2015, the boundaries of this coastal fen were adjusted with a new Great Lakes marsh element occurrence (Taganing Marsh, EO ID 20450) also being mapped in Jensen Harbor. Within the coastal fen, the soils are characterized as alkaline (pH 8.0) peats and marl over wet alkaline (pH 8.0) sands. Scattered sphagnum hummocks are concentrated along the inland margin of the fen. Numerous marl pools and crayfish burrows occur throughout the fen.

Dominant ground cover vegetation include spike-rush (*Eleocharis rostellata*), twig-rush (*Cladium mariscoides*), beak-rush (*Rhynchospora capillacea*), tufted bulrush (*Trichophorum cespitosum*), and sedges (*Carex* spp.). Additional characteristic species include butterwort (*Pinguicula vulgaris*, state special concern), pitcher-plant (*Sarracenia purpurea*), false asphodel (*Triantha glutinosa*), grass-of-Parnassus (*Parnassia glauca*), bird's-eye primrose (*Primula mistassinica*), hardstem bulrush (*Schoenoplectus acutus*), Kalm's lobelia (*Lobelia kalmii*), blue-joint (*Calamagrostis canadensis*), white beak-rush (*Rhynchospora alba*), round-leaved sundew (*Drosera rotundifolia*), and small cranberry (*Vaccinium oxycoccos*). Scattered low shrubs include shrubby cinquefoil (*Dasiphora fruticosa*), Kalm's St. John's-wort (*Hypericum kalmianum*), sweet gale (*Myrica gale*), alder-leaved buckthorn (*Rhamnus alnifolia*), bog rosemary (*Andromeda glaucophylla*), and Labrador-tea (*Rhododendron groenlandicum*), and scattered understory species include northern white-cedar (*Thuja occidentalis*), tamarack (*Larix laricina*), and trembling aspen (*Populus tremuloides*). This fen supports a population of Hine's emerald dragonfly (*Somatochlora hineana*, state and federally threatened).

Threats: Species composition and zonation are patterned by natural processes. No threats were observed during the survey.

Management Recommendations: The main management recommendations are to allow natural processes (i.e., Great Lakes water level fluctuations) to operate unhindered, maintain a natural community buffer surrounding the shoreline to minimize surface water flow into the fen and to maintain groundwater seepage, and monitor for invasive plant populations.

Jensen Harbor coastal fen. Photos by Joshua G. Cohen.

Aerial photograph of Jensen Harbor coastal fen.

Jensen Harbor coastal fen. Photo by Joshua G. Cohen.

4. Northcutt and Monatou Bays
Natural Community Type: Coastal Fen
Rank: G1G2 S2, globally critically imperiled to imperiled and imperiled within the state
Element Occurrence Rank: AB
Size: 37 acres
Location: Garden Island
Element Occurrence Identification Number: 10574 (EO update)

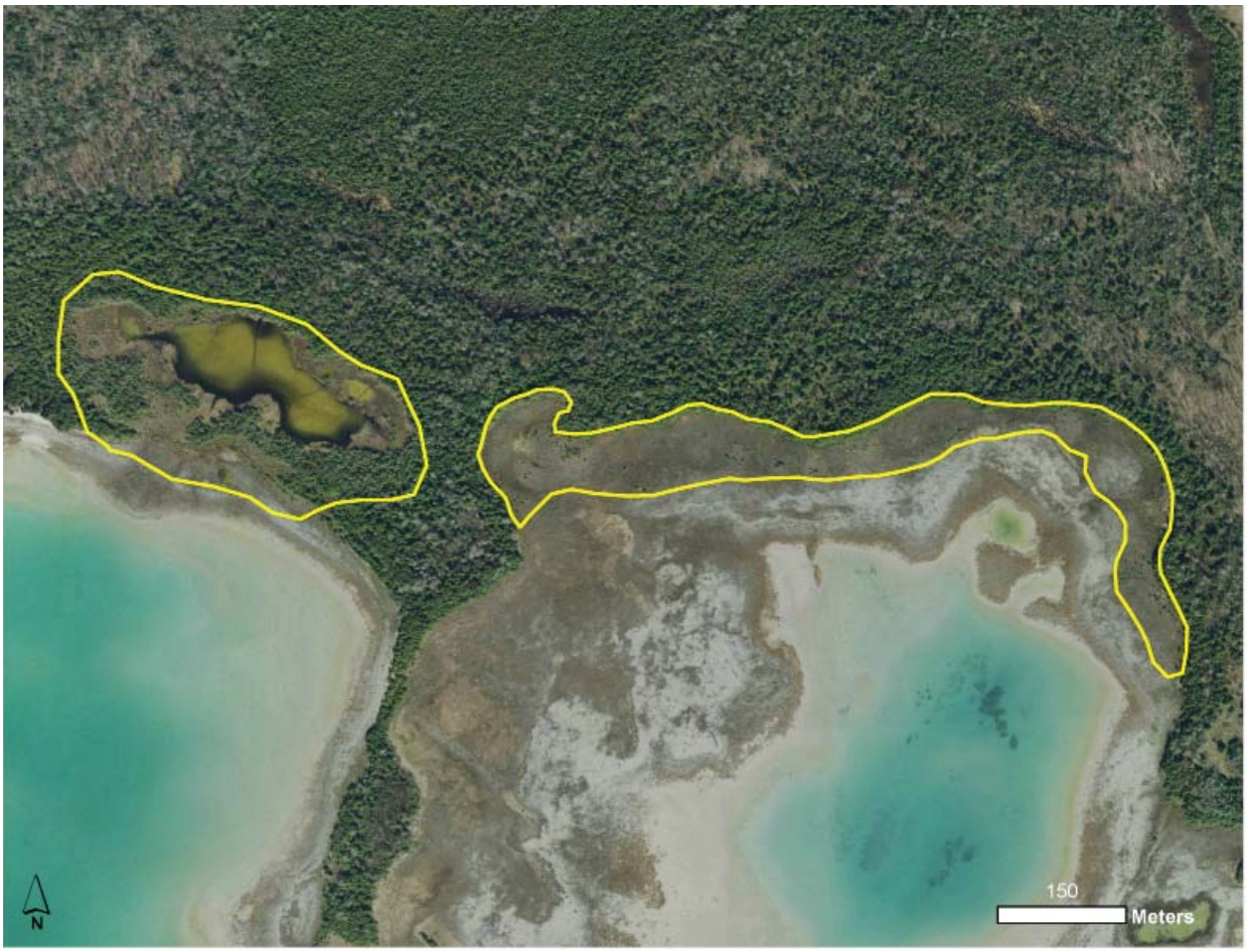
Site Description: This coastal fen occurs in Northcutt and Monatou Bays on Garden Island. In 2015, surveys focused on the shoreline in Monatou Bay just east of Northcutt Bay. Surveys resulted in the expansion of this coastal fen to include areas of fen along the Monatou Bay shoreline and this site description summarizes this portion of the complex. This area of coastal fen grades to Great Lakes marsh and limestone cobble shore lakeward and the margin between these communities shifts from year to year with fluctuations of the Great Lakes. Soils of the coastal fen in Monatou Bay are characterized as alkaline (pH 8.0) gravelly marl. Soils of the coastal fen in Northcutt Bay are characterized as shallow (8-10cm) organics over alkaline (pH 8.0) sands. Scattered sphagnum hummocks are concentrated along the inland margin of the fen. Numerous marl pools occur throughout the Monatou Bay fen.

Within the Monatou Bay coastal fen characteristic ground cover vegetation include tufted bulrush (*Trichophorum cespitosum*), sedge (*Carex livida*), twig-rush (*Cladium mariscoides*), pitcher-plant (*Sarracenia purpurea*), false asphodel (*Triantha glutinosa*), grass-of-Parnassus (*Parnassia glauca*), bird's-eye primrose (*Primula mistassinica*), hardstem bulrush (*Schoenoplectus acutus*), bog goldenrod (*Solidago uliginosa*), and Indian paintbrush (*Castilleja coccinea*). Areas around the marl pools include spatulate-leaved sundew (*Drosera intermedia*), pitcher-plant, and tufted bulrush. Shrubby cinquefoil (*Dasiphora fruticosa*) is prevalent in the low shrub layer and scattered understory species include northern white-cedar (*Thuja occidentalis*) and tamarack (*Larix laricina*). The portion of fen associated with Northcutt Bay wraps around a large marl pond and is dominated by a mat of wiregrass sedge (*Carex lasiocarpa*) with associates including tufted bulrush, bulrush (*Trichophorum alpinum*), pitcher-plant, false asphodel, bog goldenrod, Indian paintbrush, and bastard-toadflax (*Comandra umbellata*). The coastal fen in Monatou Bay appears to have suitable habitat for Hine's emerald dragonfly (*Somatochlora hineana*, state and federally threatened).

Threats: Species composition and zonation are patterned by natural processes. No threats were observed during the survey.

Management Recommendations: The main management recommendations are to allow natural processes (i.e., Great Lakes water level fluctuations) to operate unhindered, maintain a natural community buffer surrounding the shoreline to minimize surface water flow into the fen and to maintain groundwater seepage, and monitor for invasive plant populations.

Northcutt and Monatou Bays coastal fen. Photos by Joshua G. Cohen.



Aerial photograph of Northcutt and Monatou Bays coastal fen.

Northcutt and Monatou Bays coastal fen. Photo by Joshua G. Cohen.

5. Sweat Lodge Swale
Natural Community Type: Coastal Fen
Rank: G1G2 S2, globally critically imperiled to imperiled and imperiled within the state
Element Occurrence Rank: B
Size: 6.7 acres
Location: Garden Island
Element Occurrence Identification Number: 9513 (EO update)

Site Description: Sweat Lodge Swale is a coastal fen composed of two distinct polygons that occur along the northern shore of Garden Island. This coastal fen is backed by boreal forest and limestone cobble shore occurs lakeward. The soils are characterized as shallow, alkaline (pH 7.5-8.0) organics over cobble. Scattered sphagnum hummocks are concentrated along the inland margin of the fen and a marl pool occurs in the eastern portion of the largest fen polygon.

Dominant ground cover vegetation include tufted bulrush (*Trichophorum cespitosum*), threesquare (*Schoenoplectus pungens*), and twig-rush (*Cladium mariscoides*) with additional characteristic species including Baltic rush (*Juncus balticus*), Kalm's lobelia (*Lobelia kalmii*), reed (*Phragmites australis*, native), horned bladderwort (*Utricularia cornuta*), and silverweed (*Potentilla anserina*). The low shrub layer is prevalent, especially in narrow portions of fen and includes shrubby cinquefoil (*Dasiphora fruticosa*), Kalm's St. John's-wort (*Hypericum kalmianum*), and northern white-cedar (*Thuja occidentalis*).

Threats: Species composition and zonation are patterned by natural processes. No threats were observed during the survey.

Management Recommendations: The main management recommendations are to allow natural processes (i.e., Great Lakes water level fluctuations) to operate unhindered, maintain a natural community buffer surrounding the shoreline to minimize surface water flow into the fen and to maintain groundwater seepage, and monitor for invasive plant populations.

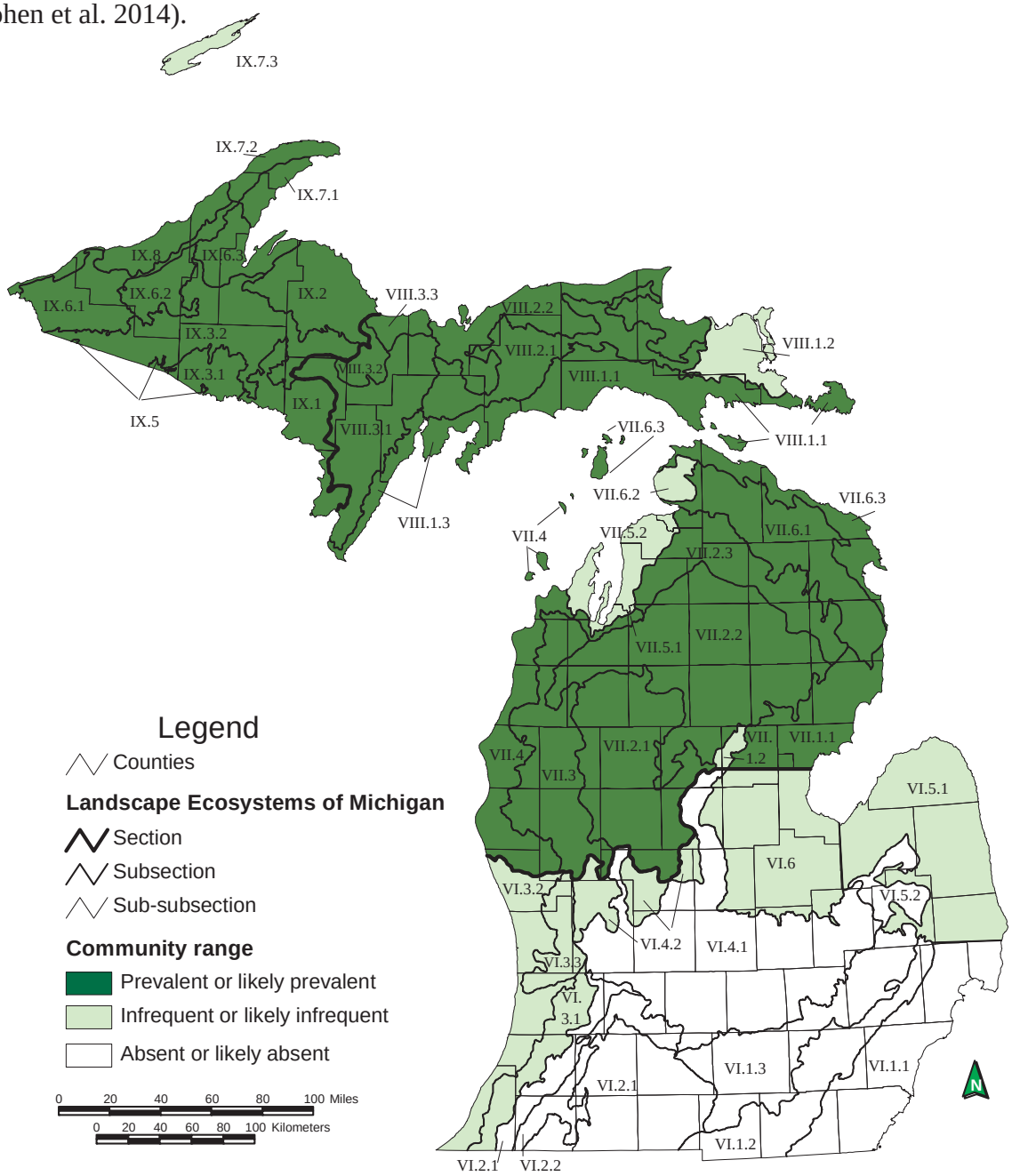
Sweat Lodge Swale coastal fen. Photo by Joshua G. Cohen.

Sweat Lodge Swale coastal fen. Photo by Joshua G. Cohen.

Aerial photograph of Sweat Lodge Swale coastal fen.

DRY-MESIC NORTHERN FOREST

Overview: Dry-mesic northern forest is a pine or pine-hardwood forest type of generally dry-mesic sites located mostly north of the transition zone. Dry-mesic northern forest is characterized by acidic, coarse- to medium-textured sand or loamy sand and occurs principally on sandy glacial outwash, sandy glacial lakeplains, and less often on inland dune ridges, coarse-textured moraines, and thin glacial drift over bedrock. The community historically originated in the wake of catastrophic fire and was maintained by frequent, low-intensity ground fires (Kost et al. 2007, Cohen et al. 2014).



Map 3. Distribution of dry-mesic northern forest in Michigan (Albert et al. 2008).

6. High Island
Natural Community Type: Dry-mesic Northern Forest
Rank: G4 S3, apparently secure globally and vulnerable within the state
Element Occurrence Rank: B
Size: 115 acres
Location: High Island
Element Occurrence Identification Number: 20453 (New EO)

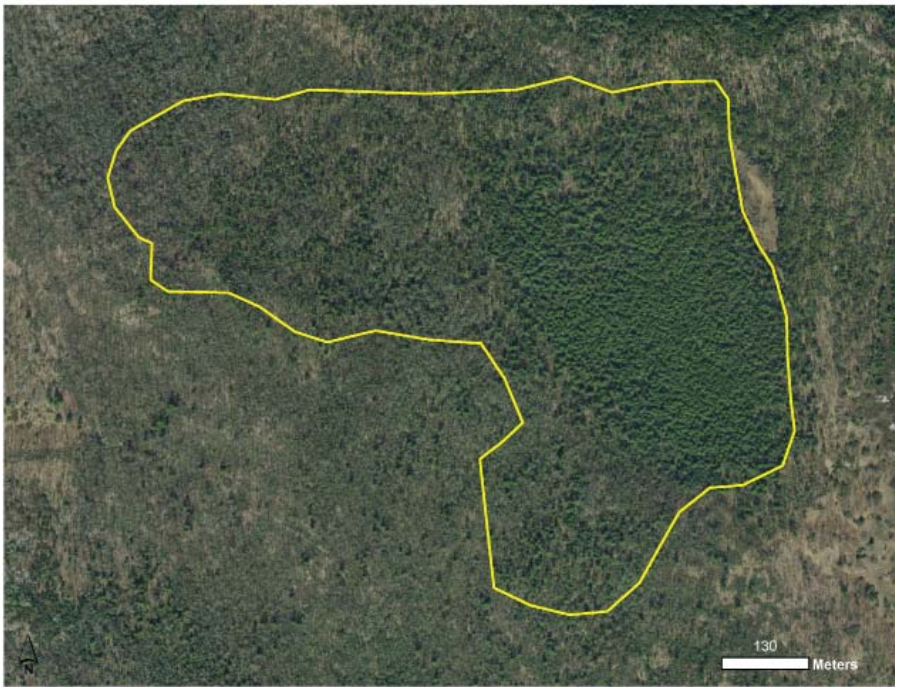
Site Description: The High Island dry-mesic northern forest occurs in the northeastern portion of High Island on undulating topography of former dune shoreline. This forest likely established over 120 years ago following a severe fire event. Charcoal was noted on old tree stumps. Estimated tree ages ranged from 100 to 120 years old: a 58 cm hemlock (*Tsuga canadensis*) was cored and estimated to be over 103 years old; a 59.2 cm hemlock was cored and estimated to be over 115 years old; and a 45.6 cm red pine (*Pinus resinosa*) was cored and estimated to be over 120 years old. Windthrow occurs throughout the forest and coarse woody debris of early-successional species is starting to accumulate. Soils are characterized by a typically shallow (5-10cm), acidic (pH 5.0) A horizon over fine- to medium-textured acidic (pH 4.5-5.0) sands. Where hemlock is prevalent in the canopy, a zone of leaching occurs in the soil profile.

The overstory of the dry-mesic northern forest ranges from 70% to 80% with canopy dominants including white pine (*Pinus strobus*), hemlock, and red oak (*Quercus rubra*). Canopy associates include red pine, paper birch (*Betula papyrifera*), red maple (*Acer rubrum*), bigtooth aspen (*Populus grandidentata*), and white spruce (*Picea glauca*). Canopy trees typically range in DBH from 40 to 60 cm. The understory ranges from 10% to 20% and characteristic species include balsam fir (*Abies balsamea*), sugar maple (*Acer saccharum*), red maple, beaked hazelnut (*Corylus cornuta*), and yew (*Taxus canadensis*). The low shrub layer ranges from sparse (0-10%) to dense (30-60%) with yew locally abundant. Additional species in the low shrub layer include Canadian fly honeysuckle (*Lonicera canadensis*), bush honeysuckle (*Diervella lonicera*), Canada blueberry (*Vaccinium myrtilloides*), balsam fir, sugar maple, and red maple. The ground cover is characterized by wild sarsaparilla (*Aralia nudicaulis*), twinflower (*Linnaea borealis*), bluebead lily (*Clintonia borealis*), starflower (*Trientalis borealis*), Canada mayflower (*Maianthemum canadense*), sedge (*Carex pedunculata*), cow-wheat (*Melampyrum lineare*), ground-pine (*Dendrolycopodium obscurum*), running ground-pine (*Lycopodium clavatum*), and stiff clubmoss (*Huperzia annotinum*).

Threats: Species composition and vegetative structure are patterned by natural processes. No threats were observed during the course of the survey. Scattered cut stumps occur within the forest.

Management Recommendations: The primary management recommendations are to allow natural processes to operate unhindered (i.e., permit wildfires to burn through this site), retain an intact buffer of natural communities surrounding the dry-mesic northern forest, and monitor for invasive species.

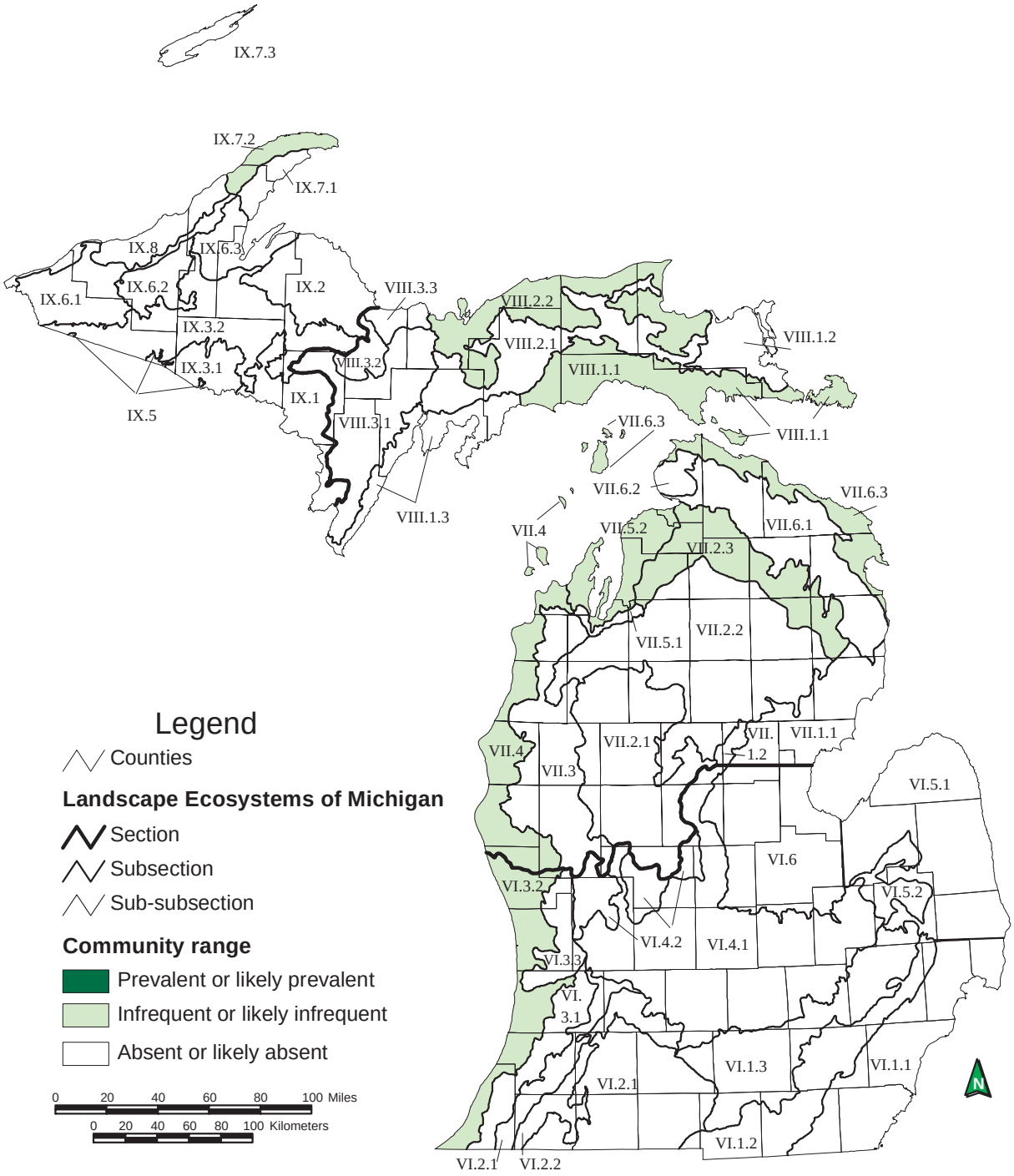
High Island dry-mesic northern forest. Photo by Joshua G. Cohen.



Aerial photograph of High Island dry-mesic northern forest.

GREAT LAKES BARRENS

Overview: Great Lakes barrens is a coniferous savanna community of scattered and clumped trees, and an often dense, low or creeping shrub layer. The community occurs along the shores of the Great Lakes where it is often associated with interdunal wetlands and open dunes (Kost et al. 2007, Cohen et al. 2014).



Map 4. Distribution of Great Lakes barrens in Michigan (Albert et al. 2008).

7. Nezewabegon Barrens
Natural Community Type: Great Lakes Barrens
Rank: G3 S2, vulnerable globally and imperiled within the state
Element Occurrence Rank: AB
Size: 19 acres
Location: High Island
Element Occurrence Identification Number: 20454 (New EO)

Site Description: The Nezewabegon Barrens consists of four polygons of Great Lakes barrens occurring along the northern portion of High Island on rolling dunes slightly elevated from the adjacent shoreline. The Great Lakes barrens polygons occur perched above low foredune and sand and gravel beach or limestone cobble shore with dry-mesic northern forest, boreal forest, and mesic northern forest inland. A combination of water erosion and wind deposition resulted in the formation of Great Lakes coastal dunes. The sand source for the coastal dunes was glacial sediment that was eroded by streams and by waves eroding bluffs along the Great Lakes shoreline. These sediments were then moved along the Great Lakes shoreline by nearshore currents, and then deposited along the shoreline by wave action. Strong winds then carried the sands inland, creating dunes. This Great Lakes barrens has developed on a small dune field where sand is stable enough to allow trees to establish and mature. A 28.8 cm red pine (*Pinus resinosa*) was cored and estimated to be 53 years old. The soils are fine- to medium-textured wind-blown and wave-worked, alkaline (pH 8.0), dune sands with shallow (1-2cm), slightly acidic (pH 6.5-6.7) organics occurring locally.

The scattered canopy of the Great Lakes barrens is diverse with canopy associates including white pine (*Pinus strobus*), red pine, northern white-cedar (*Thuja occidentalis*), white spruce (*Picea glauca*), red oak (*Quercus rubra*), paper birch (*Betula papyrifera*), and balsam fir (*Abies balsamea*). Canopy closure is typically 10% to 25%. Tree cover increases with increasing distance from the lakeshore. Many of the canopy trees are open grown with wide, sprawling branches. Canopy trees range in DBH from 10 to 20 cm with some areas of larger trees (20-40cm). The understory is scattered and includes white pine, northern white-cedar, white spruce, trembling aspen (*Populus tremuloides*), paper birch, serviceberry (*Amelanchier* sp.), and choke cherry (*Prunus virginiana*). The low shrub layer is dense and dominated by common juniper (*Juniperus communis*) and bearberry (*Arctostaphylos uva-ursi*) with associates including creeping juniper (*J. horizontalis*), sand cherry (*Prunus pumila*), soapberry (*Shepherdia canadensis*), red-osier dogwood (*Cornus sericea*), choke cherry, and yew (*Taxus canadensis*). The sparse to patchy groundcover is characterized by wormwood (*Artemisia campestris*), starry false Solomon-seal (*Maianthemum stellatum*), white camas (*Anticlea elegans*), little bluestem (*Schizachyrium scoparium*), plains puccoon (*Lithospermum caroliniense*), poison ivy (*Toxicodendron radicans*), wild strawberry (*Fragaria virginiana*), silverweed (*Potentilla anserina*), sand reed grass (*Calamovilfa longifolia*), marram grass (*Ammophila breviligulata*), wheat grass (*Elymus lanceolatus*), common milkweed (*Asclepias syriaca*), and bastard-toadflax (*Comandra umbellata*). Pitcher's thistle (*Cirsium pitcheri*, state threatened) and Lake Huron tansy (*Tanacetum huronense*, state threatened) occur locally within Great Lakes barrens. Canada bluegrass (*Poa compressa*) is locally common within the Great Lakes Barrens.

Threats: Species composition and structure are driven by natural processes. The Great Lakes barrens is threatened by invasive plants. Canada bluegrass (*Poa compressa*) is locally common within the Great Lakes barrens. Invasives found along the nearby shoreline include mossy stonecrop (*Sedum acre*), narrow-leaved cat-tail (*Typha angustifolia*), reed (*Phragmites australis* subsp. *australis*), and white sweet-clover (*Melilotus albus*).

Management Recommendations: The primary management recommendations are to allow natural processes to operate unhindered, eliminate clusters of non-native plants within the Great Lakes barrens and nearby areas of shoreline, and monitor for invasive species with the Great Lakes barrens and adjacent shoreline.

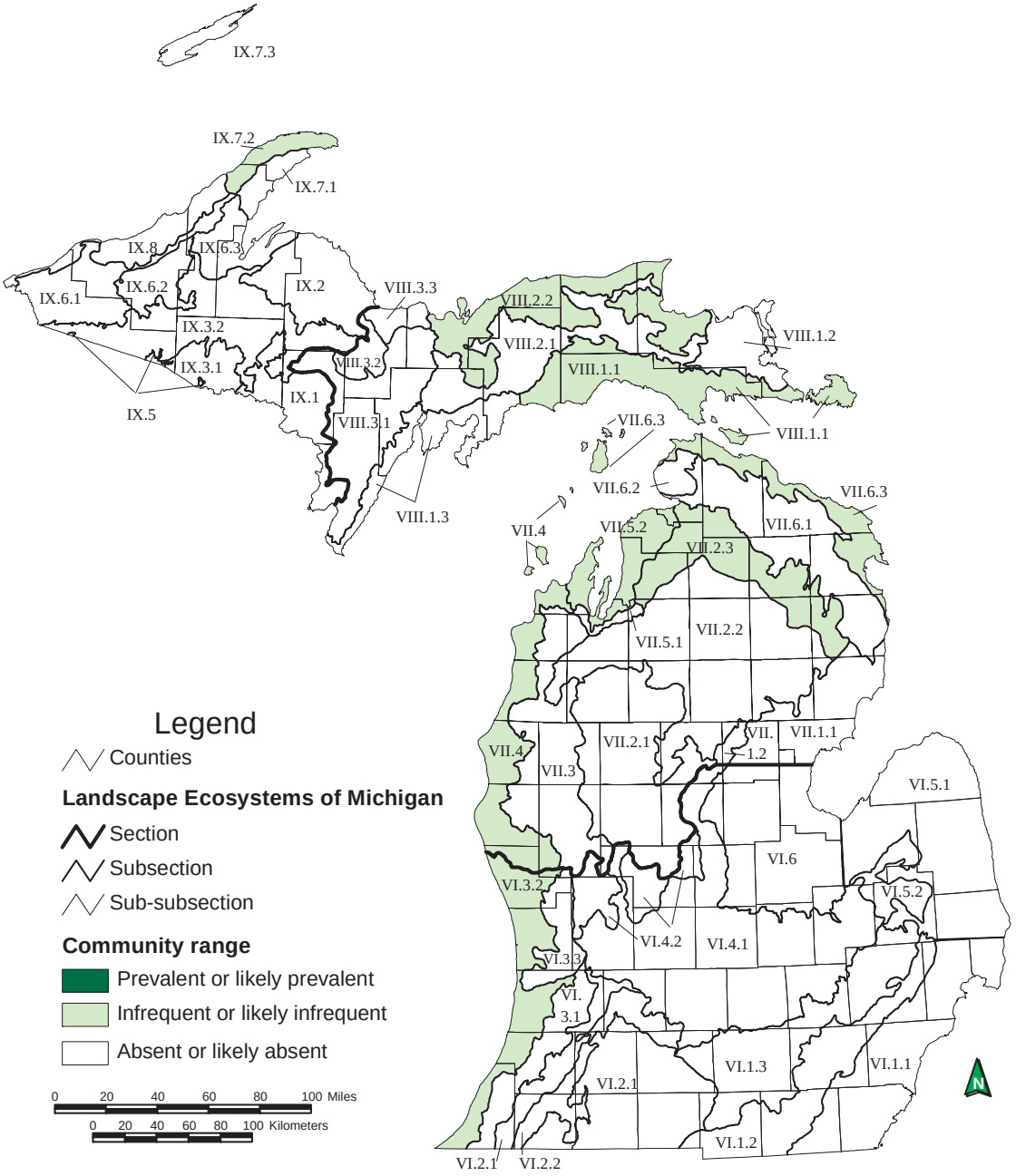
Nezewabegon Barrens Great Lakes barrens. Photo by Joshua G. Cohen.

Aerial photograph of Nezewabegon Barrens Great Lakes barrens.


Nezewabegon Barrens Great Lakes barrens. Photo by Joshua G. Cohen.

GREAT LAKES MARSH

Overview: Great Lakes marsh is an herbaceous wetland community occurring statewide along the shoreline of the Great Lakes and their major connecting rivers. Vegetational patterns are strongly influenced by water level fluctuations and type of coastal feature, but generally include the following: a deep marsh with submerged plants; an emergent marsh of mostly narrow-leaved species; and a sedge-dominated wet meadow that is inundated by storms. Great Lakes marsh provides important habitat for migrating and breeding waterfowl, shore-birds, spawning fish, and medium-sized mammals (Kost et al. 2007, Cohen et al. 2014).



Map 5. Distribution of Great Lakes marsh in Michigan (Albert et al. 2008).

8. Taganing Marsh
Natural Community Type: Great Lakes Marsh
Rank: G2 S3, globally imperiled and vulnerable within the state
Element Occurrence Rank: A
Size: 225 acres
Location: Garden Island
Element Occurrence Identification Number: 20450 (New EO)

Site Description: The Taganing Marsh is a Great Lakes marsh that occupies the outer margins of Jensen Harbor and Sturgeon Bay along Garden Island. Taganing Marsh is one of nine A-ranked Great Lakes marshes in the state. Inland from the Great Lakes marsh at Jensen Harbor is an extensive, high-quality coastal fen (Jensen Harbor, EO ID 7888). Inland from the Great Lakes marsh at Sturgeon Bay is a small wooded dune and swale complex (Taganing Dune and Swale, EO ID 20451). In both locations, Great Lakes marsh grades to coastal fen and limestone cobble shore locally and the margin between these communities shifts from year to year with fluctuations of the Great Lakes. Further inland the shoreline is backed by rich conifer swamp and boreal forest.

This extensive marsh has variable dominance patterns. Prevalent zones within the Great Lakes marsh include an emergent zone and a sand and gravel flat. The Great Lakes marsh is dominated by emergent graminoid vegetation with Baltic rush (*Juncus balticus*), threesquare (*Schoenoplectus pungens*), and twig-rush (*Cladium mariscoides*). Additional species include blue-joint (*Calamagrostis canadensis*), spike-rush (*Eleocharis rostellata*), beak-rush (*Rhynchospora capillacea*), Indian paintbrush (*Castilleja coccinea*), reed (*Phragmites australis*, native), three-way sedge (*Dulichium arundinaceum*), Ohio goldenrod (*Solidago ohioensis*), fringed gentian (*Gentianopsis crinita*), false asphodel (*Triantha glutinosa*), grass-of-Parnassus (*Parnassia glauca*), horned bladderwort (*Utricularia cornuta*), and Kalm's lobelia (*Lobelia kalmii*). Beak-rush is locally dominant in the sand and gravel flats. The transitional margin between Great Lakes marsh and coastal fen and sand and cobble spits that protrude into areas of marsh support scattered shrubs and trees and include northern white-cedar (*Thuja occidentalis*), balsam poplar (*Populus balsamifera*), tamarack (*Larix laricina*), paper birch (*Betula papyrifera*), willows (*Salix* spp.), red-osier dogwood (*Cornus sericea*), and shrubby cinquefoil (*Dasiphora fruticosa*).

Threats: Species composition and zonation are patterned by natural processes. No threats were observed during the survey.

Management Recommendations: The primary management recommendations are to allow natural processes to operate unhindered, maintain a natural community buffer surrounding the shoreline, and monitor for invasive species.

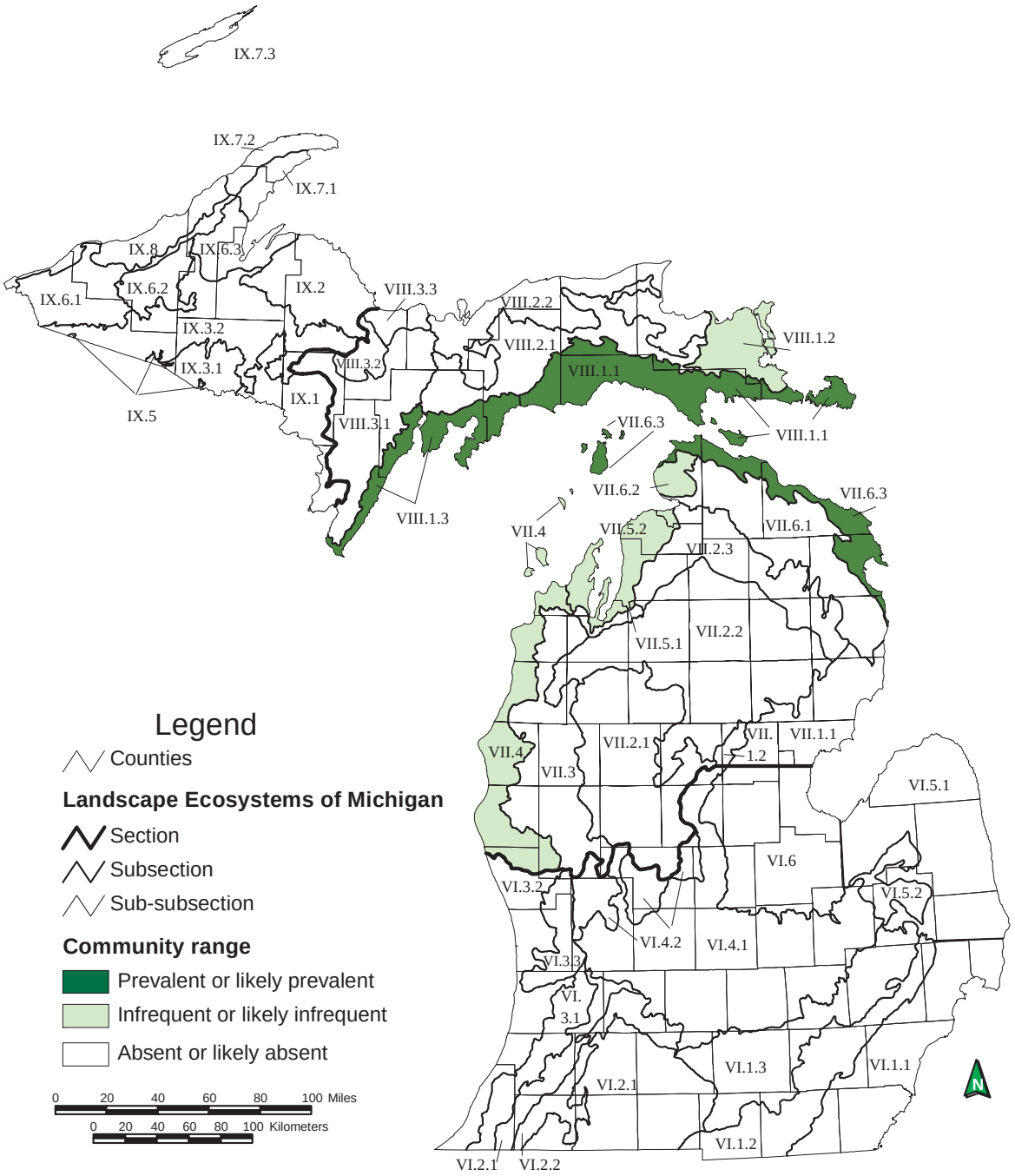
Taganing Marsh Great Lakes marsh. Photos by Joshua G. Cohen.

Aerial photograph of Taganing Marsh Great Lakes marsh.

Taganing Marsh Great Lakes marsh. Photo by Joshua G. Cohen.

LIMESTONE COBBLE SHORE

Overview: Limestone cobble shore occurs along gently sloping shorelines of Lake Michigan and Lake Huron. The community is studded with cobbles and boulders and is frequently inundated by storms and periods of high water. Limestone cobble shore is typically sparsely vegetated, because cobbles cover most of the surface and storm waves prevent the development of a diverse, persistent plant community. Soils are neutral to slightly alkaline mucks and sands that accumulate between cobbles and boulders (Kost et al. 2007, Cohen et al. 2014).



Map 6. Distribution of limestone cobble shore in Michigan (Albert et al. 2008).

9. High Island
Natural Community Type: Limestone Cobble Shore
Rank: G2G3 S3, imperiled to vulnerable globally and vulnerable within the state
Element Occurrence Rank: AB
Size: 214 acres
Location: High Island
Element Occurrence Identification Number: 6527 (EO update)

Site Description: The High Island limestone cobble shore consists of two polygons occupying the southern and northwestern shoreline of High Island. Surveys in 2015 expanded the existing element occurrence. Limestone cobble shore is subject to seasonal fluctuations in Great Lakes water levels, short-term changes due to seiches and storm surges, and long-term, multi-year lake level fluctuations. Storm waves frequently disturb limestone cobble shore, reconfiguring the substrate and removing fine mineral sediments and organic soils. Long-term cyclic fluctuations of Great Lakes water levels significantly influence vegetation patterns of limestone cobble shore, with vegetation and organic soils becoming well established during low-water periods and reduced or eliminated during high-water periods. This limestone cobble shore was surveyed after two consecutive high water years. Many woody stems were submerged under water. The limestone cobble shore ranges from narrow (15-25ft) to wide (40-60ft). Along the lake margin of the limestone cobble shore, marsh plant debris and driftwood have accumulated. The driftwood along the shoreline provides important habitat for insects and herptiles and the plant debris provides organic matter for soil development. Rocks along this stretch of shoreline range from small cobble to large boulders. Inclusions of sand and gravel beach, low foredune, and Great Lakes marsh occur locally within the limestone cobble shore. Localized areas along the inland margin of the complex grade towards coastal fen with seepage from the upland and patchy accumulation of sphagnum moss. Where wind and wave action is the most prevalent, narrow and sloping cobble storm beaches have formed locally. The soils of the limestone cobble shore are characterized by gravelly, alkaline (pH 8.0) sands mixed with organics occurring between and beneath the limestone cobble.

Vegetation within the limestone cobble shore is sparse, occurring patchily between cobbles and concentrated along the upper margin of the shore. Characteristic ground cover species include silverweed (*Potentilla anserina*), grass-of-Parnassus (*Parnassia glauca*), Baltic rush (*Juncus balticus*), sedges (*Carex* spp.), wild strawberry (*Fragaria virginiana*), common bog arrow-grass (*Triglochin maritima*), Indian paintbrush (*Castilleja coccinea*), beak-rush (*Rhynchospora capillacea*), Ohio goldenrod (*Solidago ohioensis*), wormwood (*Artemisia campestris*), bird's-eye primrose (*Primula mistassinica*), blue-joint (*Calamagrostis canadensis*), yarrow (*Achillea millefolium*), twig-rush (*Cladium mariscoides*), and false asphodel (*Triantha glutinosa*). Non-natives are locally common along the shoreline and include Canada bluegrass (*Poa compressa*) and mossy stonecrop (*Sedum acre*). Pockets of Great Lakes marsh are characterized by one to two feet of standing water and local dominance by Baltic rush. The patchy but diverse low shrub layer of the limestone cobble shore supports Kalm's St. John's-wort (*Hypericum kalmianum*), red-osier dogwood (*Cornus sericea*), shrubby cinquefoil (*Dasiphora fruticosa*), bearberry (*Arctostaphylos uva-ursi*), northern white-cedar (*Thuja occidentalis*), white spruce (*Picea glauca*), trembling aspen (*Populus tremuloides*), sand cherry (*Prunus pumila*), soapberry

(*Shepherdia canadensis*), ninebark (*Physocarpus opulifolius*), and balsam fir (*Abies balsamea*). Scattered saplings occur along the margins of the limestone cobble shore and include northern white-cedar, balsam fir, balsam poplar (*Populus balsamifera*), paper birch (*Betula papyrifera*), tamarack (*Larix laricina*), and trembling aspen.

Threats: Species composition and structure are driven primarily by natural processes. Non-natives are locally common along the limestone cobble shore and include Canada bluegrass (*Poa compressa*) and mossy stonecrop (*Sedum acre*). Additional invasives found along the shoreline include narrow-leaved cat-tail (*Typha angustifolia*), reed (*Phragmites australis* subsp. *australis*), and white sweet-clover (*Melilotus albus*).

Management Recommendations: The primary management recommendations are to allow natural processes to operate unhindered and to eliminate clusters of non-native plants within the limestone cobble shore and nearby areas of shoreline. Control efforts should be followed by monitoring for these invasive species.

High Island limestone cobble shore. Photo by Joshua G. Cohen.

Aerial photograph of High Island limestone cobble shore.

High Island limestone cobble shore. Photo by Joshua G. Cohen.

10. Monatou Bay
Natural Community Type: Limestone Cobble Shore
Rank: G2G3 S3, imperiled to vulnerable globally and vulnerable within the state
Element Occurrence Rank: A
Size: 156 acres
Location: Garden Island
Element Occurrence Identification Number: 20448 (New EO)

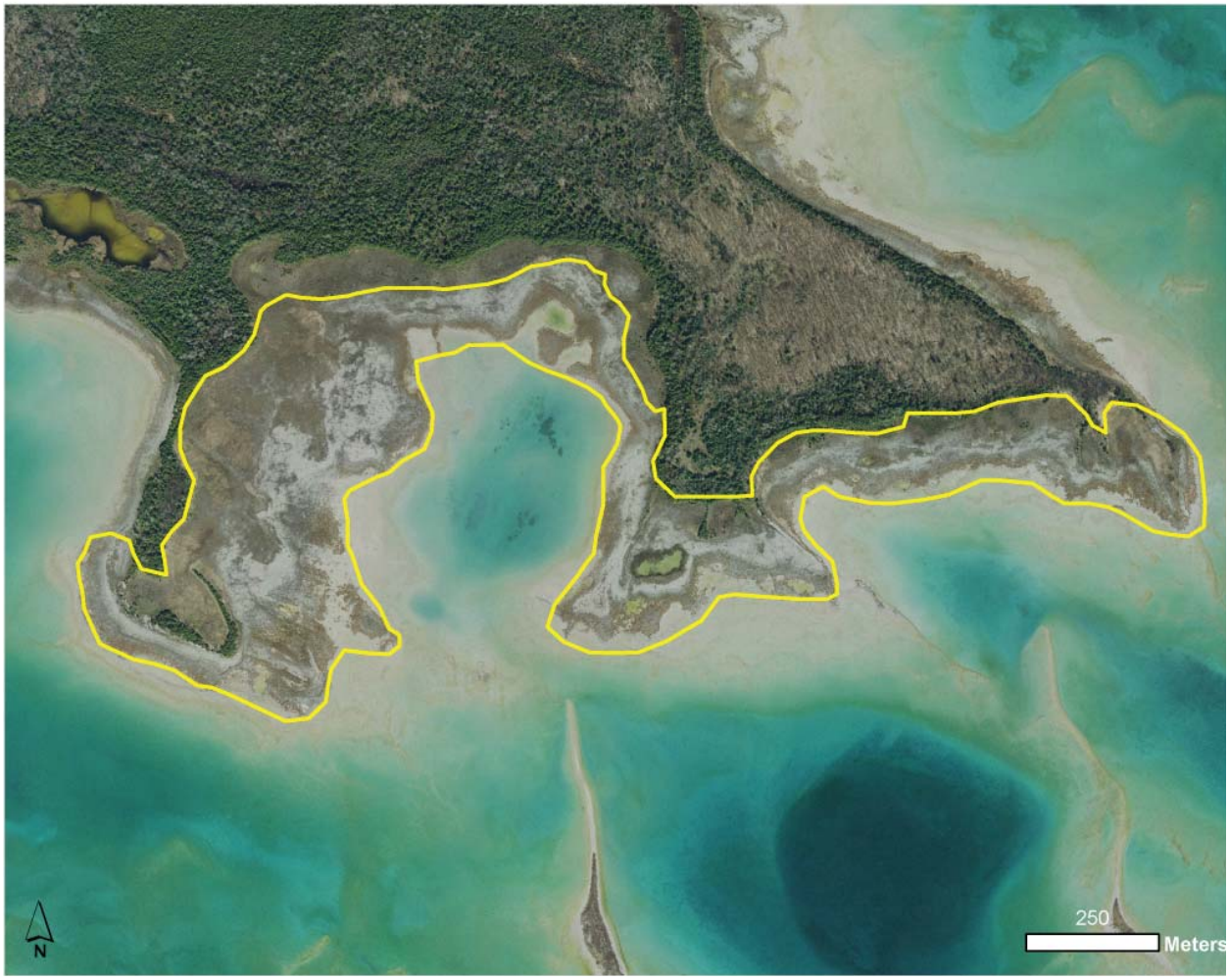
Site Description: The Monatou Bay limestone cobble shore occurs along Monatou Bay on Garden Island. Monatou Bay is the only A-ranked limestone cobble shore in the state. This limestone cobble shore grades to coastal fen inland and Great Lakes marsh lakeward. The margin between these communities shifts from year to year with fluctuations of the Great Lakes. Limestone cobble shore is subject to seasonal fluctuations in Great Lakes water levels, short-term changes due to seiches and storm surges, and long-term, multi-year lake level fluctuations. Storm waves frequently disturb limestone cobble shore, reconfiguring the substrate and removing fine mineral sediments and organic soils. Long-term cyclic fluctuations of Great Lakes water levels significantly influence vegetation patterns of limestone cobble shore, with vegetation and organic soils becoming well established during low-water periods and reduced or eliminated during high-water periods. This site was surveyed in 2015 after two consecutive high water years. Many woody stems were submerged under water during the survey. Along the lake margin of the limestone cobble shore, marsh plant debris and driftwood have accumulated. The driftwood along the shoreline provides important habitat for insects and herptiles and the plant debris provides organic matter for soil development. Rocks along this stretch of shoreline range from small cobble to large boulders. Inclusions of coastal fen and Great Lakes marsh occur locally within the limestone cobble shore. Pockets of Great Lakes marsh are characterized by one to two feet of standing water and local dominance by Baltic rush (*Juncus balticus*) and bulrushes spp. (*Schoenoplectus* spp.). Several cobble spits occur within the site. Soils within the marsh are characterized by wet, gravelly, alkaline (pH 8.0) sands mixed with organics occurring between and beneath limestone cobble.

Vegetation within the limestone cobble shore is sparse, occurring patchily between cobbles and concentrated along the upper margin of the shore. Characteristic ground cover species include Baltic rush, Ohio goldenrod (*Solidago ohioensis*), blue-joint (*Calamagrostis canadensis*), limestone calamint (*Clinopodium arkansanum*), mountain blue-eyed-grass (*Sisyrinchium montanum*), and panic grass (*Dicanthelium lindheimeri*). The patchy, low shrub layer supports Kalm's St. John's-wort (*Hypericum kalmianum*), shrubby cinquefoil (*Dasiphora fruticosa*), and northern white-cedar (*Thuja occidentalis*).
Scattered trees and shrubs occur along the margins of the limestone cobble shore and include northern white-cedar, willows (*Salix* spp.), and paper birch (*Betula papyrifera*).

Threats: Species composition and structure are driven by natural processes. No threats were observed during the course of the survey.

Management Recommendations: The primary management recommendations are to allow natural processes to operate unhindered and to monitor for invasive species.

Monatou Bay limestone cobble shore. Photos by Joshua G. Cohen.



Aerial photograph of Monatou Bay limestone cobble shore.

Monatou Bay limestone cobble shore. Photo by Joshua G. Cohen.

11. Taganing Shore
Natural Community Type: Limestone Cobble Shore
Rank: G2G3 S3, imperiled to vulnerable globally and vulnerable within the state
Element Occurrence Rank: B
Size: 117 acres
Location: Garden Island
Element Occurrence Identification Number: 20449 (New EO)

Site Description: The Taganing Shore limestone cobble shore occurs along the western shore of Garden Island and includes shoreline associated with Ninneegoes Bay, Bamways Bay, and Graham's Point. Limestone cobble shore locally grades to coastal fen inland and Great Lakes marsh lakeward. The margin between these communities shifts from year to year with fluctuations of the Great Lakes. Limestone cobble shore is subject to seasonal fluctuations in Great Lakes water levels, short-term changes due to seiches and storm surges, and long-term, multi-year lake level fluctuations. Storm waves frequently disturb limestone cobble shore, reconfiguring the substrate and removing fine mineral sediments and organic soils. Long-term cyclic fluctuations of Great Lakes water levels significantly influence vegetation patterns of limestone cobble shore, with vegetation and organic soils becoming well established during low-water periods and reduced or eliminated during high-water periods. This site was surveyed in 2015 after two consecutive high water years and surveyors observed many woody stems submerged under water. Along the lake margin of the limestone cobble shore, marsh plant debris and driftwood have accumulated. The driftwood along the shoreline provides important habitat for insects and herptiles and the plant debris provides organic matter for soil development. Rocks along this stretch of shoreline range from small cobble to large boulders. Inclusions of coastal fen and Great Lakes marsh occur locally within the limestone cobble shore. Inclusions of Great Lakes marsh and coastal fen are most prevalent in Bamways Bay and Ninneegoes Bay. Several cobble spits occur within the site. The soils of the limestone cobble shore are characterized by wet, gravelly, alkaline (pH 8.0) sands mixed with organics occurring between and beneath limestone cobble.

The vegetation within the limestone cobble shore is sparse, occurring patchily between cobbles and concentrated along the upper margin of the shore. Characteristic ground cover species include Baltic rush (*Juncus balticus*), limestone calamint (*Clinopodium arkansanum*), Indian paintbrush (*Castilleja coccinea*), bastard-toadflax (*Comandra umbellata*), sedges (*Carex* spp.), and wild columbine (*Aquilegia canadensis*). Non-native species are common to locally abundant and include Canada bluegrass (*Poa compressa*), mossy stonecrop (*Sedum acre*), spotted knapweed (*Centaurea stoebe*), and red clover (*Trifolium pratense*). The patchy but diverse low shrub layer is characterized by Kalm's St. John's-wort (*Hypericum kalmianum*), red-osier dogwood (*Cornus sericea*), shrubby cinquefoil (*Dasiphora fruticosa*), northern white-cedar (*Thuja occidentalis*), white spruce (*Picea glauca*), sand cherry (*Prunus pumila*), soapberry (*Shepherdia canadensis*), balsam poplar (*Populus balsamifera*), paper birch (*Betula papyrifera*), and willows (*Salix* spp.). Scattered saplings occur along the margins of the limestone cobble shore and include northern white-cedar, balsam poplar, paper birch, and tamarack (*Larix laricina*).

Threats: Species composition and structure are driven primarily by natural processes. Non-native species are common to locally abundant and include Canada bluegrass (*Poa compressa*), spotted knapweed (*Centaurea stoebe*), mossy stonecrop (*Sedum acre*), and red clover (*Trifolium pratense*).

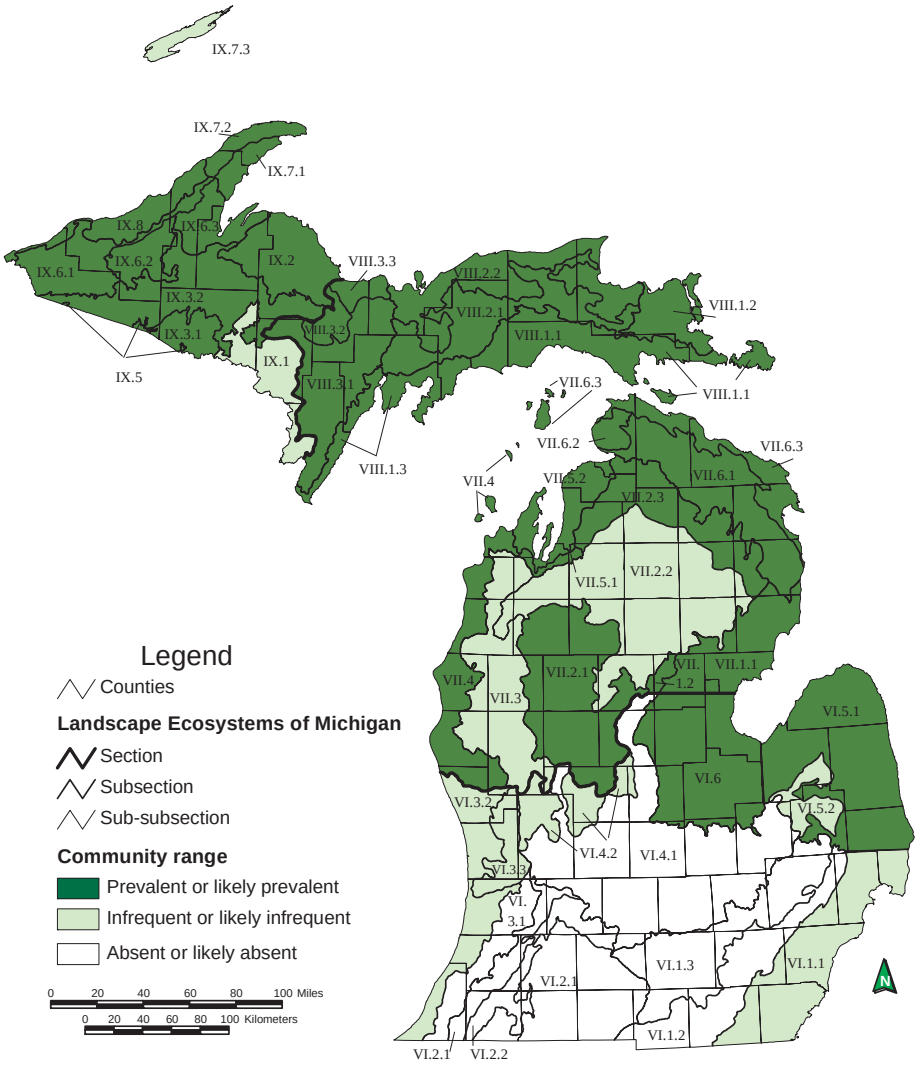
Management Recommendations: The primary management recommendations are to allow natural processes to operate unhindered and to eliminate clusters of non-native plants within the limestone cobble shore and nearby areas of shoreline. Control efforts should be followed by monitoring for these invasive species.

Taganing Shore limestone cobble shore. Photo by Joshua G. Cohen.

Aerial photograph of Taganing Shore limestone cobble shore.

MESIC NORTHERN FOREST

Overview: Mesic northern forest is a forest type of moist to dry-mesic sites lying mostly north of the climatic tension zone, characterized by the dominance of northern hardwoods, particularly sugar maple (*Acer saccharum*) and American beech (*Fagus grandifolia*). Conifers such as hemlock (*Tsuga canadensis*) and white pine (*Pinus strobus*) are frequently important canopy associates. This community type breaks into two broad classes: northern hardwood forest and hemlock-hardwood forest. It is primarily found on coarse-textured ground and end moraines, and soils are typically loamy sand to sandy loam. The natural disturbance regime is characterized by gap-phase dynamics; frequent, small windthrow gaps allow for the regeneration of the shade-tolerant canopy species. Catastrophic windthrow occurs infrequently with several generations of trees passing between large-scale, severe disturbance events. Historically, mesic northern forest occurred as a matrix system, dominating vast areas of mesic uplands in the Great Lakes region. These forests were multi-generational, with old-growth conditions lasting many centuries (Kost et al. 2007, Cohen et al. 2014).



Map 7. Distribution of mesic northern forest in Michigan (Albert et al. 2008).

12. Nezewabegon Forest
Natural Community Type: Mesic Northern Forest
Rank: G4 S3, apparently secure globally and vulnerable within the state
Element Occurrence Rank: AB
Size: 456 acres
Location: High Island
Element Occurrence Identification Number: 20452 (New EO)

Site Description: The Nezewabegon Forest is a mesic northern forest that occurs in the northwestern portion of High Island on undulating to rugged topography of former dune shoreline. Due to the proximity of this forest to Lake Michigan, the climate is moderated and there is lots of windthrow throughout the forest. This large block of mesic northern forest ranges from mature to old-growth, and throughout the forest species composition and vegetative structure are patterned by natural processes. A 98.5 cm red oak (*Quercus rubra*) was cored and 230 growth rings were counted on the two-thirds of the core that was extracted. This tree and many of the canopy dominants within this uneven-aged system are likely at least 250 years old and likely over 300 years old. In addition, a 73.6 cm hemlock (*Tsuga canadensis*) was cored and estimated to be over 300 years old (100 growth rings were counted on the partial core). This block of forest is starting to accrue many attributes of an old-growth forest including a canopy dominated by large diameter trees (60-100 cm), coarse woody debris and snags represented by large diameter trees of diverse size classes and species, and pit and mound topography. Pit and mound topography is most pronounced in the areas with flat to gently rolling topography. Numerous ravines and steep dune slopes occur throughout the forest. Interestingly a 5 cm understory yew (*Taxus canadensis*) was cored and estimated to be over 70 years old. Where yew is an overwhelming dominant in the understory, it is likely impacting species diversity and regeneration through competition for light resources. Soils within the mesic northern forest are characterized by a typically shallow (5-15 cm) A horizon with acidic loamy sands (pH 5.0-5.5) over medium-textured acidic sand and loamy sand (pH 5.0-5.5).

The overstory ranges from 75% to 100% and the canopy is dominated by sugar maple (*Acer saccharum*) with canopy associates including yellow birch (*Betula alleghaniensis*), hemlock, red oak, and northern white-cedar (*Thuja occidentalis*), which is concentrated closer to the shore. Canopy trees typically range in DBH from 60 to 100 cm. Scattered subcanopy trees include sugar maple, northern white-cedar, and American mountain-ash (*Sorbus americana*). The understory ranges from 10% to 20% and characteristic species include sugar maple, round-leaved dogwood (*Cornus rugosa*), mountain maple (*Acer spicatum*), red elderberry (*Sambucus racemosa*), beaked hazelnut (*Corylus cornuta*), American mountain-ash, choke cherry (*Prunus virginiana*), and yew (*Taxus canadensis*). The low shrub layer ranges from sparse (15-30%) to dense (80-90%) with yew locally dominant. Additional species in the low shrub layer include mountain maple, sugar maple, and beaked hazelnut. The ground cover is most developed where yew is less prevalent. Characteristic ground cover species include Canada mayflower (*Maianthemum canadense*), wild sarsaparilla (*Aralia nudicaulis*), woodferns (*Dryopteris* spp.), sedges (*Carex* spp.), blue-bead lily (*Clintonia borealis*), yellow violet (*Viola pubescens*), blue cohosh (*Caulophyllum thalictroides*), common trillium (*Trillium grandiflorum*), false spikenard (*Maianthemum racemosum*), downy Solomon seal (*Polygonatum pubescens*), partridge berry

(*Mitchella repens*), wild leek (*Allium tricoccum*), jack-in-the-pulipt (*Arisaema triphyllum*), large-flowered bellwort (*Uvularia grandiflora*), bedstraw (*Galium triflorum*), oak fern (*Gymnocarpium dryopteris*), purple meadow-rue (*Thalictrum dasycarpum*), cow-parsnip (*Heracleum maximum*), bloodroot (*Sanguinaria canadensis*), round-lobed hepatica (*Hepatica americana*), rose twisted-stalk (*Streptopus lanceolatus*), and white baneberry (*Actaea pachypoda*). Diverse mosses are prevalent on the boles of the old-growth trees.

The absence of deer on High Island provide a unique research opportunity to study the floristic composition of forested ecosystems that have not been impacted by high deer browse pressure.

Threats: Species composition and vegetative structure are patterned by natural processes. No threats were observed during the course of the survey.

Management Recommendations: The main management recommendations are to allow natural processes to operate unhindered, retain an intact buffer of natural communities surrounding the mesic northern forest, and monitor for invasive species.

Nezewabegon mesic northern forest. Photo by Joshua G. Cohen.

Aerial photograph of Nezewabegon mesic northern forest.

Nezewabegon mesic northern forest. Photo by Joshua G. Cohen.

13. Red Oak Garden
Natural Community Type: Mesic Northern Forest
Rank: G4 S3, apparently secure globally and vulnerable within the state
Element Occurrence Rank: C
Size: 81 acres
Location: Garden Island
Element Occurrence Identification Number: 10496 (EO Update)

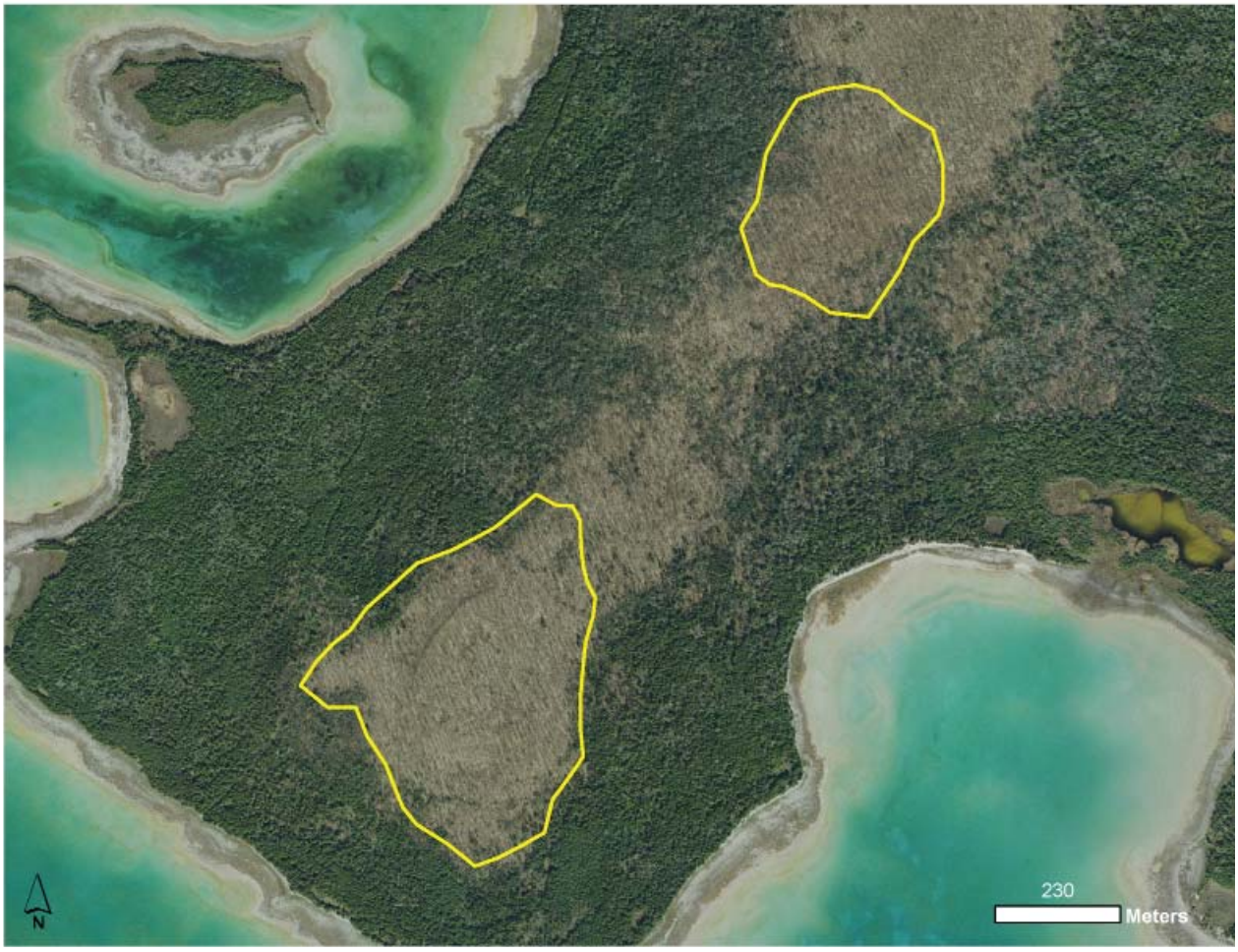
Site Description: The Red Oak Garden mesic northern forest consists of two polygons of uneven-aged forest occurring on rolling topography in the southern portion of Garden Island. Surveys in 2015 significantly expanded the element occurrence. The mesic northern forest is characterized by pit and mound topography and is starting to accrue older and larger coarse woody debris. A 52.5 cm white ash (*Fraxinus americana*) was cored in the southern polygon and estimated to be over 137 years old. A 72.7 cm red oak (*Quercus rubra*) was cored in the northern polygon and estimated to be over 155 years old. The soils in the southern polygon are characterized by shallow (5-10 cm), alkaline (pH 7.5) loams overlying limestone cobble. The soils in the northern polygon are characterized by deeper sands (50-60cm) overlying cobble. The A horizon (10-30 cm) of organics mixed with sands (pH 4.5-5.0) overlies medium-textured, acidic, sands (pH 5.5-6.0).

The canopy of the Red Oak Garden mesic northern forest is dominated by sugar maple (*Acer saccharum*) with canopy associates including red oak, yellow birch (*Betula alleghaniensis*), white ash, and paper birch (*Betula papyrifera*). Canopy trees typically range in DBH from 40 to 60 cm with larger red oak (60-80cm) occurring in the northern oak-dominated polygon. Canopy closure ranges from 75% to 95%. The subcanopy is scattered with sugar maple, ironwood (*Ostrya virginiana*), and yellow birch. The understory is characterized by sugar maple, ironwood, striped maple (*Acer pensylvanicum*), white ash, round-leaved dogwood (*Cornus rugosa*), red elderberry (*Sambucus racemosa*), and beaked hazelnut (*Corylus cornuta*). Prevalent species in the low shrub layer include Canadian fly honeysuckle (*Lonicera canadensis*), balsam fir (*Abies balsamea*), wild red raspberry (*Rubus strigosus*), ironwood, and red oak. Characteristic ground cover species include blue cohosh (*Caulophyllum thalictroides*), false spikenard (*Maianthemum racemosum*), downy Solomon seal (*Polygonatum pubescens*), jack-in-the-pulipt (*Arisaema triphyllum*), bedstraw (*Galium triflorum*), oak fern (*Gymnocarpium dryopteris*), purple meadow-rue (*Thalictrum dasycarpum*), cow-parsnip (*Heracleum maximum*), round-lobed hepatica (*Hepatica americana*), hairy sweet cicely (*Osmorhiza claytonii*), large-leaved aster (*Eurybia macrophylla*), zigzag goldenrod (*Solidago flexicaulis*), and white baneberry (*Actaea pachypoda*).

Threats: Species composition and vegetative structure are patterned by natural processes and past logging history (cut stumps occur within the forest). A trail passes through the northern portion of the occurrence.

Management Recommendations: The main management recommendations are to allow natural processes to operate unhindered, retain an intact buffer of natural communities surrounding the mesic northern forest, and monitor for invasive species.

Red Oak Garden mesic northern forest. Photos by Joshua G. Cohen.

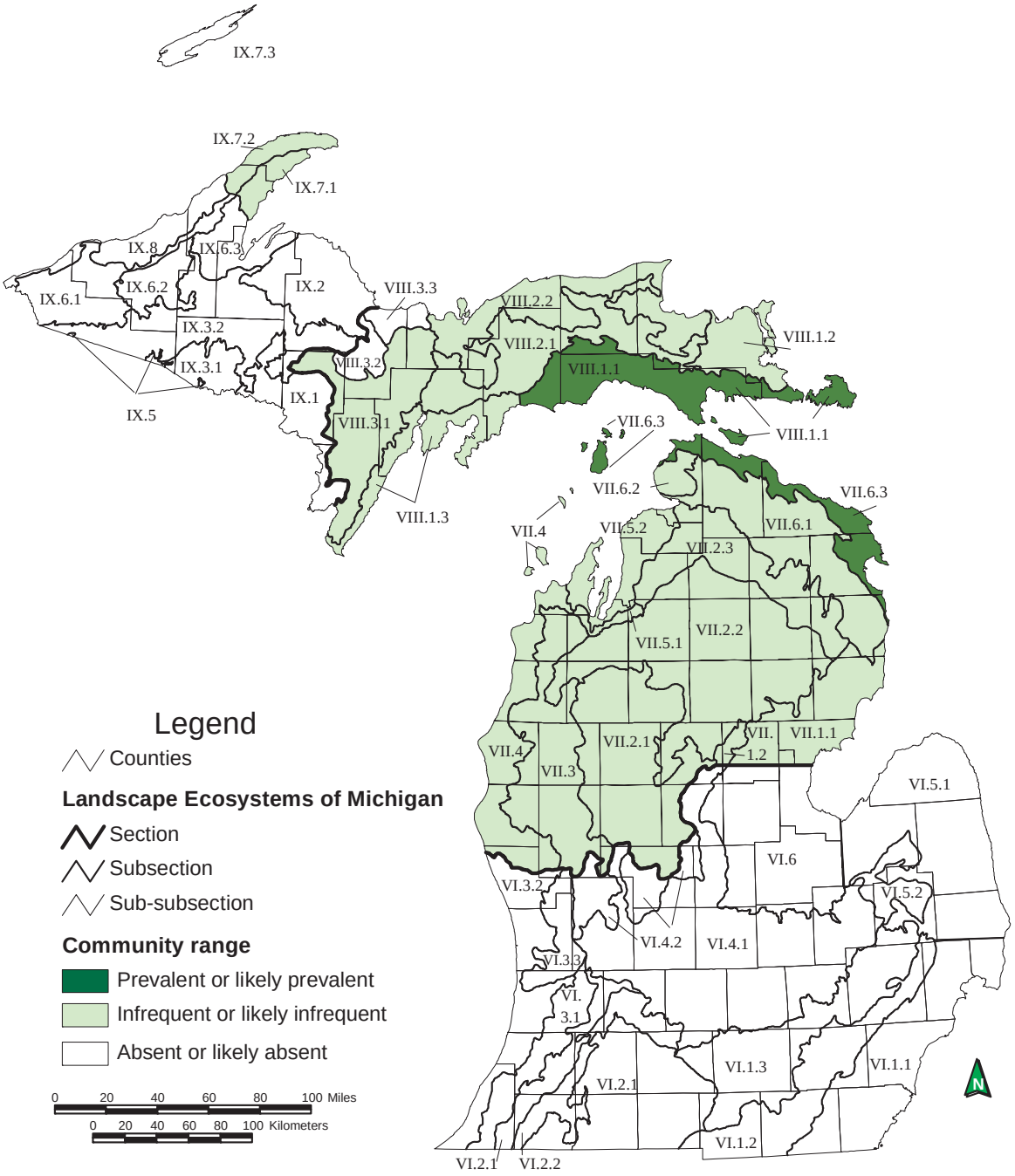


Aerial photograph of Red Oak Garden mesic northern forest.

Red Oak Garden mesic northern forest. Photo by Joshua G. Cohen.

OPEN DUNES

Overview: Open dunes is a grass- and shrub-dominated multi-seral community located on wind-deposited sand formations near the shorelines of the Great Lakes. Dune formation and the patterning of vegetation are strongly affected by lake-driven winds. The greatest concentration of open dunes occurs along the eastern and northern shorelines of Lake Michigan, with the largest dunes occurring along the eastern shoreline due to the prevailing southwest winds (Kost et al. 2007, Cohen et al. 2014).



Map 8. Distribution of open dunes in Michigan (Albert et al. 2008).

14. High Island
Natural Community Type: Open Dunes
Rank: G3 S3, vulnerable throughout range
Element Occurrence Rank: A
Size: 142 acres
Location: High Island
Element Occurrence Identification Number: 10698 (EO update)

Site Description: The High Island open dunes consists of two miles of pristine open dunes extending along the western side of High Island adjacent to the Lake Michigan shoreline. The High Island dunes is one of four A-ranked open dunes in the state. This site is an extensive parabolic dune complex with a low foredune, a broad flat dune field, and four fingers of rolling to rugged high dunes with blowouts occurring locally. In addition, a narrow band of Great Lakes barrens occurs within the southern portion of the dunes. Old northern white-cedar (*Thuja occidentalis*) snags occur along the margins of some of the blowouts demonstrating the dynamic nature of these dunes: over hundreds of years, the open dunes have encroached on former forested dunes. An 18 cm red pine (*Pinus resinosa*) was cored and estimated to be over 25 years old. Tens of thousands of Pitcher's thistle (*Cirsium pitcheri*, state and federally threatened) occur throughout the dunes. In addition, Lake Huron locust (*Trimerotropis huroniana*) also occurs throughout the dunes. The soils of the open dunes are fine-textured, wind-blown and wave-worked, alkaline (pH 8.0) dune sands.

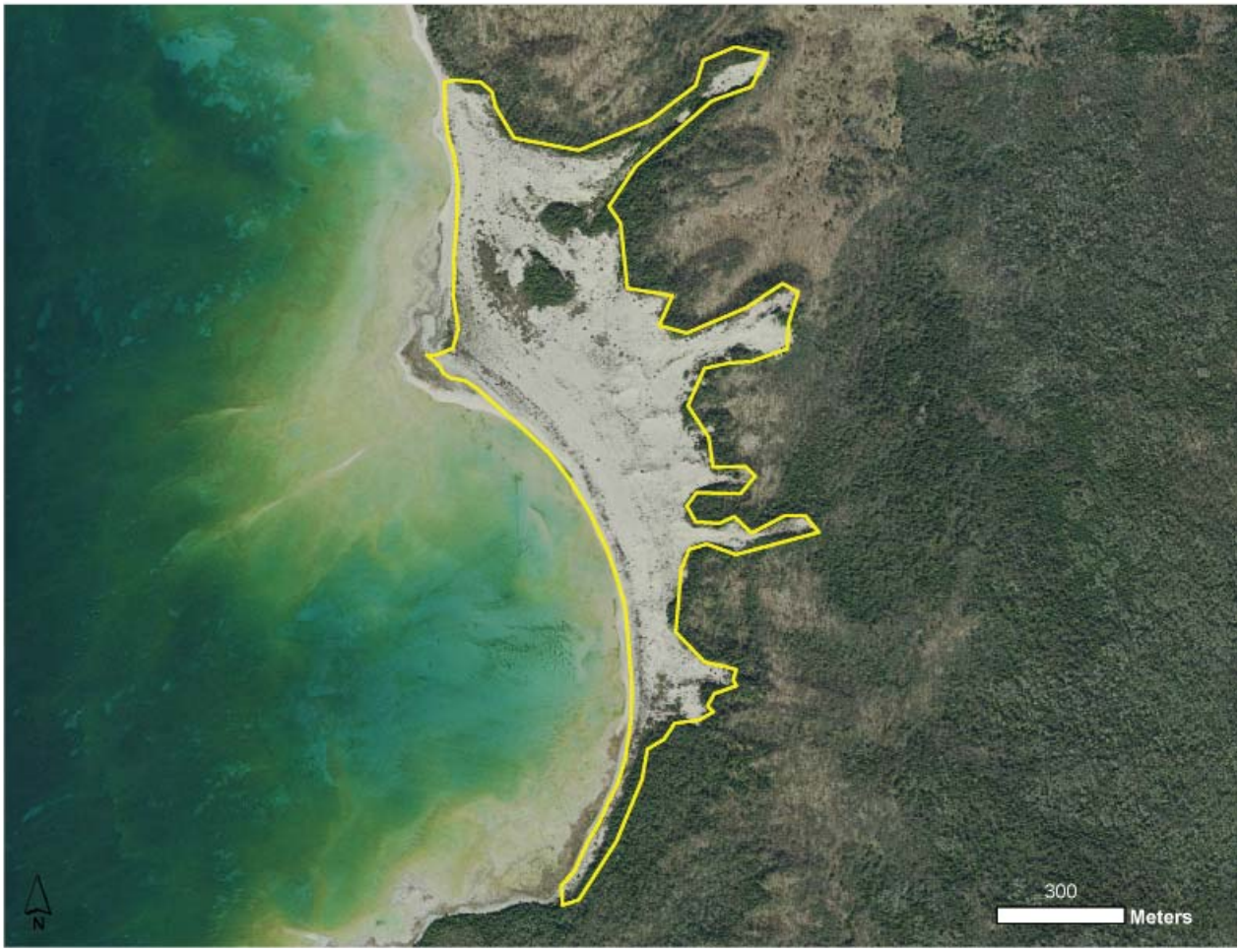
The low foredune is dominated by marram grass (*Ammophila breviligulata*) with ground cover associates including wormwood (*Artemisia campestris*), pitcher's thistle, wheat grass (*Elymus lanceolatus*), beach pea (*Lathyrus japonicus*), Gillman's goldenrod (*Solidago simplex*), and common evening-primrose (*Oenothera biennis*). Prevalent shrubs and trees in the low foredune include balsam poplar (*Populus balsamifera*), willows (*Salix* spp.), sand cherry (*Prunus pumila*), and red-osier dogwood (*Cornus sericea*). The broad flat dune field has 10% to 15% ground cover with sand reed grass (*Calamovilfa longifolia*), little bluestem (*Schizachyrium scoparium*), white camas (*Anticlea elegans*), and wormwood. Prevalent low shrubs include bearberry (*Arctostaphylos uva-ursi*), shrubby cinquefoil (*Dasiphora fruticosa*), common juniper (*Juniperus communis*), sand cherry, and balsam poplar. The scattered understory contains paper birch (*Betula papyrifera*), balsam poplar, and northern white-cedar. Areas of high parabolic dunes are characterized by sand reed grass, wormwood, white camas, little bluestem, Gillman's goldenrod, plains puccoon (*Lithospermum caroliniense*), starry false Solomon-seal (*Maianthemum stellatum*), common milkweed (*Asclepias syriaca*), harebell (*Campanula rotundifolia*), yarrow (*Achillea millefolium*), and Pitcher's thistle. Common low shrubs include common juniper, bearberry, and sand cherry. The scattered understory contains balsam poplar, blueleaf willow (*Salix myricoides*), and northern white-cedar. Overstory northern white-cedar and paper birch occur infrequently. The backside of the high dunes supports thickets of red-osier dogwood and climbing bittersweet (*Celastrus scandens*) winding on the dogwoods. A narrow band of Great Lakes barrens occurs in the southern portion of the dune complex. Canopy coverage here ranges from 2% to 5% and canopy trees include white pine (*Pinus strobus*) and white spruce (*Picea glauca*). Common understory species include white pine, white spruce, and red-osier dogwood. The low shrub layer is dense (80-90%) and dominated by common juniper, creeping

juniper (*Juniperus horizontalis*), bearberry, and sand cherry. Characteristic ground cover species include white camas, starry false Solomon-seal, sand reed grass, and poison ivy (*Toxicodendron radicans*).

Threats: Species composition and structure are driven by natural processes. Invasives found along the shoreline nearby include mossy stonecrop (*Sedum acre*), narrow-leaved cat-tail (*Typha angustifolia*), reed (*Phragmites australis* subsp. *australis*), and white sweet-clover (*Melilotus albus*).

Management Recommendations: The primary management recommendations are to allow natural processes to operate unhindered, to control invasive species along the adjacent shoreline, and monitor for invasive species.

High Island open dunes. Photo by Joshua G. Cohen.

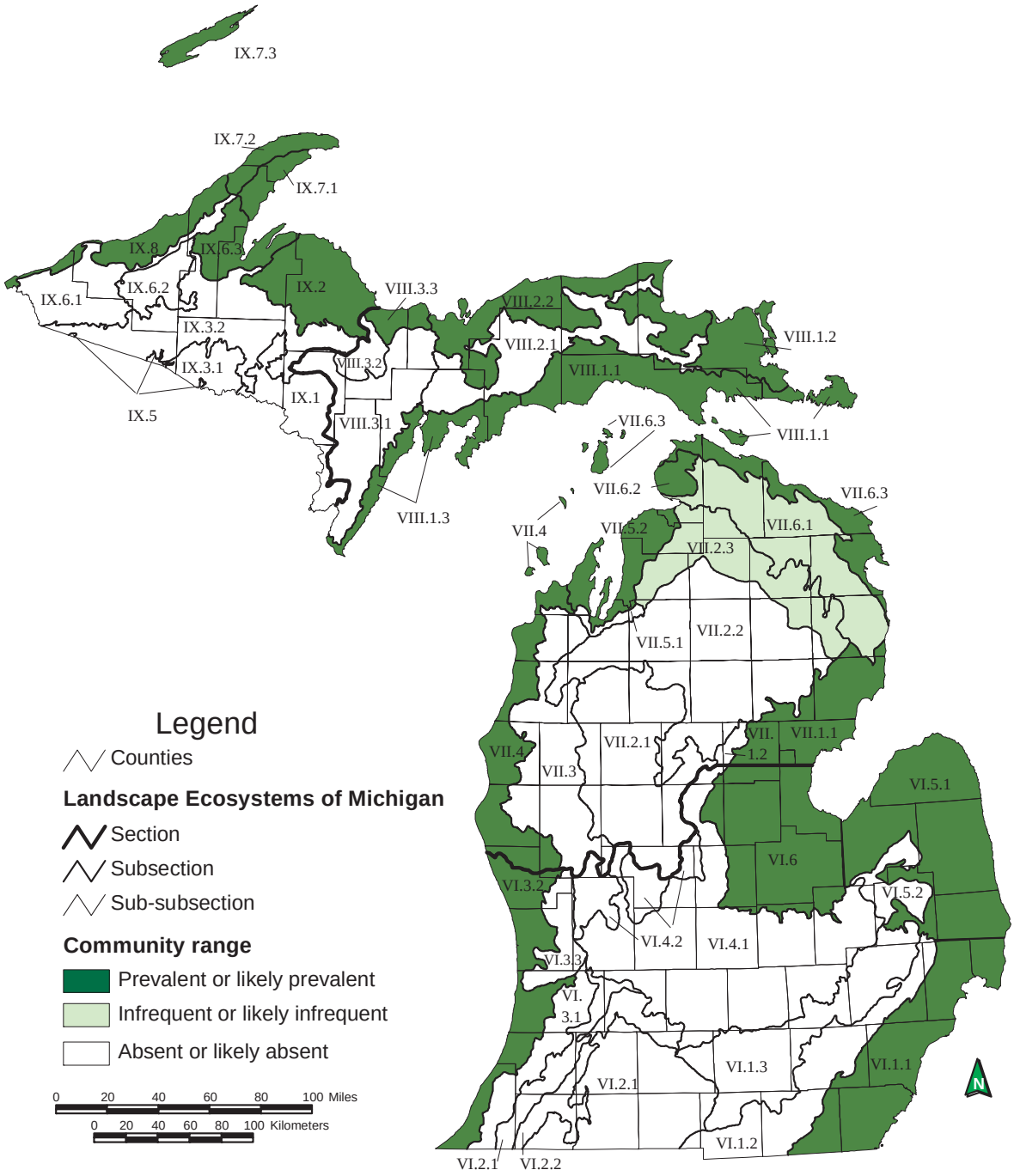


Aerial photograph of High Island open dunes.

High Island open dunes. Photo by Joshua G. Cohen.

SAND AND GRAVEL BEACH

Overview: Sand and gravel beaches occur along the shorelines of the Great Lakes and on some of Michigan's larger freshwater lakes, where wind, waves, and winter ice cause the shoreline to be too unstable to support aquatic vegetation. Because of the high levels of disturbance, these beaches are typically quite open, with sand and gravel sediments and little or no vegetation (Kost et al. 2007, Cohen et al. 2014).



Map 9. Distribution of sand and gravel beach in Michigan (Albert et al. 2008).

15. High Island
Natural Community Type: Sand and Gravel Beach
Rank: G3? S3, vulnerable throughout range
Element Occurrence Rank: A
Size: 15 acres
Location: High Island
Element Occurrence Identification Number: 13026 (EO update)

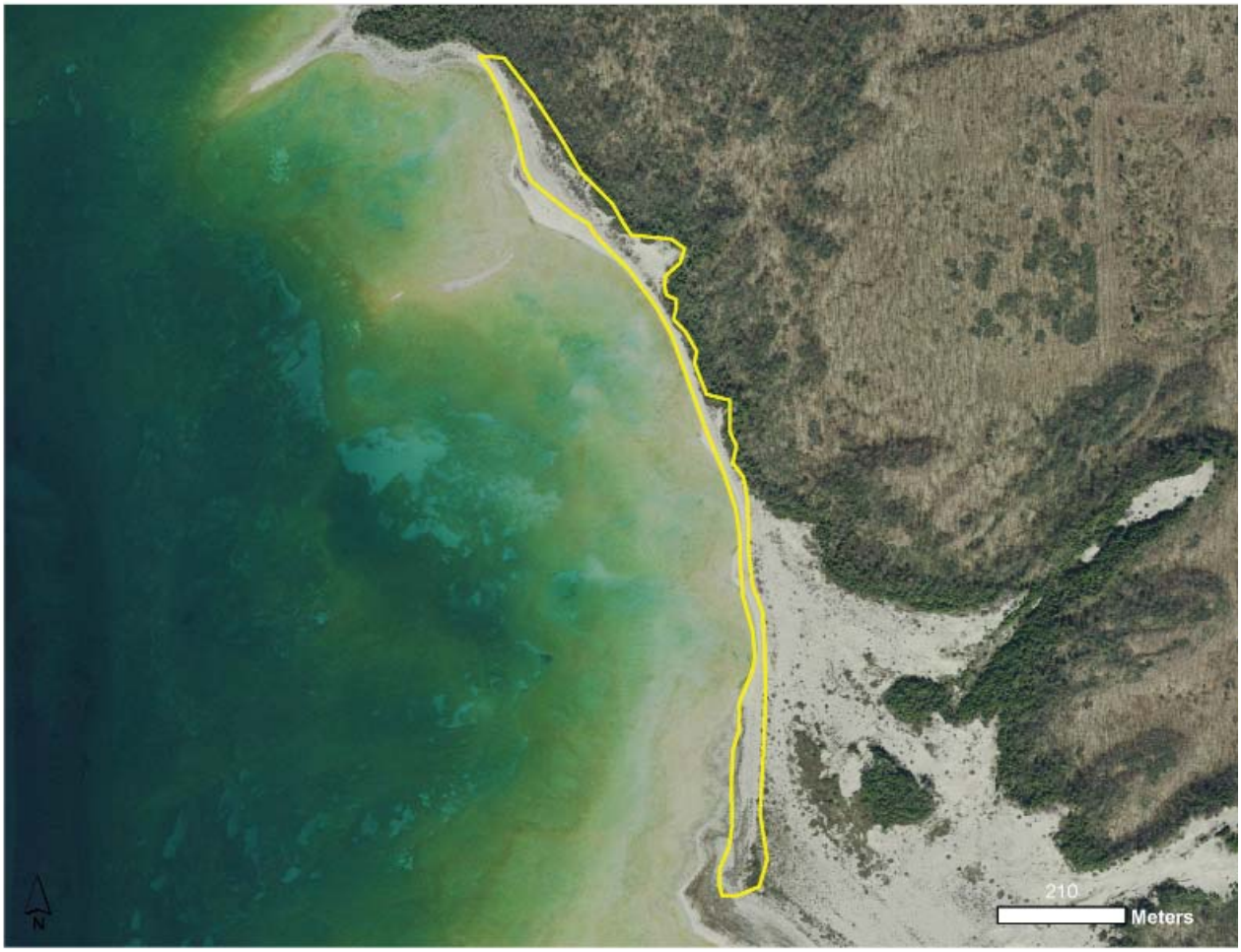
Site Description: The High Island sand and gravel beach occurs along a mile stretch of Lake Michigan shoreline along the northwestern shore of High Island. This stretch of sand and gravel beach is backed by low foredune, which is backed by Great Lakes barrens, dry-mesic northern forest, and boreal forest. Species composition and community structure are patterned by natural processes. This sand and gravel beach occurs along the Great Lakes shoreline of Lake Michigan, where wind, waves, and winter ice cause the shoreline to be too unstable to support aquatic vegetation. Because of the high levels of disturbance, this beach is typically quite open, with sand and gravel sediments and little or no vegetation. Energy from waves and ice abrasion maintain an open beach. The beach is characterized by a mixture of alkaline sands, gravel, and cobble.

This sand and gravel beach is characterized by both a low diversity of plant species and low levels of plant cover. A wide variety of plants can develop at the inland margin of sand and gravel beaches, but few establish and persist on the active beach, where there is often intense wind and wave action, resulting in almost constantly moving sand. Species noted along the margin of the sand and gravel beach and along the low foredune include marram grass (*Ammophila breviligulata*), wheat grass (*Elymus lanceolatus*), plains puccoon (*Lithospermum caroliniense*), wormwood (*Artemisia campestris*), poison ivy (*Toxicodendron radicans*), common milkweed (*Asclepias syriaca*), Pitcher's thistle (*Cirsium pitcheri*, state and federally threatened), and red-osier dogwood (*Cornus sericea*). Mossy stonecrop (*Sedum acre*) is locally common within the sand and gravel beach.

Threats: Species composition and structure are driven by natural processes. Mossy stonecrop (*Sedum acre*) is locally common within the sand and gravel beach. Additional invasives found along the shoreline include Canada bluegrass (*Poa compressa*), spotted knapweed (*Centaurea stoebe*), narrow-leaved cat-tail (*Typha angustifolia*), reed (*Phragmites australis* subsp. *australis*), and white sweet-clover (*Melilotus albus*).

Management Recommendations: The primary management recommendations are to allow natural processes to operate unhindered, eliminate clusters of non-native plants along the shoreline, and monitor for invasives.

High Island sand and gravel beach. Photos by Joshua G. Cohen.



Aerial photograph of High Island sand and gravel beach.

16 High Island Bay
Natural Community Type: Sand and Gravel Beach
Rank: G3? S3, vulnerable throughout range
Element Occurrence Rank: A
Size: 28 acres
Location: High Island
Element Occurrence Identification Number: 10977 (EO update)

Site Description: The High Island Bay sand and gravel beach occurs along a two mile stretch of Lake Michigan shoreline along the northeastern shore of High Island. This sand and gravel beach is backed by low foredune, Great Lakes barrens, dry-mesic northern forest, and boreal forest. Species composition and community structure are patterned by natural processes. This sand and gravel beach occurs along the Great Lakes shoreline of Lake Michigan, where wind, waves, and winter ice cause the shoreline to be too unstable to support aquatic vegetation. Because of the high levels of disturbance, this beach is typically quite open, with sand and gravel sediments and little or no vegetation. Energy from waves and ice abrasion maintain an open beach. The beach is characterized by a mixture of sands, gravel, and cobble.

This sand and gravel beach is characterized by both a low diversity of plant species and low levels of plant cover. A wide variety of plants can develop at the inland margin of sand and gravel beaches, but few establish and persist on the active beach, where there is often intense wind and wave action, resulting in almost constantly moving sand. Species noted along the margin of the sand and gravel beach and along the low foredune include marram grass (*Ammophila breviligulata*), wheat grass (*Elymus lanceolatus*), plains puccoon (*Lithospermum caroliniense*), wormwood (*Artemisia campestris*), poison ivy (*Toxicodendron radicans*), common milkweed (*Asclepias syriaca*), Pitcher's thistle (*Cirsium pitcheri*, state and federally threatened), and red-osier dogwood (*Cornus sericea*). Mossy stonecrop (*Sedum acre*) and spotted knapweed (*Centaurea stoebe*) are locally common within the sand and gravel beach.

Threats: Species composition and structure are driven by natural processes. Mossy stonecrop (*Sedum acre*) and spotted knapweed (*Centaurea stoebe*) are locally common within the sand and gravel beach. Additional invasives found along the shoreline include Canada bluegrass (*Poa compressa*), narrow-leaved cat-tail (*Typha angustifolia*), reed (*Phragmites australis* subsp. *australis*), and white sweet-clover (*Melilotus albus*).

Management Recommendations: The primary management recommendations are to allow natural processes to operate unhindered, eliminate clusters of non-native plants along the shoreline, and monitor for invasive species.

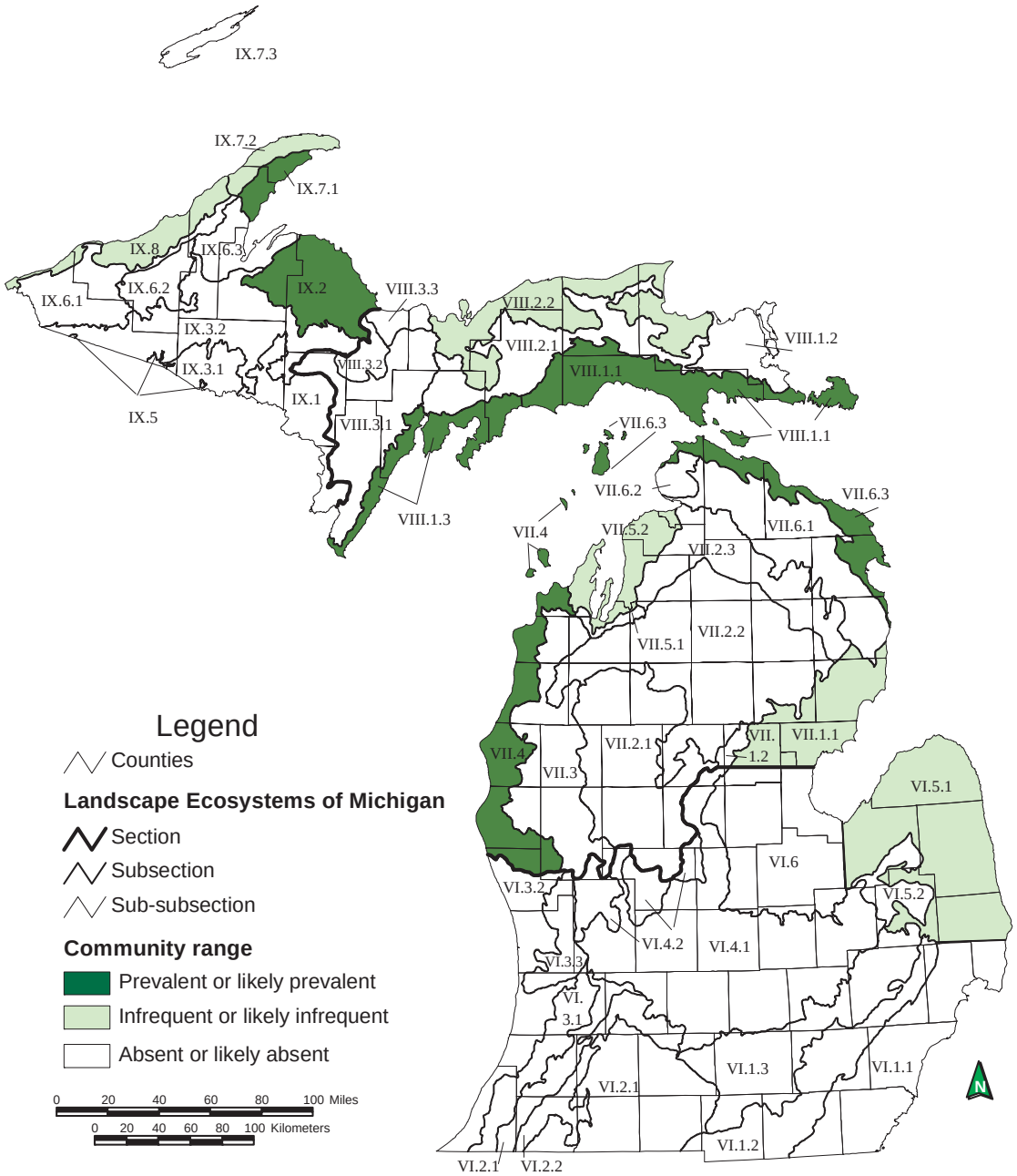
High Island Bay sand and gravel beach. Photos by Joshua G. Cohen.

Aerial photograph of High Island Bay sand and gravel beach.

High Island Bay sand and gravel beach. Photo by Joshua G. Cohen.

WOODED DUNE AND SWALE COMPLEX

Overview: Wooded dune and swale complex is a large complex of parallel wetland swales and upland beach ridges (dunes) found in coastal embayments and on large sand spits along the shorelines of the Great Lakes. The upland dune ridges are typically forested, while the low swales support a variety of herbaceous or forested wetland types, with open wetlands more common near the shoreline and forested wetlands more prevalent further from the lake. Wooded dune and swale complexes occur primarily in the northern Lower and Upper Peninsulas and Thumb region (Kost et al. 2007, Cohen et al. 2014).



Map 10. Distribution of wooded dune and swale complex in Michigan (Albert et al. 2008).

17. Taganing Dune and Swale
Natural Community Type: Wooded Dune and Swale Complex
Rank: G3 S3, vulnerable throughout range
Element Occurrence Rank: C
Size: 67 acres
Location: Garden Island
Element Occurrence Identification Number: 20451 (New EO)

Site Description: Hundreds to thousands of years of lacustrine processes have developed a subtle but complex patterning of northeast to southwest oriented dune ridges and swales of variable depth and width that characterize the Taganing Dune and Swale. The complex community structure includes dry-mesic northern forest, northern hardwood swamp, rich conifer swamp, northern shrub thicket, and northern wet meadow. Along the ridges the soils are characterized by a shallow A horizon (10-30 cm on one ridge) of acidic (pH 4.5) organics and sands overlying medium- to coarse-textured, alkaline (pH 7.5-7.8) sands. The sands along the ridges are more acidic closer to the surface, where the needle layer increases the acidity and less acidic with increasing depth. Shrub and meadow swales have saturated, alkaline (pH 7.5-8.0) peats (> 1 meter in one swale) overlying sands. The ridges are typically low and narrow (10-30 meters wide) and the swales are also narrow (10-20 meters wide). Many of the swales hold standing water, with measured water depths ranging from 30 to 60 cm in sedge- and shrub-dominated swales. Compared to other examples across this state, this is a very small wooded dune and swale complex. Nevertheless, the site is characterized by complex ecological patterning that results in high species and community diversity in an area with minimal anthropogenic disturbance. In addition, the site is unique in that it occurs immediately adjacent to a high-quality Great Lakes marsh (Taganing Marsh, EO ID 20450).

The ridges and swales are linear and trend northeast to southwest. Coarse woody debris of early-successional species [paper birch (*Betula papyrifera*) and balsam fir (*Abies balsamea*)] is abundant. Pockets of windthrow are common on both the forested ridges and swales. Trees falling from adjacent uplands into the swales provide important substrate for plant establishment and growth. Throughout the gently rolling dune ridges, there are charred snags and cut stumps, indicating that the complex burned and was locally logged in the past. A 31.5 cm northern white-cedar (*Thuja occidentalis*) from a dry-mesic dune ridge was cored and estimated to be over 133 years old. Where the dune ridges and swales are narrowest, they intergrade with each other vegetatively. The wooded dune and swale complex occurs adjacent to high-quality Great Lakes marsh.

The dry-mesic dune ridges are dominated by northern white-cedar with common associates including paper birch, trembling aspen (*Populus tremuloides*), and red pine (*Pinus resinosa*). Diameters of canopy trees range from 10 to 30 cm. Early-successional species (i.e., paper birch and balsam fir) are senescing and their small diameter coarse woody debris is prevalent along the dune ridges. Prevalent understory species include balsam fir and yew (*Taxus canadensis*). Balsam fir is locally dense in the understory. The low shrub layer is patchy to dense with mountain maple (*Acer spicatum*), yew, and Labrador-tea (*Rhododendron groenlandicum*). Characteristic ground cover species include bracken fern (*Pteridium aquilinum*), Canada mayflower (*Maianthemum*

canadense), wild sarsaparilla (*Aralia nudicaulis*), twinflower (*Linnaea borealis*), gay-wings (*Polygala paucifolia*), starflower (*Trientalis borealis*), and naked miterwort (*Mitela nuda*).

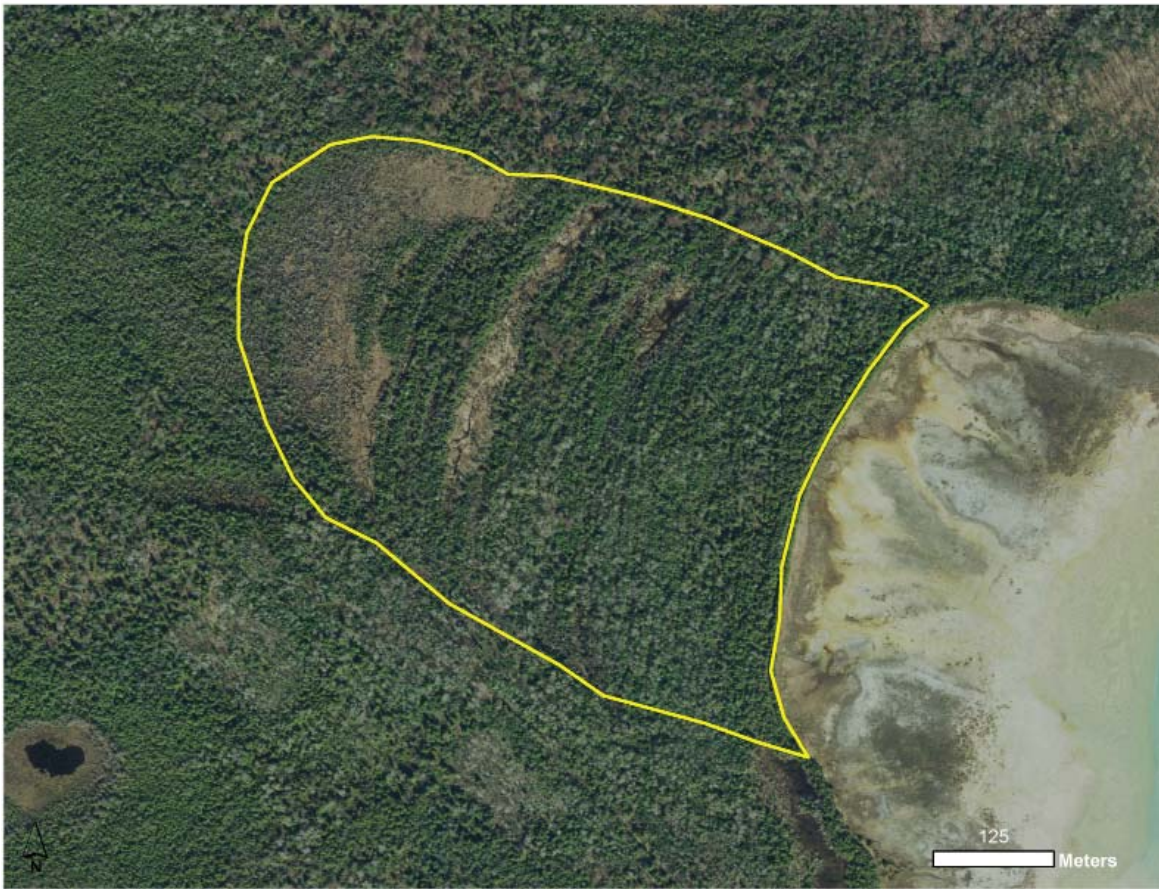
The northern hardwood swamp swales are dominated by black ash (*Fraxinus nigra*) with prevalent ground cover species including starflower, bunchberry (*Cornus canadensis*), goldthread (*Coptis trifolia*), and Canada mayflower. Areas of rich conifer swamp are dominated by northern white-cedar with canopy associates including black ash and tamarack (*Larix laricina*). Prevalent understory species include tag alder (*Alnus incana*), mountain holly (*Ilex verticillata*), balsam fir, red-osier dogwood (*Cornus sericea*), and northern white-cedar. Common species of the low shrub layer include Labrador-tea, alder-leaved buckthorn (*Rhamnus alnifolia*), and bog rosemary (*Andromeda glaucophylla*). Characteristic ground cover species include tussock sedge (*Carex stricta*), bunchberry, marsh fern (*Thelypteris palustris*), starflower, goldthread, royal fern (*Osmunda regalis*), creeping snowberry (*Gaultheria hispidula*), sensitive fern (*Onoclea sensibilis*), and miterwort.

Taganing Dune and Swale wooded dune and swale complex. Photo by Joshua G. Cohen.

Shrub swales are dominated by tag alder with tall shrub associates including red-osier dogwood and mountain holly and common low shrubs including Labrador-tea, alder-leaved buckthorn, and bog rosemary. Characteristic ground cover species in the shrub swales include tussock sedge, wild blue flag (*Iris versicolor*), bunchberry, wild strawberry (*Fragaria virginiana*), marsh fern, royal fern, and sensitive fern, and mad-dog skullcap (*Scutellaria lateriflora*). Standing water in the shrub swales was typically between 30 to 60 cm deep. Graminoid-dominated meadow swales are characterized by sedge dominance with tussock sedge and wiregrass sedge (*Carex lasiocarpa*) prevalent and ground cover associates including wild blue flag, marsh fern, marsh cinquefoil (*Comarum palustre*), and hardstem bulrush (*Schoenoplectus acutus*).

Threats: The site is characterized by complex ecological patterning that results in high species and community diversity in a small area with minimal anthropogenic disturbance. Logging has occurred in portions of the complex on the ridges. Cut and charred stumps occur scattered throughout the wooded dune and swale complex and the diameters of the cut stumps are smaller or similar to the diameter of living trees. No current threats were observed during the course of the survey.

Management Recommendations: The main management recommendations are to allow natural processes to operate unhindered, retain an intact buffer of natural communities surrounding the wooded dune and swale complex, and monitor for invasive species.



Aerial photograph of Taganing Dune and Swale wooded dune and swale complex.

Stewardship Prioritization Results and Observations

The stewardship scores for each natural community element occurrence are presented in Table 2. We sorted the element occurrences by their stewardship prioritization scores and assigned them a high (red), medium (yellow), or low (blue) stewardship priority. During the course of the 2015 surveys, invasive species were noted to be most common within the shoreline ecosystems. The highest ranking sites on Garden and High Islands are both Great Lakes marsh occurrences found on Garden Island. When a stewardship prioritization analysis was run for Northern Michigan, a similar result was found with Great Lakes marsh ranking highly; Great Lakes marsh was consistently the most abundant natural community in the sites categorized as high stewardship priority. This is partially due to the global rarity of this ecosystem that is endemic to the Great Lakes region (Great Lakes marsh has a global rarity ranking of G2, or globally imperiled). In addition, this system is particularly susceptible to infestation by invasive species. The invasives that become established within Great Lakes marsh can quickly expand and dominate, with homogenous beds of reed (*Phragmites australis* subsp. *australis*) and invasive cattails (*Typha angustifolia* and *T.* x*glauca*) dramatically altering floristic composition and structure of affected sites. Medium priority sites on Garden and High Islands include the following shoreline ecosystems: coastal fen, open dunes, limestone cobble shore, Great Lakes barrens, and sand and gravel beach. Low priority sites include more common natural community types that occur within the interior of the islands and most of these types are forested systems.

This prioritization framework was developed to help focus stewardship efforts to those sites with the greatest stewardship need. During the 2015 surveys many of the surveyed sites were not currently impacted by threats or threats were limited in scope and severity. Many of the sites on Garden and High Islands currently do not have pressing stewardship needs. However, for this unique circumstance, this framework can also be used to help resource managers determine where to focus future monitoring efforts.

Discussion

This report provides site-based assessments of 17 natural community element occurrences within Garden and High Islands. Threats, management needs, and restoration opportunities specific to each individual site have been discussed. The baseline information presented in the current report provides resource managers with an ecological foundation for prescribing site-level biodiversity stewardship, monitoring these management activities, and implementing landscape-level biodiversity planning to prioritize management efforts. The framework for prioritizing stewardship and monitoring efforts across sites across these islands will help facilitate difficult decisions regarding the distribution of finite stewardship resources for site-based management.

The framework for stewardship and monitoring prioritization presented in this report offers a method for targeting biodiversity management and monitoring within these islands. This method could be refined to suit the specific and local needs of resource agencies. This stewardship prioritization could also be refined within broader ecological or political regions such as ecological subsection, county, or the

entire Beaver Island Archipelago. In addition, the stewardship priority scores could be sorted by natural community type. Furthermore, other indices could be incorporated into the stewardship prioritization matrix. Additional indices to consider incorporating include indices that measure or score the potential for management success of a site, the presence of rare species, and the functionality of the landscape surrounding the site. Implementation of stewardship efforts within prioritized areas will need to be followed by monitoring to gauge the success of biodiversity management efforts and refine future stewardship prioritization efforts.

Figure 5. Nezewabegon mesic northern forest. (Photo by Joshua G. Cohen.)

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Appendix 1

GLOBAL RANKS

G1 = critically imperiled: at very high risk of extinction due to extreme rarity (often 5 or fewer occurrences), very steep declines, or other factors.

G2 = imperiled: at high risk of extinction due to very restricted range, very few occurrences (often 20 or fewer), steep declines, or other factors.

G3 = vulnerable: at moderate risk of extinction due to a restricted range, relatively few occurrences (often 80 or fewer), recent and widespread declines, or other factors.

G4 = apparently secure: uncommon but not rare; some cause for long-term concern due to declines or other factors.

G5 = secure: common; widespread.

GU = currently unrankable due to lack of information or due to substantially conflicting information about status or trends.

GX = eliminated: eliminated throughout its range, with no restoration potential due to extinction of dominant or characteristic species.

G? = incomplete data.

STATE RANKS

S1 = critically imperiled in the state because of extreme rarity (often 5 or fewer occurrences) or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the state.

S2 = imperiled in the state because of rarity due to very restricted range, very few occurrences (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the state.

S3 = vulnerable in the state due to a restricted range, relatively few occurrences (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation.

S4 = uncommon but not rare; some cause for long-term concern due to declines or other factors.

S5 = common and widespread in the state.

SX = community is presumed to be extirpated from the state. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.

S? = incomplete data

Rare Plant Surveys
Methods

Target Species

Both Garden and High Islands have been fairly well-inventoried for populations of state and federal listed vascular plants (e.g., Higman et al. 2012a, 2012b). Based on previous findings, the 2015 field surveys had three main targets: (1) new populations of state-listed plants in shoreline natural communities; (2) surveys of apparently suitable habitat for listed taxa that have not been reconfirmed in recent years (i.e., climbing fumitory and calypso orchid; and (3) counts and GPS demarcation of *Cirsium pitcheri* (Pitcher's thistle) individuals, including flowering or fruiting plants and sterile rosettes.

Field Surveys

Field surveys on Garden Island were conducted on the southern and western shoreline and through boreal forest and mesic northern forest on the western and far eastern interior of the island. Surveys of High Island were conducted along the shoreline (excluding the southern quarter of the island) and in the open dunes complex on the western side of the island.

Surveys were conducted utilizing two approaches: targeted meander surveys of potentially suitable habitats for the majority of species, and counts and GPS demarcation of individual Pitcher's thistle plants. GPS tracks and waypoints were recorded on BackCountry Navigator PRO GPS for Android or ArcPad on an Ashtech Mobile Mapper 10 handheld unit. Information on population size and distribution, habitat, and potential threats was recorded in a field notebook and transcribed on MNFI field forms (either the MNFI Special Species Form for element occurrence updates or the MNFI Special Plant Survey Form for new records).

Data Processing

Following field surveys, field data for new and updated element occurrences was transcribed into the MNFI natural heritage database. Where appropriate, element occurrence ranks were updated to reflect new data, including documentation of new populations, identification of new threats, and trends in population size inferred from previous surveys.

Results

Garden Island

One new element occurrence of Lake Huron tansy was documented in the southwestern part of the island. This was comprised of a very small colony on a limestone cobble storm beach. Three previously documented element occurrences were redocumented and element occurrence records were updated. These included two populations of Pitcher's thistle and one population of butterwort. The element occurrence rank was upgraded for butterwort. Element occurrence ranks for the Pitcher's thistle populations will be reviewed following completion of counts in 2016. The dwarf lake iris occurrence reported to us in 2011 in Indian Harbor was also documented. It was comprised of many small patches at the edge of boreal forest and limestone cobble shoreline. Surveys for two general records of *Adlumia fungosa* (climbing fumitory) and *Calypso bulbosa* (calypso orchid), both documented in 1966 were unsuccessful. In addition, a 1981 report of *Solidago houghtonii* (Houghton's goldenrod) from the southern shoreline of the island could not be confirmed. Survey targets and these findings are summarized in Table 3 and shown in Figure 6.

High Island

The special concern species *Dryopteris filix-mas* (male fern) was newly documented on High Island in the northeastern mesic northern forest. Previously known fascicled broomrape was observed, and two Pitcher's thistle populations were updated on the eastern and western sides of the island. Several new colonies of the known Lake Huron tansy occurrence were documented and mapped. The element occurrence rank for Lake Huron tansy was upgraded. Element occurrence ranks for the Pitcher's thistle populations will be reviewed following completion of counts in 2016. A previously identified population of dune stitchwort was not rediscovered despite several surveys in the appropriate area. These findings are shown in Figure 7 and summarized in Table 4.

Table 3. Targeted, updated, and new rare plant element occurrences for Garden Island, based on the MNFI Natural Heritage Database, 2016.

Scientific Name	Common Name	State, Federal Status	EO Number	Year First Observed	Year Last Observed
Adlumia fungosa	climbing fumitory	SC	13	1966	1966
Calypso bulbosa	calypso orchid	T	27	1966	1966
Cirsium pitcheri	Pitcher's thistle	T, LT	105	1983	2015
Cirsium pitcheri	Pitcher's thistle	T, LT	177	2015	2015
Dryoptertis filix-mas	Male fern	SC	29	2015	2015
Iris lacustris	dwarf lake iris	T, LT	101	2011*	2015
Pinguicula vulgaris	butterwort	SC	29	1998	2015
Solidago houghtonii	Houghton's goldenrod	T, LT	45	1981	1990
Tanacetum huronense	Lake Huron tansy	T	134	2015	2015

*****this occurrence was reported to us in 2011, but originally observed earlier.

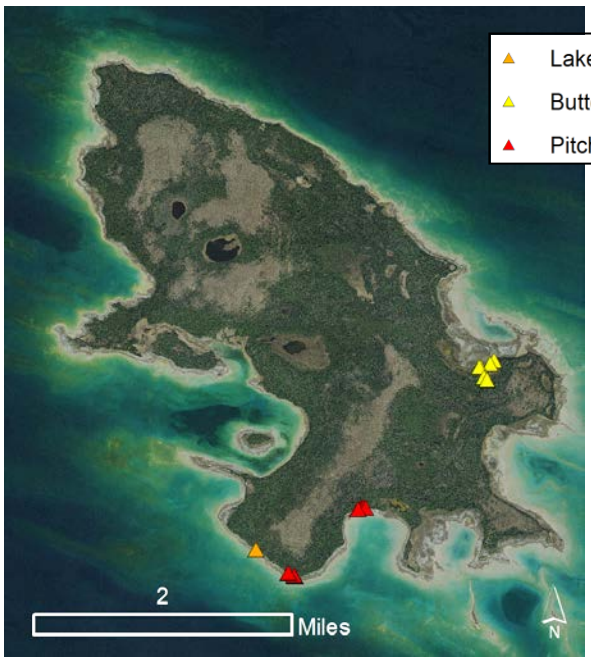

Figure 32. Rare plants mapped on Garden Island during 2015.

Figure 33. Rare plants mapped on High Island during 2015.

Table 4. Targeted and updated rare plant element occurrences for High Island, based on the MNFI Natural Heritage Database, 2016.

Scientific Name	Common Name	State, Federal Status	EO Number	Year First Observed	Year Last Observed
Cirsium pitcheri	Pitcher's thistle	T, LT	68	1958	2015
Cirsium pitcheri	Pitcher's thistle	T, LT	108	1981	2015
Orobanche fasciculata	fascicled broomrape	T	19	1986	2015
Stellaria longipes	dune stitchwort	SC	11	1986	1986
Tanacetum huronense	Lake Huron tansy	T	8	1958	2015

Discussion

Garden Island

The shoreline of Garden Island is apparently well-surveyed for listed vascular plants. The primary needs are a census and updated delineation of the Pitcher's thistle population on the northern shore of the island and an update of the Lake Huron tansy element occurrence on the northern shore of the island. The interior portion of the island, however, is less well-inventoried, and there remains potential for additional discoveries. Despite the recent failure to redocument the calypso orchid on Garden Island, there is good potential for this species to persist in the island's boreal forests. Due to its early blooming period (flowering began in the eastern Upper Peninsula in mid-May 2015; R. Routledge, pers. comm.), tiny size, and often sparse distribution, future surveys should target this species in particular. Surveys should take place earlier in the year, potentially at the end of May. Surveys for climbing fumitory should also continue, although the broad ecological amplitude of this disturbance-dependent, short-lived biennial complicate targeted inventory effort. The majority of Michigan records for climbing fumitory are historical, with very few reports over the past several decades (MNFI 2015). However, a new occurrence of this species was documented on Trout Island in 2012 (Higman pers. comm.).

High Island

The finding of male fern on High Island was significant, as it represents the only known rare species that occurs in the AB-ranked mesic northern forest to date. This is a highly diverse, rich forest and additional surveys of this area are warranted. Only two occurrences of this species are known in Lower Michigan, both in Alpena County. Three occurrences are known from Mackinac County and one from Chippewa County. The 21 other known occurrences are all further west in the Upper Peninsula.

High Island supports extensive populations of Pitcher's thistle. A census was initiated during the 2015 surveys and is anticipated to be completed for the island in 2016. The census will result in an estimated population size and improved spatial representation of the element occurrences on the island. The population of Lake Huron tansy is also in need of a targeted survey, including better demarcation of the extent of the populations on the island. Based on the incidental discovery of several previously unmapped populations along the shoreline in 2015, the element occurrence rank was significantly upgraded, and may further improve with a thorough inventory of the entire shoreline.

We were unable to confirm the presence of *Stellaria longipes* (dune stitchwort) in 2015. This species was documented from the open dunes on the western side of High Island in 1986, but no voucher specimen was apparently preserved. This is the only report for dune stitchwort from Lower Michigan. Additional surveys of appropriate areas within the dunes should be conducted in future years to determine if this species is extant and to procure a specimen for the state's major herbaria (MICH and MSC).

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Butterwort in flower on Garden Island. (Photo by Bradford S. Slaughter.)

Rare Invertebrate Surveys
Methods

Selection of Survey Targets

Rare animal surveys on Garden and High Islands targeted the Lake Huron locust (*Trimerotropis huroniana*, state threatened), a dune species, and the Hine's emerald dragonfly (*Somatochlora hineana*, federal and state endangered), known from calcareous wetlands. These species have also been identified as Species of Greatest Conservation Need in Michigan's Wildlife Action Plan (Derosier 2015). They were selected based on their conservation status or importance, available project resources, MNFI's results and recommendations from surveys conducted in 2011, and interests of the scientists from the Little Traverse Bay Band (LTBB) of the Odawa Indians (Higman et al. 2012).

The first occurrence of Lake Huron locust on Garden Island was documented in 2011 (Higman et al. 2012), along a low sand dune and sandy shoreline in Northcutt Bay and in a small foredune area with sand and cobbles in Jensen's Harbor. These findings indicated that this species can occur in areas with small open sand dunes or even narrow, open sandy shorelines. As a result, there was potential for the species to occur in other similar habitat around the island. On High Island, 2011 surveys revealed that Lake Huron locust was more prevalent than previously documented. It was reconfirmed at its original location and documented in three additional areas. Additional surveys were recommended for both Islands to determine the full extent and size of these populations and to monitor their status and viability (Higman et al. 2012).

The Hine's emerald dragonfly was documented for the first time on Garden Island in 2011. An adult male was found along the southern edge of a large coastal fen at Jensen Harbor (Higman et al. 2012). This was a particularly exciting discovery as it was the first new population documented in the state since 2007, and remains the only known population on an island in Lake Michigan, (MNFI 2016). This species has not been documented on High Island and it was not targeted in 2011 as there appeared to be little to no suitable northern fen or coastal fen habitat (Higman et al. 2012). Due to limited surveys on Garden Island in 2011 and the challenge of finding this species, additional surveys were recommended in 2015 at Jensen Harbor and other sites with suitable habitat, to determine the species' extent and population size. Limited surveys for Hine's Emerald were also conducted on High Island and surveys were conducted on both Islands for other rare and common dragonflies.

Surveys

Surveys 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 the identification of new occurrences or locations, and the confirmation of known or historical occurrences of rare species. Brief descriptions of the target species, their habitats, and survey methods are provided below.

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 black band covers half the inner surface of the hind femora near the body. It is most active in late morning, after 9:30 or 10 am. Males

crepitate in flight, making a cracking noise. 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 sand reed grass, marram grass, and wormwood, but will eat other forbs also, including the federal and state threatened pitcher's thistle (*Cirsium pitcheri*).

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/or an aerial net to catch individuals were used to confirm identification. Surveys occurred on Garden Island on August 11 and 13 in areas with suitable habitat primarily along Northcutt Bay, Indian Harbor, and Jensen Harbor (Figure 8). Incidental surveys were conducted in other parts of the island with suitable habitat during other MNFI surveys in August 2015. Surveys occurred on High Island on August 12 and 14 in two main areas with suitable habitat along the northeast shore of the island (Figure 9). Surveys focused on confirming and extending the known occurrence or extent of the species on the island.

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 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.

Meander surveys for the Hine's emerald dragonfly were conducted on Garden Island on August 11 and 13 and on High Island on August 12 and 14. Surveys were conducted by walking through appropriate habitat and looking for individuals in flight or resting on vegetation. Surveyors used close-focusing binoculars and aerial nets during surveys, as netting individuals to examine and photograph them before release provides the most definitive method for identification. Surveys on Garden Island were conducted in areas with suitable habitat along Northcutt Bay, Indian Harbor, and Jensen Harbor (Figure 8). Surveys for other dragonfly species were also conducted along the south side of Sorry Burn Lake north of Indian Harbor (Figure 8). On High Island, surveys were mainly conducted along the north side of Lake

Maria, and opportunistically during Lake Huron locust surveys along the northeast shore of the island (Figure 9).

Data Processing

Following field surveys, data from field forms, notes, and species lists were compiled and examined, and GPS locations and photographs were downloaded. 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.

Figure 8. Map showing areas surveyed for target invertebrate species on Garden Island in 2015.

Figure 9. Areas that were surveyed for rare invertebrate targets on High Island in 2015.

Results

Hine's emerald dragonfly

No Hine's emerald dragonflies were found during surveys on Garden Island in 2015. Other dragonfly species observed included twelve-spotted skimmers (*Libellula pulcella*), four-spotted skimmers (*Libellula quadrimaculata*), rusty snaketails (*Ophiognomphus rupinsulensis*), common green darners (*Anax junius*), other darners (*Aeshna* spp.), saffron-winged meadowhawks (*Sympetrum costiferum*), and other (red-colored) meadowhawks (*Sympetrum* spp.) (Figure 10). Several emerald dragonflies were observed along the south side of Sorry Burn Lake. These were identified as Williamson's emerald dragonflies (*Somatochlora williamsoni*) based on the coloration and markings on the thorax and abdomen and the terminal appendage on the males (i.e., the shape and presence of lateral spines on the cerci or top part of the terminal appendage) (Figure 10).

Figure 10. Photos of dragonfly species found during rare invertebrate surveys on Garden Island in 2015. These include the Williamson's emerald dragonfly (upper and lower left), saffron-winged meadowhawk (upper right), and four-spotted skimmer (lower left). (Photos by Yu Man Lee.)

Although we were not able to reconfirm Hine's emerald dragonflies in 2015, LTBB scientists have documented small numbers of individuals in Jensen Harbor in 2013 and 2014. Surveys in 2015 confirmed that extensive, high quality habitat appears to be available along most of Jensen Harbor and Northcutt Harbor (Figure 11, 13). The population should still be extant and have good or fair viability (BC-rank), based on NatureServe's generic element occurrence ranking guidelines (Table 5; Hammerson et al. 2008). The BC-rank indicates the population either has good likelihood for persisting in the foreseeable future (i.e., at least 20-30 years) in its current condition or better, if current conditions prevail, or the likelihood of this population persisting is non-optimal or uncertain under current conditions. This rank was based on the small numbers of Hine's emerald dragonflies that have been documented during recent surveys, the amount, condition, and landscape context of available habitat, and minimal threats to the population on the island.

No Hine's emerald dragonflies or suitable habitat for the species was found during surveys on High Island in 2015. Other dragonfly species observed including twelve-spotted skimmers (*Libellula pulcella*), widow skimmers (*Libellula luctuosa*), common green darners (*Anax*

junius), and meadowhawks (*Sympetrum* spp.) around Lake Maria, and rusty snaketail dragonflies (*Ophiognomphus rupinsulensis*) along the shoreline (Figure 14)
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Figure 11. Map showing known locations and extent of Lake Huron locust and Hine's emerald dragonfly element occurrences on Garden Island, based on surveys in 2011 and 2015.

Figure 12. Map showing known locations and extent of Lake Huron locust element occurrences on High Island (shown in red), based on surveys in 2011 and 2015. Surveys in 2015 expanded known extent of the species along the northern and eastern shoreline of the island.

Table 5. Previously documented and updated invertebrate/insect element occurrences for Garden Island, based on MNFI Natural Heritage Database (2016).

Scientific Name	Common Name	State, Federal Status	EO Number	Year First Observed	Year Last Observed	EO Rank
Insects						
Trimerotropis huroniana	Lake Huron Locust	T	92	2011	2015	C
Somatochlora hineana	Hine's Emerald Dragonfly	E, LE	16	2011	2014	BC

Figure 13. Photos of coastal fen and other suitable habitat for Hine's emerald dragonfly along Northcutt Bay (upper left), Indian Harbor (upper right), and Jensen Harbor (lower left and right) on Garden Island on August 11 and 13, 2015. (Photos by Yu Man Lee.)

Lake Huron locust

On Garden Island, the Lake Huron locust was only found along Northcutt Bay in 2015 (Figures 11 and 15). Over six individuals were observed in an area with a small, low sand dune and sandy shoreline on August 11. This species was observed in this same area in 2011. Several individuals of the more common Carolina locust (*Dissosteira carolina*) also were found in this area. These two species often occur together. These results reconfirmed and updated the known occurrence For Garden Island (Table 5). Based on NatureServe's (2015) element occurrence specifications and the species' ability to move between areas with available suitable habitat, observations of this species at Northcutt Bay and Jensen Harbor (in 2011) are considered multiple locations within a single element occurrence record. Using NatureServe element occurrence rank specifications (Schweitzer and Whittaker 2007), this population maintains its rank of fair viability (C-rank, Appendix 2). This is based on the observation of between 10 and 50 individuals in less than 100 acres of suitable habitat.

Figure 14. Photos of dragonfly species found during invertebrate surveys on High Island in 2015. These include the twelve-spotted skimmer (upper left), widow skimmer (upper right), and rusty snaketail (lower left and right). (Photos by Yu Man Lee.)

The Lake Huron locust was found throughout the areas surveyed on High Island in 2015 (Figure12). Large numbers of this species were observed along the extensive sand and gravel beach (High Island Bay Sand and Gravel Beach EO ID 10977), and also within the low foredunes behind the beach on the northeast shore of the island (Figures 12, 15, and 16). Lake Huron locusts were also observed in small patches with open sand in two areas with Great Lakes barrens habitat (Nezewabegon Barrens Great

Lakes Barrens EO ID 20454) along this stretch of shoreline (Figures 15). The sand and gravel beach community extends for about two miles along this stretch of shoreline, and has been ranked as having excellent viability (Cohen 2016). The Great Lakes barrens natural community is also ranked as having excellent to good viability (Cohen 2016). Over 800 individual locusts were observed throughout the surveyed areas. Similar to the locust occurrence on Garden Island, the more common Carolina locust (*Dissosteira carolina*) was also found alongside the Lake Huron locust in some areas on High Island.

The 2015 survey results reconfirmed and expanded the known occurrence and extent of Lake Huron locusts on High Island. This occurrence was first documented in 1996, with 25 to 30 locusts observed along a 600-m transect in extensive dunes on the west side of the island (Table 6), MNFI 2016). Documentation of high numbers of the locust in the large, open sand dunes on the west side of the island and at three additional sites on the northwest, northeast, and south sides of the island in 2011 (MNFI 2016), resulted in an update and substantial expansion of the known occurrence. Survey results from 2015 further expanded the known extent of the species along the eastern shoreline of the island by 1.3 km. The surveys also expanded the extent of the species further to the west and further inland along the northeast shoreline. Using Nature-Serve's criteria (2015), these observations represent one element occurrence record with multiple locations on the island.

Based on the 2015 survey results, the Lake Huron locust occurrence on High Island was upgraded from having good to fair viability to excellent to good viability (Schweitzer and Whittaker 2007, Nature Serve Appendix 2). This ranking is based on the large numbers of individuals observed, the extent of the species' distribution, its long history of occurrence, and minimal or manageable threats to the species on the island.

Figure 15. Photos of Lake Huron locust and habitat found along Northcutt Bay on Garden Island on August 11, 2015. (Photos by Yu Man Lee.)

Figure 16. Photos of Lake Huron locusts found on High Island in 2015. Photos by Yu Man Lee.

Table 6. Previously documented and updated invertebrate element occurrences for High Island, based on MNFI Natural Heritage Database (2016).

Scientific Name	Common Name	State, Federal Status	EO Number	EO ID	Year First Observed	Year Last Observed	EO Rank
Invertebrates							
Euxoa aurulenta	Dune Cutworm	SC	4	6390	1935	1935	H
Trimerotropis huroniana	Lake Huron Locust	T	49	3096	1996	2015	AB

Figure 17. Photos of different natural communities and habitats in which Lake Huron locusts were found on High Island in 2015. These include sand and gravel beach (photos A, B, C, and E), low foredune (photo D), and Great Lakes barrens (photo F) natural communities/habitats along the northeastern shore of High Island (High Island Bay). (Photos taken by Yu Man Lee.)

Other Animal Observations

Additional animal species observed on Garden Island include several eastern garter snakes (*Thamnophis sirtalis sirtalis*), and a northern water snake (*Nerodia sipedon sipedon*) along Northcutt Bay, Indian Harbor, and/or Jensen Harbor (Figure 18). Other species observed on High Island include, a merlin (*Falco columbarius*), bald eagles (*Haliaeetus leucocephalus*), northern water snake (*Nerodia sipedon sipedon*), eastern garter snake (*Thamnophis sirtalis sirtalis*), and eastern newt (*Notophthalmus viridescens*) around Lake Maria. Monarch butterflies (*Danaus plexippus*) were observed along the shoreline.

Figure 18. Photos of eastern garter snake and northern water snake found during rare invertebrate surveys along Jensen Harbor on Garden Island on August 13, 2015. (Photos by Yu Man Lee.)

Discussion

Lake Huron locust

The occurrence of Lake Huron locust on Garden Island was confirmed in at least one location on the island in 2015. Only six individuals were observed in 2015 compared to over 46 individuals observed in the same area along Northcutt Bay in 2011 (Higman et al. 2012). This might have been due to surveys being conducted a little later in 2015 than in 2011. Additionally, less time was spent surveying for this species in 2015. Surveys on High Island in 2015 confirmed that the locust is quite abundant and more prevalent there than originally documented. These observations indicate that Lake Huron locust occurs in a variety of sandy habitats in addition to open dunes, including sand and gravel beaches and Great Lakes barrens. The potential exists for this species to occur in additional areas along the shoreline on Garden Island and it is very likely that the species occurs throughout the shoreline on High Island wherever there are open, sandy habitats.

Additional surveys on Garden Island, particularly along the northern shoreline should be conducted to determine the full extent and distribution of this occurrence. MNFI's surveys in 2011 and 2015 have likely documented most of the species' distribution on High Island; however, some additional small areas primarily along the southern portion of the island should be surveyed. Surveys should also be conducted periodically on both Islands to monitor the status and viability of these populations.

Maintaining the Lake Huron locust population on Garden and High Islands is significant for conservation of the species in Michigan and globally. This species is a Great Lakes endemic known only from Michigan, Wisconsin, and Ontario (Otte 1984, Ballard 1989, Rabe 1999, NatureServe 2015). However, the species may be extirpated from Ontario and restricted to only a small number of sites in Wisconsin (NatureServe 2015). Thus, Michigan contains the majority of the global population of this species, and its conservation here has important implications for the species' long-term viability.

Although the Garden Island population is currently ranked as having only fair viability, there are only about 90 known occurrences or populations of this species in the state, and about 40% of them are historical or are ranked as having poor viability (MNFI 2016). The rank for the population on High Island was upgraded from good to fair viability to excellent to good viability (Appendix A). This population is one of only 37 populations in the state ranked as having excellent or good viability (MNFI 2016). The Garden and High Island locust populations are two of only six populations documented on Great Lakes islands (MNFI 2016). Scholtens (1996, 1997) identified the Lake Michigan islands as one of six major shoreline areas in the state with significant populations of the species.

Protection of suitable habitat is critical for sustaining the locust populations on the islands. Throughout its range, significant portions of the species' dune habitat have been degraded or destroyed by residential and/or recreational development (Rabe 1999). Shorelines that are one mile or more in length with extensive, wide dunes with at least two sets of dunes and blow-out 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. 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). However, it generally occurs in large numbers in high quality sites, and quickly diminishes or disappears when dunes become heavily vegetated or disturbed (Ballard pers. comm.). On High Island, the open dunes on the west side and low foredunes along a portion of the shoreline at the northeast end of the island represent good examples of optimal or high quality habitat for the species. Although Garden Island may not contain ideal or exceptional habitat, it appears to provide relatively undisturbed pockets of habitat and it may continue to persist there into the foreseeable future (i.e., at least 20-30 years). However, the population should be monitored closely.

Natural processes and anthropogenic factors that increase vegetation and reduce open sandy areas along the shoreline have the potential to impact the Lake Huron locust and availability of suitable habitat on the Islands. Scattered pockets of spotted knapweed have been found along Northcutt Bay on Garden Island and along the eastern and northern shore of High Island near or in areas where the locust occurs. A single, small patch was also located at the southern edge of the western dunes, which until now, has remained uninvaded. Spotted knapweed has become well established and quite dense along the northeast corner of High Island, with huge source infestation occurring on the sand spit. While Lake Huron locusts still occur in these areas presently, the continued establishment and spread of spotted

knapweed will almost certainly impact the species' habitat significantly in the future. Other troublesome species that co-occur with spotted knapweed include bouncing bet (*Saponaria officinalis*) and bladder campion (*Silene vulgaris*). Efforts to control or eliminate invasive species should be considered and implemented, to maintain suitable habitat for the Lake Huron locust.

In addition to surveys and monitoring, research is needed to obtain additional information 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. 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 in 2011 was a very exciting and significant discovery. Surveys on the island since then have focused on determining the size, distribution, and condition of the population and the extent and availability of suitable habitat to assess the viability of this population and inform conservation efforts. Surveys in 2015 confirmed the availability of extensive, apparently suitable habitat for the dragonfly, particularly along Jensen Harbor and Northcutt Bay. However, we were unable to document the species in 2015 in the area where it had been found in the past, or in other areas with suitable habitat. This may have been due to the timing of surveys in 2015, small population size or low abundance on the island, and/or the challenging nature of finding this species. Surveys conducted in recent years prior to 2015 were conducted during the last week of July and first week in August, compared to the second week of August in 2015 (Higman et al. 2012, Parsons et al. pers. comm.). The adult flight period may occur or peak earlier, in mid-late July or early August on the Island. Also, LTBB scientists have generally documented only one or several individuals (<5) during each of their surveys and only at the Jenson Harbor locations. Despite extensive suitable habitat on the island, the Hine's emerald dragonfly population may be fairly small. Cuthrell (pers. comm.) has suggested perhaps the population has been impacted by and not yet recovered from low Great Lakes water levels over the past 10-15 years. The population should continue to be monitored to determine its status and condition.

Because of the global and state rarity of the Hine's emerald dragonfly, all known populations should be maintained and protected. It is known primarily from the Great Lakes region, and globally it has been documented from about 50-80 sites in seven U.S. states and one Canadian province. However; it is believed to be currently extant at less than 50 sites in only five states and provinces (NatureServe 2015). The population on Garden Island is one of only 16 known sites or populations in Michigan and the only known island population on a Lake Michigan island (MNFI 2016). Also, it is currently one of only seven (43%) known populations in the state that may have good viability. This viability ranking is primarily based on the extensive habitat and relatively undisturbed nature of the island; additional surveys and monitoring are needed to ascertain the true status of this population. If protected, it will contribute significantly to the overall conservation of the species.

The most significant threats to the Hine's emerald across its range are habitat destruction or alteration and chemical

contamination (Cuthrell 1999). These threats do not appear to be an issue at the Garden Island site currently, highlighting the importance of protecting this site. Maintenance of hydrology at occupied sites is particularly important (Cuthrell 1999). Also, invasive plant species, such as non-native phragmites (*Phragmites australis australis*), narrow-leaved cattail (*Typha angustifolia*), hybrid cat-tail (*Typha* x*glauca*), and reed canary grass (*Phalaris arundina*cea) have been documented on the island. They are currently not established in the coastal fens; however, some colonies are nearby. They should be closely monitored, and treated promptly to prevent their spread into these high quality habitats, which the Hine's emerald dragonflies rely on. Chemical contamination may become an issue for this species in the future. Chemicals move slowly through coastal fens and could impact the dragonfly during its 2-4 year aquatic larval stage (Cuthrell 1999). Potential chemical contamination should be considered during monitoring.

Additional surveys and monitoring for the Hine's emerald dragonfly should be conducted, particularly along Jensen Harbor and Northcutt Bay as well as other areas with suitable habitat. These should focus on determining the size, distribution, condition and viability of the population. Larva and larval habitats within occupied sites need to be identified and protected. Surveys for these could supplement surveys for adults, providing an additional measure of viability. Additional research to clarify the ecological requirements of Hine's emerald dragonfly adults and larvae is also needed.

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Appendix 2.

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.

Acoustic Surveys for Bat Species on High and Garden Islands
Methods

Selection of Survey Targets

There has been increasing interest in bats due to a number of factors, including recognition that bats provide valuable "ecosystem services" in terms of insect pest control, and, conversely, due to emerging sources of bat mortality. It is well known that bats forage on agricultural pests (Kurta 2008) and Maine and Boyles (2015) have shown that bats can reduce corn damage by earworms by 60%. They estimate that bats save $1 billion in corn damage worldwide annually and perhaps as much as $23 billion annually for all crops. Thus, bats serve an important function with respect to economic activity and food supplies and their conservation can benefit humans from this respect. However, this ecosystem service is threatened by emerging sources of bat mortality. One such source is alternative energy generation by wind farms. It is now estimated that approximately 600,000 bats are killed by interactions with wind turbines throughout the United States (US) on an annual basis (Hayes 2012). The bats are killed by striking turbine blades and monopoles (Kunz et al., 2007) and through a phenomenon called barotraumas (Baerwald et al. 2008) in which bats suffer fatal levels of lung damage due the low pressure vortices created by the turbines. The other source of mortality is white nose syndrome (WNS) which is caused by a fungus called *Pseudogymnoascus destructans*. WNS, first found in New York state, has been expanding across the US and has reportedly killed 90% of the cave bats in the northeast US; it now occurs in Michigan where similarly high levels of mortality are expected (MDNR, undated).

The relative importance of these mortality sources differ substantially among different groups of bats. Of the deaths caused by wind turbines, 75% are accounted for by three species: the Eastern red bat (*Lasiurus borealis*), the hoary bat (*Lasiurus cinereus*), and the silver-haired bat (*Lasionycteris noctivagans*). These three species are known as the "tree bats", due to the fact that their year-round habitat is trees. These species overwinter not in caves, but migrate each year from the Midwest to the southern US where they spend the winter. Alternatively, WNS primarily affects those bat species that hibernate in caves. The fungus results in mortality by causing hibernating bats to arouse more frequently, reducing energy reserves necessary to carry them through the hibernation period until food sources once again become available. The effect of WNS on Michigan's bats has been severe enough that it has resulted in the listing of the Northern long-eared bat (*Myotis septentrionalis*) as threatened by the US Fish and Wildlife Service (USFWS).

Until the recent upswing in interest in bats, few researchers in Michigan investigated these species. Consequently, answers to basic questions such as what is the general and specific distribution of the nine species of bats that occur in the state were only partially known. Such was the case for the islands in the northern Lake Michigan. For example, range maps in Kurta (2008) show that the big brown bat (*Eptesicus fuscus*), hoary bat, and the Northern long-eared bat, while having wide distributions in the state were not listed as occurring on the Beaver Island archipelago. The limited ranges were almost certainly not due to those species being absent from the islands, but rather reflected a lack of sampling effort. Consequently, as the current project is part of a larger effort to better inventory the Beaver Island archipelago, it seemed reasonable that at least a minimal effort

should be made to investigate the bat community of the islands. This seemed particularly prudent in consideration of the presence of WNS in the Upper Peninsula of Michigan and the fact that the Beaver Island archipelago is located in high wind-energy zone (WERZB 2009).

Monitor descriptions

Acoustic monitors were placed in four locations, two on Garden Island and two on High Island (Figures 19 and 20). Monitors were placed to have one monitor on the windward side and one monitor on the lee side of each island. The latitude and longitudes of the monitors are presented in Table 6.

The acoustic monitors consisted of Wildlife Acoustics SM2Bat+ monitor and SM-UX microphones with foam windscreens. Microphones were placed approximately 1.5 meters above ground level and were oriented slightly downward to avoid microphone damage due to precipitation. Monitors were in place from June 10, 2015 through July 8, 2015, which is within the May 15 – August 15 summer residence period defined by the U.S. Fish and Wildlife Service Range Wide Indiana Bat Summer Survey Guideline (USFWS 2015).

Acoustic analysis

Acoustic data were analyzed using the automatic classification routine of Wildlife Acoustics' Kaleidoscope software, version 3.1.2. Kaleidoscope is approved by the US FWS for automatic identification of bat calls (USFWS 2015).

Figure 19. Acoustic monitoring locations on Garden Island.

Figure 20. Acoustic monitoring locations on High Island.

Table 6. Locations of bat monitors on Garden and High Islands.

Monitor	Station	Location	Latitude	Longitude
GARDEN	Bat Station #3	East side of island, Jensen's Harbor, Garden Island	45.797268	-85.4586
GARDEN	Bat Station #4	West side of island, Indian Harbor, Garden island	45.799155	-85.5117
HIGH1	Bat Station #1	East side of High Island	45.730781	-85.6536
HIGH2	Bat Station #2	West shore of High Island	45.717319	-85.6866

Results

Eight of the nine species of bats known to occur in Michigan were detected at all four monitoring locations. The most commonly detected species on the islands were the Eastern red bat, hoary bat, silver-haired bat, and the little brown bat, with the little brown bat being the most frequently detected at three of the four monitoring stations. Results for each site are presented in Table 7. Alpha codes for the bat species are presented in column 1. NOID indicates that the software could not identify the call to species.

Table 7. Number of bat passes detected at each bat monitoring site.

			Garden1	Garden2	High1	High2
			No. of passes	No. of passes	No. of passes	No. of passes
EPFU	*Eptesicus fuscus*	Big brown bat	8	83	42	84
LABO	*Lasiurus borealis*	Eastern red bat	949	44	225	352
LACI	*Lasiurus cinereus*	Hoary bat	90	940	21	5
LANO	*Lasionycteris noctivagans*	Silver-haired bat	151	68	258	643
MYLU	*Myotis lucifugus*	Little brown bat	1031	440	3265	758
MYSE	*Myotis septentrionalis*	Northern long-eared bat	4	7	3	2
MYSO	*Myotis sodalis*	Indiana bat	18	26	63	46
PESU	*Perimyotis subflavus*	Tricolored bat	54	9	64	14
NOID	*Software unable to identify call to species*		1338	1979	728	3076

Discussion

The results of this study present notable exceptions to previous reports regarding the distribution of bats in the Beaver Island archipelago; however, we must state immediately that these findings must also be viewed cautiously as will be explained. As noted earlier, Kurta (2008) indicated that the Indiana bat, big brown bat, hoary bat, Northern long-eared bat, silver-haired bat, and tricolored bat were not known to occur in the archipelago, whereas all of these species were detected in the current study, based on the Kaleidoscope analyses. Seefelt (2013) also reported the presence of the big brown bat, hoary bat, and silver-haired bat on High Island based on acoustic monitoring and the present study should be viewed as a confirmation of the presence of these species in the archipelago. This conclusion is further supported by the results of Klatt and Gehring (2014) in that the Eastern red bat, hoary bat, and silver-haired bat were

regularly detected throughout the summer of 2014 at the mid-lake plateau in Lake Michigan. As there are no roosting sites in the area of mid-lake plateau, it should be assumed that the bats were, in fact, making nightly foraging trips far out into Lake Michigan (60+ mile roundtrips). Thus, the far-ranging behavior of the tree bats, known from their migratory habits and Klatt and Gehring (2014), would argue that it would be surprising that these species did not occur throughout the archipelago.

This study presents the first reported occurrences, based on acoustic detections, of the Indiana bat, Northern long-eared bat, and the tricolored bat for the islands. The detection of the Northern long-eared bat may not be considered all that surprising, as this species is widely distributed across the state and is reported from areas around the archipelago by Kurta (2008), as well as on the mainland across the Upper Peninsula and the northern Lower Peninsula by Klatt and Gehring (2013) and Schools and Klatt (2015). The lack of previous reports of this species is likely due to low sampling effort.

The report here of the tricolored bat on both High and Garden Islands is also the first such report for these species from the islands, but once again may very well represent real occurrence. Kurta (2008) reports that the tricolored bat may not have occurred in pre-settlement Michigan, but rather entered the state as man-made hibernacula were established via mining operations. He notes that the northern progression of the tricolored bat occurred along the shores of Lake Michigan. His distribution map shows a series of disjunct occurrences along the eastern shore of Lake Michigan and several areas of the Upper Peninsula. The detections on High and Garden Islands may represent a limited number of summer roosting individuals which return to known hibernacula in the UP or that of Tippy Dam.

The most surprising result of this study, and the one that should probably be viewed with the most caution, is that, based on the Kaleidoscope analyses, we had multiple detections at all four monitoring locations of the Indiana bat. The islands are far outside the core range of the Indiana bat in Michigan, which is the southern Lower Peninsula and the nearest well-documented occurrence of the Indiana bat is at Tippy Dam near Manistee over 100 miles away. However, we cannot rule out that individual bats may be summer roosting in the islands, having come from Tippy Dam. The distance is not outside this species' ranging capacity, as many of the Indiana bats found in Lower Michigan migrate to summer roosts from hibernacula in Kentucky.

However, while the Wildlife Acoustics Kaleidoscope software is a USFWS approved program to analyze acoustic bat data, the results must be used with caution. Acoustically differentiating some bat species, especially those of the genus *Myotis*, can be extremely difficult because of overlapping call parameters between species within the same genus (such as the Indiana bat and the little brown bat). Quality of the recorded call can also induce uncertainty into automated call detection. For instance, a partial call from one species within a genus could be misidentified as a different species within the same genus. Partial calls can also be misidentified as a species from another genus. Consequently, results from acoustic sampling should be used in conjunction with live capture techniques. Verification of acoustic results with live capture techniques is critical when important or controversial decisions could be made based on the results, especially in

cases where rare or legally protected species are involved.

The cautions of acoustic monitoring and analysis aside, based on USFWS guidance regarding determining presence/likely absence of Indiana bats and Northern long-eared bats, our results indicate the presence of both on both High and Garden Islands. Under the Endangered Species Act, the USFWS has listed the long-eared bat as a Threatened Species and the Indiana bat as an Endangered Species. Both High and Garden Islands are well within the established range of long-eared bats and both islands have potential Northern long-eared bat summer roosting habitat. Similarly, High and Garden Islands are within the ranging capacity of summer roosting Indiana bats that over-winter at Tippy Dam. While these facts provide a level of confidence in the acoustic results, further verification with live capture would be prudent before making any decisions based on the acoustic results.

Additionally, sole use of acoustic monitoring only allows for the determination of a species presence at a site. It does not allow for determination of gender, breeding status, or how the species is utilizing the site. While standardized sampling methodology permits a relative comparison of bat pass counts between different sites, the number of bat passes may or may not be an accurate indicator of population density. Further study would be required to make any determinations about bat populations or habitat use on the islands.

As a final note, Seefelt (2013) found a significant effect of wind direction on the number of bat passes detected. While this study was also designed to examine in a limited way the question of the effect of wind on bat activity levels, no consistent pattern was found among the species with respect to activity levels on the windward versus lee sides of the islands.

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Photo by Bradford S. Slaughter.

Rare Snail Surveys
Methods

Target Species

Four rare aquatic snails (Gastropoda) have been documented in the Beaver Island archipelago. Great Lakes physa (*Physella magnalacustris*), a species of special concern, was collected on the Beaver Island shoreline by Bryant Walker pre-1936, and High Island shoreline by Sherman Moore circa-1920. Campeloma spire snail (*Cincinnatia cincinnatiensis*), a species of special concern, was collected along the shoreline and at one stream site on Beaver Island by Calvin Goodrich pre-1954. Deepwater pondsnail (*Stagnicola contracta*), a state endangered species, was documented in two lakes on Beaver Island in 1939 and 1940. Coldwater pondsnail (*Stagnicola woodruffi*), a species of special concern, was documented at one location on High Island and four locations on Beaver Island in 2009.

Of these four species, Great Lakes physa and Campeloma spire snail were prioritized as targets over the other two, since a thorough survey for deepwater pondsnail requires use of SCUBA, which was beyond the scope of this project, and the presence of coldwater pondsnail had already recently been confirmed on High Island.

Although there were no existing records for rare terrestrial snails in the Beaver Island archipelago, the potential for them to occur there was clear based on available habitat and occurrences documented in nearby inland counties. For example, multiple rare species of the Vertigo genus have been documented in Delta, Mackinac, and Schoolcraft counties (Nekola 2003).

No occurrences of rare aquatic or terrestrial snails had previously been recorded from Garden Island. This is likely due to a lack of survey effort in recent decades.

Field Surveys

Collection of aquatic and terrestrial snails was made by hand picking shells and live individuals. Collection sites, in some cases, were grouped near each other in order to sample different microhabitat types across a general location. Snails were placed in poly bags, and when live individuals were collected, ethanol was added. One bag of forest leaf litter and one bag of shoreline drift were collected at two sites for later processing. A handheld GPS was used to record the location of collection sites. Photographs of microhabitat and larger scale habitat types were taken.

Though survey effort focused on collection of aquatic and terrestrial snails, a freshwater mussel (Unionidae) survey was performed at one site. An approximately 84m^2 area in wadeable water off the Garden Island shoreline was searched with the aid of a glass bottom bucket. Shells found were identified to species. Collections were covered by a threatened and endangered species permit and scientific collector's permit from MDNR.

Sample Processing

Snail shells were separated from organic and inorganic material, and then shells were identified to species under a stereo microscope. Magnification of 10x was used for most shells, with occasional use of 20-30x to see detailed identification characters on small specimens. Photographs of several species were taken through the microscope for documentation and future use.

Results

Garden Island

Eleven sites were surveyed for snails on Garden Island, June 10, 2015 (Figure 21, Table 9). A total of 24 species were found, including a new occurrence of the special concern Tapered vertigo (*Vertigo elatior*) (Table 10). This is the first record of any of the rare Vertigo species in the Beaver Island archipelago. The greatest species richness (18) was found at Site 15 on Garden Island. The only unionid mussel species found in the area searched at Site A was fatmucket (*Lampsilis siliquoidea*). These were all empty shells. Numerous empty zebra mussel (*Dreissena polymorpha*) shells were also found in this area.

High Island

Collections of aquatic and terrestrial snails were made at six sites on High Island, June 9, 2015 (Figure 22). A total of 15 species were found, including one updated historical record (Table 11). The occurrence of the special concern Great Lakes physa is an update of a circa-1920 record. A non-native snail species, Mud bithynia, (*Bithynia tentaculata*), was found at one site on High Island.

A total of 28 snail species were found on High and Garden Islands combined. Photographs of several snail species are shown in Figures 23-31. Bar (pencil lead) in all photographs is 0.7mm x 5mm.

Figure 21. Location of snail survey sites 1-6 on Garden Island.

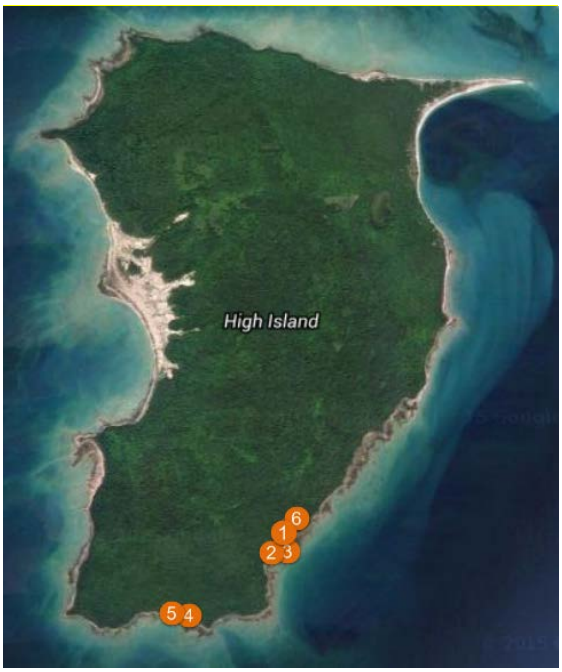

Figure 22. Locations of snail survey sites 7-17 and unionid mussel survey site A on High Island.

Table 9. Location of snail collection sites on High and Garden Islands, and unionid mussel survey site on Garden Island.

Site #	Island	Latitude (N)	Longitude (W)	Location/Habitat Note
1	High	45.70433	85.67078	seeping shoreline
2	High	45.70290	85.67260	near anchor point
3	High	45.70270	85.67135	shoreline marsh
4	High	45.69799	85.68330	S. tip pond
5	High	45.69807	85.68430	S. tip pond
6	High	45.70537	85.67113	ash clearing
7	Garden	45.79939	85.45707	marsh
8	Garden	45.79826	85.46262	wet edge of fen/bay
9	Garden	45.79520	85.46440	back in coastal fen
10	Garden	45.77975	85.48035	10m from water's edge
11	Garden	45.79788	85.46039	coastal fen wet flats
12	Garden	45.77990	85.48060	shoreline between Lake MI and fen
13	Garden	45.79781	85.46007	coastal fen
14	Garden	45.79848	85.50689	physella from water, others water's edge drift
15	Garden	45.77991	85.48107	N. cut pond
16	Garden	45.79953	85.45728	near anchor point
17	Garden	45.78080	85.48024	N. cut lake
A	Garden	45.79969	85.45702	mussel survey site near anchor point

Table 10. Numbers of aquatic and terrestrial snails collected at Sites 7-17 on Garden Island, June 2015.

Common Name	Species	7	8	9	10	11	12	13	14	15	16	17
Suboval ambersnail	*Catinella vermeta (=avara)*	2	9		5	3		9	9	1	12	
Pointed campeloma	*Campeloma decisum*								2			
Angular disk	*Discus catskillensis* (terrestrial)	2						2	1			
Liver elimia	*Elimia livescens*		4			5					1	
Lowland pillsnail	*Euchemotrema leai* (terrestrial)				15		3	11	26	10		
Dusky fossaria	*Fossaria dalli*				1	5		2	1			
Golden fossaria	*Fossaria obrussa*									1		
White snaggletooth	*Gastrocopta tappaniana* (terr.)								4			
Disc gyro	*Gyraulus circumstriatus*							1				
Flexed gyro	*Gyraulus deflectus*								1			
Minute gem	*Hawaiia minuscula* (terrestrial)					2						
Two-ridge rams-horn	*Helisoma anceps*				2	1			1	1	1	
Amber glass	*Nesovitrea electrina* (terrestrial)								2	1		
Blunt ambersnail	*Oxyloma retusum* (terrestrial)	1			4		2		6	9		
Tadpole physa	*Physella gyrina*	2	1		2		1	1	9	1	1	
Marsh rams-horn	*Planorbella trivolvis*			3					2			1
St. Lawrence pondsnail	*Stagnicola emarginata*		1						3			
Costate vallonia	*Vallonia costata* (terrestrial)								2			
Iroquois vallonia	*Vallonia excentrica* (terrestrial)		1						1			
Threeridge valvata	*Valvata tricarinata*		1			1						6
Tapered vertigo	*Vertigo elatior (SC) (terrestrial)*								1			
Ovate vertigo	*Vertigo ovata* (terrestrial)								1			
Quick gloss	*Zonitoides arboreus* (terrestrial)				4							
Black gloss	*Zonitoides nitidus* (terrestrial)								1			

Table 11. Numbers of aquatic and terrestrial snails collected at Sites 1-6 on High Island, June 2015.

Common Name	Species	1	2	3	4	5	6
Mud bithynia	*Bithynia tentaculata* (introduced)	4					
Suboval ambersnail	*Catinella vermeta (=avara)*	9	1	8		1	
Liver elimia	*Elimia livescens*	1	1				
Dusky fossaria	*Fossaria dalli*	4		2		3	
Golden fossaria	*Fossaria obrussa*				5		
Disc gyro	*Gyraulus circumstriatus*				11		
Flexed gyro	*Gyraulus deflectus*						9
Ash gyro	*Gyraulus parvus*	1					
Blunt ambersnail	*Oxyloma retusum* (terrestrial)	5	2	3			1
Tadpole physa	*Physella gyrina*			1		1	3
Great Lakes physa	*Physella magnalacustris* (SC)		8				
Marsh rams-horn	*Planorbella trivolvis*					11	
St. Lawrence pondsnail	*Stagnicola emarginata*		8				
Flat-whorled pondsnail	*Stagnicola exilis*				5	1	
Quick gloss	*Zonitoides arboreus (terrestrial)*			11			

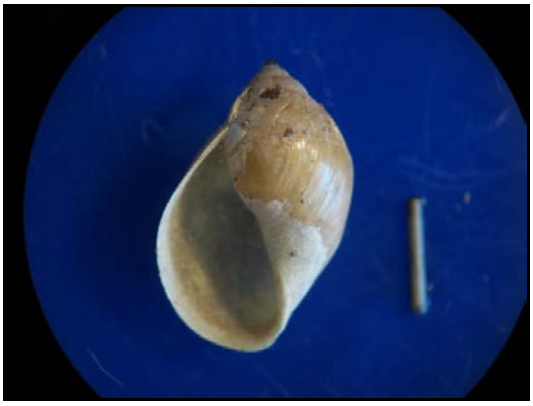

Figure 23. Great Lakes physa (*Physella magnalacustris*), a species of special concern, (Site 2) on High Island. Bar (pencil lead) in all photographs is 0.7mm x 5mm.

Figure 24. Costate vallonia (*Vallonia costata*) left and Iroquois vallonia (*Vallonia excentrica*) right (Site 14) on Garden Island.

Figure 25. Iroquois vallonia (*Vallonia excentrica*) (Site 8) on Garden Island.

Figure 26. White snaggletooth (*Gastrocopta tappaniana*) *left* and Tapered vertigo (*Vertigo elatior,* SC) *right*, (Site 14) on Garden Island.

Figure 27. Threeridge valvata (*Valvata tricarinata*) from Site 17 on Garden Island.

Figure 28. Lowland pillsnail (*Euchemotrema-leai*) from Site 10 on Garden Island.

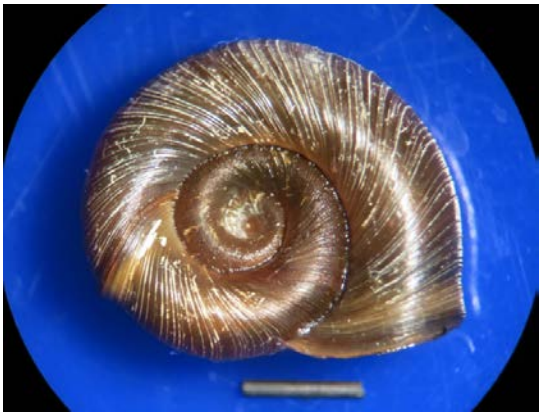

Figure 29. March rams-horn (Planorbella trivolvis) from Site 17 on Garden Island. Right (umbilical) side up.

Figure 30. Marsh rams-horn (*Planorbella trivolvis*) from Site 17 on Garden Island. Left (spire) Side up.

Figure 31. Ovate vertigo (*Vertigo ovata*) from Site 14 on Garden Island.

Discussion

The documentation of snail species occurrences, even if not currently considered state endangered, threatened, or special concern, provides needed information for assessing the conservation status of these species at the state and range-wide level. Due to very low levels of survey effort across the state in the last 50+ years, the current status and distribution of snails in Michigan is not well known. Impacts such as habitat alteration, fragmentation, changing moisture and temperature regimes, and historical water quality issues have made snails one of the most endangered animal groups in North America. In a recent assessment of freshwater snail species from Canada and the United States done by the American Fisheries Society, 74% of 703 species were considered imperiled, with 67 of these species extinct (Johnson et al. 2013).

Only a small fraction of potential habitat for rare snails on the islands was surveyed. Much information on rare snail communities could be gained by further survey, especially Garden Island, which has had very little, if any, survey effort for snails in the past. Surveys of the inland lakes on Garden Island (with mask and snorkel) could reveal new occurrences of coldwater pondsnail.

No deepwater pondsnail were found in this survey, however SCUBA would be needed for a thorough survey of the deeper habitats it is typically found in. Surveys targeting historical deepwater pondsnail occurrences in four inland lakes and two streams on Beaver Island were made in 1999, but none were found (Penskar et al. 1999). Nine species of relatively common snails were documented in those surveys (*Campeloma decisum, Physella gyrina, Planorbella campanulata, Lymnaea stagnalis, Valvata tricarinata, Elimia livescens, Helisoma anceps, Bythynia spp.,* and *Stagnicola elodes*).

All of the terrestrial snail species found in this 2015 survey have also been found in nearby counties on the mainland of Michigan, except for one. Iroquois vallonia (*Vallonia excentrica*) was not recorded historically from Chippewa, Delta, Luce, Mackinac, or Schoolcraft Counties, and it was not found in recent (circa 2000) surveys within these same counties (though it is known from other counties in Michigan). It was present at only three out of 242 sites in 17 Wisconsin counties (Nekola 2003). Though not a listed species, it appears to be rare, and the occurrences documented in this 2015 survey may represent important populations for this species.

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Invasive Plant Surveys
Methods

Selection of Target Species

Invasive plants were selected from those identified 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 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. European marsh thistle was moved from the lower threat list (2011) to the priority species list in 2015, based on its observed spread on Beaver Island and elsewhere throughout northern Michigan.

Table 12 lists the invasive species targeted, the natural communities they invade, and the rare species on Garden and High Islands that occur in those communities. While these species were the primary focus for survey, observations of any other species known to be invasive elsewhere, but not yet documented from the region were also noted. Also, species that have colonized in large patches, but are not currently on the radar as having significant impacts were also mapped.

Table 12. Priority invasive species targeted on Garden and High Island, the natural communities they are likely to colonize and the rare species that occur in these communities.

Invasive Species	Natural Communities	Vulnerable Plants	Vulnerable Animals
coltsfoot	coastal fen	bulrush sedge (T)	American bittern (SC)
European marsh thistle	Great Lakes marsh	butterwort (SC)	Caspian tern (T)
hybrid cat-tail	limestone cobble shore	English sundew (SC)	common loon (T)
Japanese knotweed	northern fen	Houghton's goldenrod (LT, T)	common tern (T)
narrow-leaved cat-tail		Lake Huron tansy (LT, T)	Great Lakes physa (SC)
non-native phragmites		native phragmites	Hine's emerald dragonfly
purple loosestrife		Richardson's sedge (SC)	(LE, E)
reed canary grass			least bittern (T)
sweet clovers			tapered vertigo (SC)
baby's-breath	open dune	dune stitchwort	dune cutworm
lyme grass	Great Lakes barrens	dwarf lake iris (LT, T)	Lake Huron locust (T)
Oriental bittersweet	Wooded dune and swale	fascicled broomrape (T)	
spotted knapweed		Lake Huron tansy (T)	
		pitcher's thistle (LT, T)	
		Pumpelly's brome grass (T)	
wild parsnip	prairies		
autumn olive	boreal forest	calypso orchid (T)	Lake Huron locust (T)
common buckhorn	dry-mesic northern forest	climbing fumitory (SC)	merlin (T)
Eurasian honeysuckles	dry northern forest	dwarf-lake iris (LT, T)	northern Goshawk (T)
garlic mustard	mesic northern forest	gensing (T)	osprey (SC)
glossy buckthorn	wooded dune and swale	green spleenwort (SC)	red-shouldered Hawk (T)
multiflora rose		male fern	
Oriental bittersweet		pine drops (T)	
		ram's-head orchid (SC)	
		round leaf orchid (E)	
		Michigan monkeyflower (LE, E)	

Field Surveys

The primary focus was to search for target species in areas where natural community and rare species surveys were being conducted. Surveys were conducted while en route to survey sites and at the sites themselves. 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 13 and are based on protocols established by the Michigan Department of Natural Resources (MDNR) Parks Stewardship Program (Clancy 2011).

Table 13. 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 and location of each mapped infestation was created. The invasive species points were superimposed over a map with the, high quality natural community for each island, and are shown in Figures 18 and 19.

Results

Seven of the priority invasive plants targeted were documented on Garden and High Islands, including European marsh thistle, hybrid cat-tail, narrow-leaved cat-tail, non-native phragmites, reed canary grass, spotted knapweed and wild parsnip (Table 14). Non-native phragmites was less abundant than in 2011, due to recent treatments, but there were some sizable patches of cat-tails and reed canary grass. European marsh thistle was frequent along the transition zone of coastal fen and boreal forest on the north side of Garden Island. The first known patch of spotted knapweed to be noted in the dunes on the west side of High Island was documented. A huge source infestation of spotted knapweed was documented along the northeast sand spit on High Island. Garlic mustard, common buckthorn, glossy buckthorn, multiflora rose, baby's-breath and lyme grass were still notably absent since our 2011 surveys. Nine lower priority species were also documented and are listed in Table 15.

Table 14. Priority invasive plants documented on Garden Island during 2015 surveys.

Common Name	Scientific Name	Common Name	Scientific Name
European marsh thistle	*Cirsium palustre*	reed canary grass	*Phalaris arundinacea*
hybrid cat-tail	*Typha* x*glauca*	spotted knapweed	*Centaurea stoebe*
narrow-leaved cat-tail	*Typha angustifolia*	wild parsnip	*Pastinaca sativa*
non-native phragmites	*Phragmites australis* ssp. *australis*		

Table 15. Lower threat invasive plants documented on Garden Island during 2015 surveys.

Common Name	Scientific Name	Scientific Name	Common Name
bittersweet nightshade	*Solanum dulcamara*	common St. John's-wort	*Hypericum perforatum*
bladder campion	*Silene vulgaris*	common tansy	*Tanacetum vulgare*
bull thistle	*Cirsium vulgare*	mossy stonecrop	*Sedum acre*
Canada thistle	*Cirsium arvense*	sweet clover	*Melilotis alba, M*
common mullein	*Verbascum thapsis*		

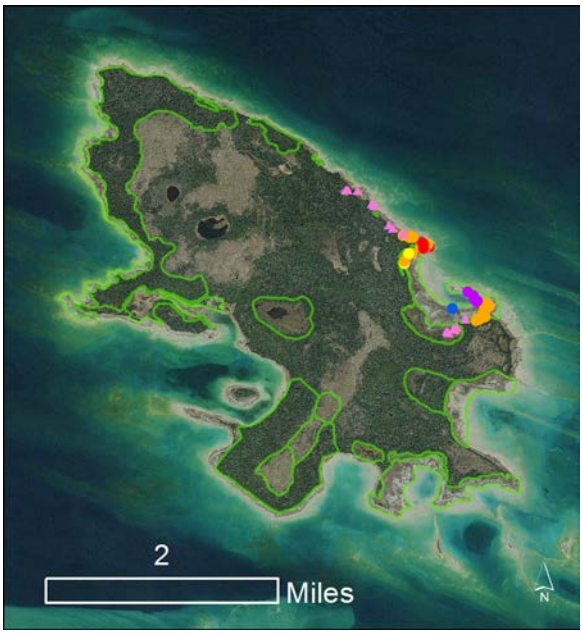

Figure 32. Priority invasive species mapped on Garden Island during 2015 surveys.

Figure 33. Priority invasive species mapped on High Island during 2015 surveys.

Discussion

As noted in our 2011 report and in the Natural Community section of this report, the high quality natural communities on Garden and High Islands are relatively free of invasive species. While this is good news, complacency is not recommended. The six priority species documented have a foothold in the more disturbed areas on the islands and will spread rapidly over time. Aggressive early detection and rapid response is recommended as soon as possible for all high priority species.

Most of the invasive phragmites mapped in 2011 has been treated, due to rapid response efforts. However, some small patches were documented along with patches of cat-tails and reed canary grass. The latter two species will take the place of phragmites, if not treated. Eurasian marsh thistle spreads very

quickly by wind dispersal of seed and a dedicated effort to nip it in the bud is required to prevent it from become a serious problem. This thistle has the potential to spread into the boreal forests, wooded dune and swale and open coastal communities. Spotted knapweed has expanded dramatically on the northeast side of High Island and it now has a toehold at the southern end of the western dunes. It is a near monoculture on the northeastern spit of High Island. This is an enormous source population for the open dunes and Great Lakes barrens communities, as well as smaller foredunes and sand and gravel beaches where Pitcher's thistle, Lake Huron tansy and Lake Huron locust are holding on. Mossy stonecrop has established sizable patches on several small spits on both islands, but its long-term impacts are not known.

Recommended Priorities for Invasive Plants

Invasive phragmites
Early detection and treatment of phragmites should be continued throughout the entire coastline. This has been highly effective. Annual monitoring and treatment as needed should be conducted to prevent regrowth and establishment of root and seed propagules. Care should be taken to distinguish native from non-native phragmites, as the desirable native phragmites is common around the islands.

Cat-tails and reed canary grass:
These species should be monitored and treated throughout the coastal zone as soon as possible, even if they are not in high quality areas. Occurrences of particular concern are those that are established on the edges of Jenson harbor.

European marsh thistle
A dedicated effort to treat European marsh thistle and determine its full extent on the islands should be undertaken. Since this species is often difficult to get to for treatment—it often occurs as clusters of widely distributed plants in dense forested areas such as boreal forest and cedar swamp—it is most cost-effective to treat plants while surveying. It will be difficult and expensive to relocate for later treatment. Initial survey findings will dictate where future surveys should be focused. This is a sleeper that should not be ignored.

Spotted knapweed
Spotted knapweed is the phragmites of the dunes. While it doesn't spread by underground rhizomes as phragmites does, it is a prolific seeder and population densities increase rapidly, as witnessed by the near mono-culture patches now established on the northeastern spit of High Island. This is degrading habitat for the Lake Huron locust, piping plover and terns. Knapweed is making its' way through the Great Lakes barrens on High Island and is documented in sandy coastal areas on Garden Island that are colonized by Pitcher's thistle, Lake Huron tansy and Lake Huron locust. A small population has finally reached the southern end of High Island's western dunes.

Best control practices for spotted knapweed are not as well-known as those for invasive phragmites. It is a strong seed-banker with seeds that can remain viable for over ten years. The goal is to remove plants before they produce new seeds year after year to deplete the seedbank. Plants can be hand-pulled in areas where the root crown can be extracted easily. Gloves should be worn as this species can be a skin irritant for some people. There are reports that hand-pulling can cause substantial disturbance to native

species in high quality habitat and this should be taken into consideration when treating. There are pros and cons to herbicide application, but in places where knapweed is very dense this may be a viable option.

A reasonable strategy for High Island includes the following (all hand-pulling should be done prior to seed production and extract the root):

1) Aggressively and thoroughly hand pull any plants in the high quality open dunes on the west side of High Island starting with the mapped colony at the southern end.
2) Work systematically north from there to detect and hand-pull any observed plants all the way around the north end of the island pushing knapweed back towards the source populations on the east side.
3) Traverse the entire Great Lakes barrens and hand-pull any observed plants. This high quality site is already under considerable threat from patches of spotted knapweed and it is also close to the large source population on the spit. An immediate dedicated effort to hand pull any observed plants within the barrens will make a big difference. Waiting a few years, will result in escalating costs and reluctant stewards.
4) Consider treatment options carefully for the large source population on the spit. Engage experts who are knowledgeable about the rare plants and animals that occur there. Carry out selected options as experimental treatments using an adaptive management approach. Conduct pre- and post-monitoring and adapt techniques accordingly. Testing of treatments could be conducted in old fields on the Islands where knapweed is also abundant. Keep in mind that many mainland restoration efforts for prairies have the luxury of eradicating knapweed by wiping the slate clean with herbicides first. This is not the case for the High Island spit; it has many vulnerable species that need to be considered carefully before treatment is undertaken.
5) Hand-pull plants in lower priority areas on High Island starting in areas where there are occurrences of Lake Huron tansy and Pitcher's thistle.
6) Work systematically around Garden Island and hand pull observed plants. Focus on habitat for Pitcher's thistle, Lake Huron tansy and Lake Huron locust. Note larger source populations and consider alternative treatments for these as necessary, using the findings from test treatments on High Island.
7) Establish no-cross zones around the high quality natural communities and monitor them to keep knapweed out.

Oriental bittersweet

A single occurrence of bittersweet was documented in 2011 at the top of one of the open dune blowouts on High Island. Determination of whether it was invasive or native was not possible as it was immature. This species is wreaking havoc at Indiana dunes and poses a distinct threat to the islands. A rigorous effort to track down and assess this occurrence should be made and regular monitoring for this species is advised. This would be early detection at its best, for an extremely high threat species that has not been seen elsewhere on either island. A determination of whether it is native or non-native should be made before attempting treatment.

Japanese Hops

Relocate the infestation of Japanese hops, mapped in 2011 near Sorry Burn Lake. Assess its status and treat as necessary.

Mossy stonecrop
Sizable patches of this species were documented in several locations on both Garden and High Islands, on disturbed spits along the coast. It should be researched to determine the risk of impacts and potential control methods.

Wild parsnip
Chemicals in the sap of wild parsnip react with sunlight and can burn exposed skin. It is quite abundant on Garden Island in most of the openings and old fields and along many trails. It was also documented on High Island, but much less frequently. Control requires extracting or slicing the root and managing the seed bank. Extreme caution should be taken when working with this species to avoid serious skin burns.

Other species
Start in the high quality natural communities and treat lower threat species that are already mapped or as they are newly observed. Monitor a buffer around the high quality natural communities as a no-cross line for invasive species. Additional propagules of known or new invasive plants will continue to arrive on the islands. Field staff, landowners and recreationists are often the first to determine the next big problem. Be vigilant and report what you find. Reports can be made to the Midwest Invasive Species Information Network (MISIN).

Monitoring
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.

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