Natural Community Surveys of West Sister Island, Ottawa National Wildlife Refuge, Lake Erie

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Cover Photo: West Sister Island's lighthouse and colonial nesting waterbirds. Photo by Joshua G. Cohen.

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Erie Angler Fishing Charters provided safe transport to and from West Sister Island. Photo by Joshua G. Cohen.

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Introduction

Great Lakes islands provide critical habitat for native biodiversity and support rare and endemic natural communities. A diverse assemblage of over 32,000 islands occurs across the Great Lakes and in the connecting channels (Henson et al. 2010). The United States Fish and Wildlife Service (USFWS) National Wildlife Refuge (NWR) system includes thirty-six islands across the Great Lakes. These islands are managed to maintain the ecological integrity of natural communities in order to support the needs of priority and migratory bird species, threatened and endangered species, and resident wildlife and also to provide stopover habitat for birds and pollinators migrating across the Great Lakes.

Many of the islands within the Great Lakes that are part of the NWR system are remote, difficult to access, and challenging to survey due to lack of infrastructure and rugged terrain. Despite limited access, these islands face a variety of threats to native biodiversity and rare taxa including establishment and spread of invasive plant and animal species and the impacts of climate change. Unfortunately, within these unique geographies biodiversity data is limited or outdated, which hinders effective management and decision-making.

To address this information gap, the USFWS contracted Michigan Natural Features Inventory (MNFI) to conduct rare and invasive plant species mapping, qualitative natural community surveys, and quantitative forest sampling over the course of two years on NWR Great Lakes islands. In 2021, surveys were conducted in the Shiawassee and Horicon Complexes. Within the Horicon Complex, work was completed in the Green Bay NWR and natural communities were evaluated on Detroit, Plum, Poverty, Rocky, and Saint Martin Islands in northern Lake Michigan (Cohen et al. 2022a). Within the Shiawassee Complex, work was completed in the Michigan Islands NWR and natural community surveys and forest plot sampling were conducted on Big Charity, Crooked, and Sugar Islands in Lake Huron (Cohen et al. 2022b). In 2022, surveys were conducted in the Ottawa and Seney Complexes. Within the Ottawa Complex natural community surveys and forest plot sampling were conducted on West Sister Island in Lake Erie (Figure 1). Within the Seney Complex natural community surveys were conducted on the Huron Islands in Lake Superior, Harbor Island in Lake Huron, and Gull Island in Lake Michigan. In addition, forest plot sampling was conducted on the Huron Islands and Harbor Island (USFWS 2021a).

West Sister Island limestone bedrock lakeshore. Photo by Elizabeth A. Haber.

This report focuses on the natural community surveys conducted in 2022 on West Sister Island. For information on the natural community surveys conducted on the Gull Island (Lake Michigan), Harbor Island, and the Huron Islands refer to Cohen et al. 2023a, Cohen et al. 2023b, and Cohen et al. 2023c. For information on the rare and invasive plant species surveys conducted on West Sister Island, refer to USFWS 2021b Bassett et al. 2023.

A natural community is defined as an assemblage of interacting plants, animals, and other organisms that repeatedly occurs under similar environmental conditions across the landscape and is predominantly structured by natural processes rather than modern anthropogenic disturbances. Historically, Indigenous Peoples were an integral part of natural communities across the Great Lakes region with many natural community types being maintained by native management practices such as prescribed fire, wildlife management, and plant harvesting, seeding, and planting. MNFI's natural community classification recognizes 77 natural community types in Michigan (Kost et al. 2007, Cohen et al. 2015). 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 evolved over the millennia (Kost et al. 2007, Cohen et al. 2015).

A critical goal of this project was to collect new data for natural communities to provide natural resource managers and planners with accurate, detailed, standardized baseline information on the current status of ecosystems on these islands that can help guide biodiversity stewardship and restoration and ongoing planning efforts with a focus on invasive species management. Qualitative surveys assessed the integrity, classification, and delineation of natural community occurrences and detailed the vegetative structure and composition, ecological boundaries, landscape and abiotic context, threats, management needs, and restoration opportunities associated with each site. 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 natural community surveys and also presents a prioritization of stewardship and monitoring of the natural communities documented on West Sister Island.

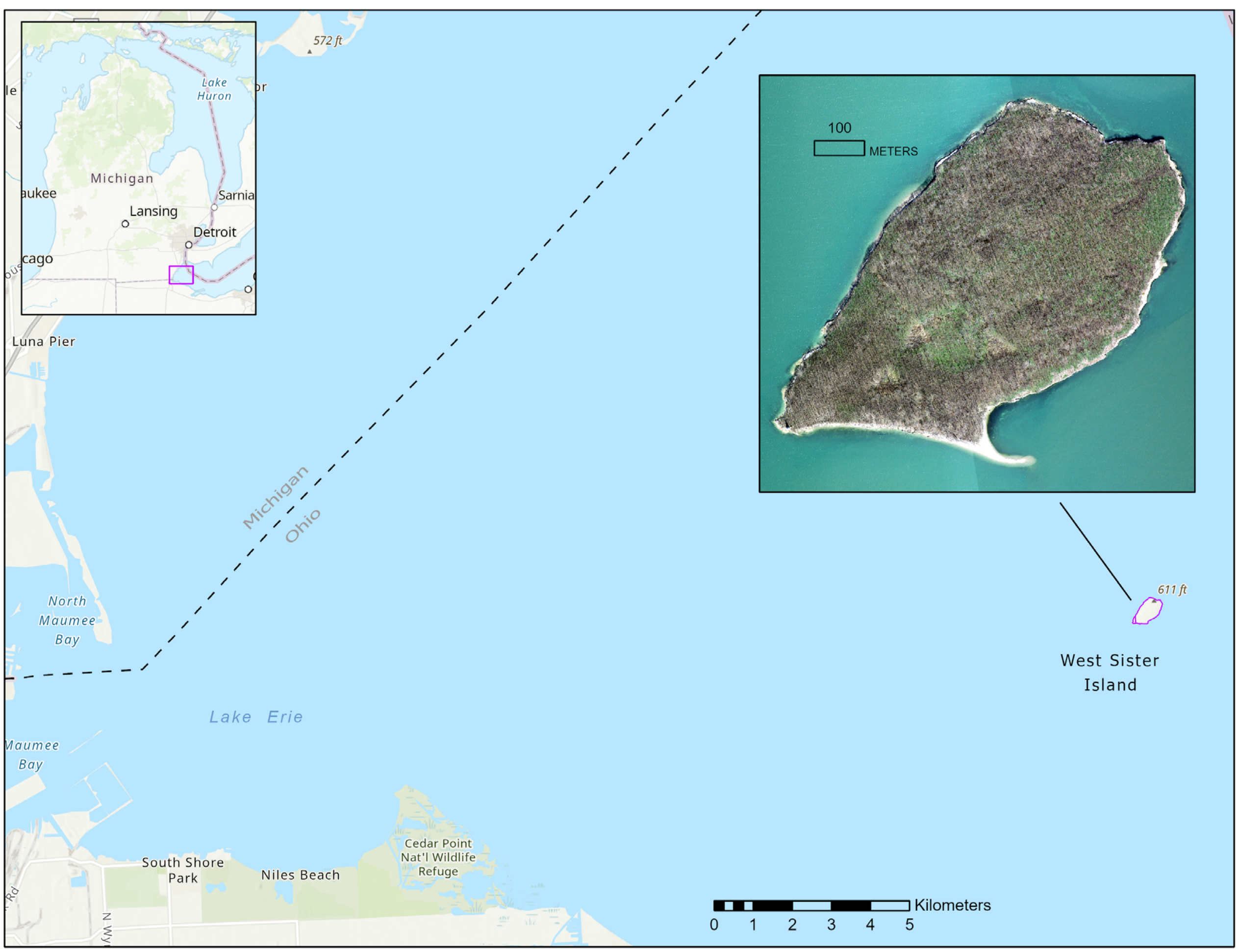

Figure 1. Map of West Sister Island. West Sister Island occurs in Lake Erie and is part of the Pelee Archipelago.

Methods

Study Area

West Sister Island occurs in Ohio in the Western Basin of Lake Erie and is part of the Pelee Archipelago. The island is located 8.75 miles north of the Ohio mainland. West Sister Island is characterized by glacial till overlying a limestone shelf from the Tymochtee Dolomite formation (Forsyth 1988). The interior of the island is dominated by hackberry (*Celtis occidentalis*) forest and supports nesting colonies of great blue heron (*Ardea herodias*), great white egret (*Ardea alba*), black-crowned night heron (*Nycticorax nycticorax*), and double-crested cormorant (*Phalacrocorax auritus*) (Shieldcastle and Martin 1999). The shoreline of West Sister Island is primarily composed of exposed limestone bedrock with both limestone lakeshore cliff and limestone bedrock lakeshore and localized pockets of limestone cobble shore. Limestone bedrock lakeshore occurs along the western shore of the island and limestone lakeshore cliff occurs primarily along the eastern shoreline.

The 82-acre island is jointly owned by the United States Coast Guard and the U.S. Fish and Wildlife Service. The West Sister Island National Wildlife Refuge was established in 1937 as a refuge and breeding ground for migratory birds and other wildlife and the island supports the largest wading bird nesting colony on the U.S. Great Lakes. West Sister Island provides nesting habitat for 40% of all the nesting herons and egrets in the U.S. Great Lakes, although competition by increasing numbers of double-crested cormorant has contributed to declines in nest numbers of black-crowned night heron on the island (Shieldcastle and Martin 1999). West Sister Island is managed by the NWR to maintain the existing natural communities in order to support the needs of priority and migratory bird species, threatened and endangered species, and resident wildlife. Access to the island is restricted to permitted research and public access is prohibited.

The West Sister Island lighthouse remains an important navigational aid in Lake Erie's Western Basin. Photo by Joshua G. Cohen.

West Sister Island has a rich cultural history (McMeans 1982, Dykes 2018). In 1847, a lighthouse was constructed on the southwestern point of the island to mark the west end of the South Passage through Lake Erie's Bass Islands. The lighthouse and accompanying keeper's quarters were staffed for 90 years until 1937 when the light was automated and the island was designated as a wildlife refuge. During the 90 years of occupancy, selective logging and clearing occurred across the island with wood being used for firewood and building materials and clearings being created to feed the livestock that the lighthouse keepers brought to the island. In the 1920s, West Sister Island was utilized by bootleggers running liquor from Canada to Ohio. During World War II, West Sister Island was used for artillery practice, which resulted in the destruction of the lighthouse keeper's house. The West Sister Island Lighthouse remains an active aid to navigation (McMeans 1982, Dykes 2018).

Natural community surveys were conducted on West Sister Island from July 18th through July 20th, 2022. Prior to this survey effort, the West Sister Island had never been surveyed by MNFI staff.

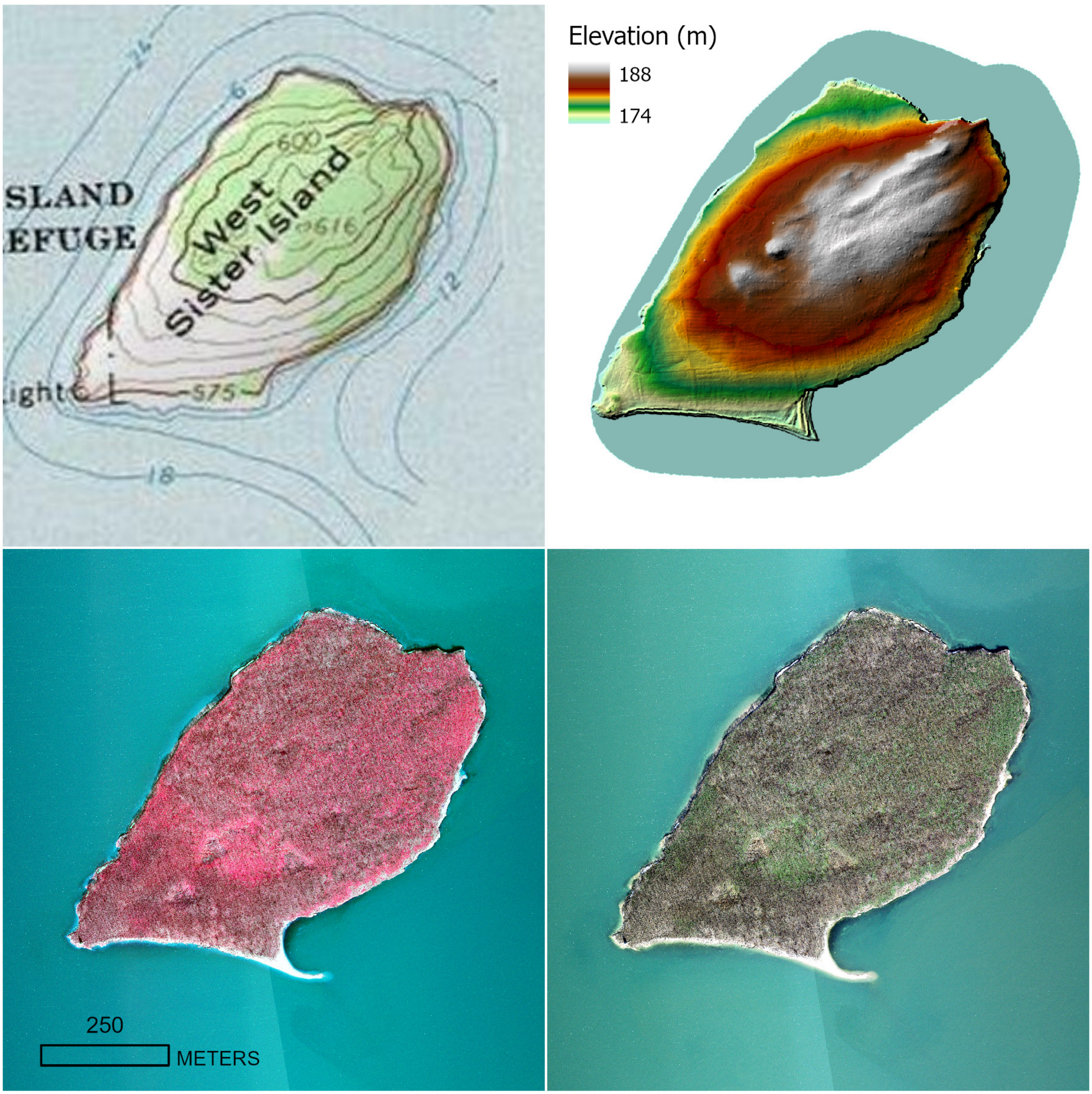

Figure 2. Spatial data layers and imagery used to prioritize survey effort on West Sister Island. Clockwise from top left: topographic map, elevation with shaded relief, recent true color leaf-off imagery (2020), and color infrared imagery imagery (2020) (USGS 2016, State of Ohio 2020, USGS 2022).

Field Survey Prioritization

Prior to on-the-ground-surveys, MNFI ecologists conducted Geographic Information System (GIS) analysis and aerial photo interpretation to delineate preliminary natural communities for West Sister Island and identify potential survey targets. To assist with delineation, we evaluated multiple series of aerial imagery and spatial data layers, including color infrared imagery (2020), recent true color leaf-off imagery (2020), topographic maps, digital elevation models, and hillshade (a grayscale 3D representation of the terrain surface) (Figure 2). The preliminary delineation of natural community types across the island helped focus subsequent surveys of natural communities as well as invasive species and rare plant surveys and provided the framework for stratifying random sampling for the forest plot sampling effort. The MNFI natural community classification system was used as the classification framework since no equivalent contemporary classification system has been developed for Ohio (Anderson 1982, Kost et al. 2007, Cohen et al. 2015, Cohen et al. 2020).

The targets for the natural community assessment were prioritized based on the rarity and estimated integrity of the preliminarily delineated natural communities using the Natural Heritage sampling prioritization principal. This prioritization principal emphasizes that natural community survey efforts should be focused on the rarest and highest quality natural communities (Figure 3) (NatureServe 2002, Rocchio et al. 2018). Rarity is determined by evaluating a natural community's conservation status both at the state and global levels (i.e., S and G Ranks) (Appendix 1). Integrity is determined by employing Natural Heritage 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, Faber-Langendoen et al. 2016).

Field Survey

A qualitative, plotless sampling design was employed to survey natural communities on the NWR islands. For every island, MNFI ecologists evaluated each natural community type that was delineated during the GIS analysis described above and each natural community type polygon was ground-truthed through meander surveys. The meander survey covered a representative sample of each polygon, and involved investigating typical and unique aerial signatures, traversing topographic variation, and visiting noticeable vegetation zones and soil moisture types. A Samsung Tablet in tracking mode was used during the meander surveys to create a record of routes taken within the surveyed natural community polygons. Prioritized communities (rare community types and high-quality examples of any community type) received more survey effort than common and degraded communities. According to Natural Heritage Methodology, if a site meets defined requirements for ecological condition, landscape context, and size of the area of interest (MNFI 1988) it is categorized as an example of that specific natural community type, entered into MNFI's database as an element occurrence, and given a letter rank. Ecological field surveys were conducted during the 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 GIS analysis was employed.

<table>
<tr><th rowspan="2">Global / State Conservation Status Rank Combination</th><th colspan="4">Ecological Integrity Assessment Rank</th></tr>
<tr><th>A
Excellent Integrity</th><th>B
Good Integrity</th><th>C
Fair Integrity</th><th>D
Poor Integrity</th></tr>
<tr><td>G1S1, G2S1,
GNRS1, GUS1</td><td bgcolor="red"></td><td bgcolor="red"></td><td bgcolor="red"></td><td bgcolor="red"></td></tr>
<tr><td>G2S2, GNRS2,
G3S1, G3S2, GUS2</td><td bgcolor="red"></td><td bgcolor="red"></td><td bgcolor="red"></td><td></td></tr>
<tr><td>GUS3, GNRS3, G3S3, G4S1,
G4S2, G5S1, G5S2, any SNR</td><td bgcolor="red"></td><td bgcolor="red"></td><td></td><td></td></tr>
<tr><td>G4S3, G4S4, G5S3, G5S4, G5S5,
GNRS4, GNRS5, GUS4, GUS5</td><td bgcolor="red"></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Red Shading = Natural Community Survey Targets</td></tr>
</table>

Figure 3. Decision matrix to determine natural community survey targets (NatureServe 2002, Rocchio et al. 2018). G = Global Rank, S = State Rank, U = currently unrankable, NR = not ranked; lower numbers are more imperiled than higher numbers. For more information, see Appendix 1.

The ecological field surveys involved:

a) compiling comprehensive plant species lists to be summarized in a floristic quality index and noting dominant, co-dominant, and representative species

b) estimating percent coverage of prevalent or key overstory and understory species

c) describing site-specific structural attributes (e.g., vegetative zonation, vegetative strata, and coarse woody debris) and ecological processes (e.g., windthrow, ground-water seepage, paludification, wildfire, and beaver flooding)

d) measuring tree diameter at breast height (DBH) of representative canopy trees and aging canopy dominants (where appropriate)

e) analyzing soils and recording representative soil texture, pH, and depth

f) describing hydrology (e.g., noting high-water marks, indicator vegetation, and soil mottling)

g) noting current and historical anthropogenic disturbances (e.g., ditching, trails, pollutants, and logging)

h) evaluating potential threats to ecological integrity (i.e., invasive plant species, pests, diseases, deer herbivory) with an emphasis on recording geospatial locations of invasive plant infestations

i) ground-truthing aerial photographic interpretation using GPS (Garmin units and Samsung Tablets were utilized)

j) taking digital photos and GPS points at significant locations

k) surveying adjacent lands when possible to assess landscape context

l) evaluating the natural community classification and mapped ecological boundaries

m) determining the ecological integrity of mapped natural communities by assigning element occurrence ranks

n) noting management needs and restoration opportunities

For each natural community element occurrence, MNFI scientists compiled comprehensive plant species lists. Quantitative plot sampling within the mesic southern forest also informed the documentation of floristic composition and vegetative structure of the forest. Photo by Joshua G. Cohen.

Following completion of the field surveys, the collected data were analyzed and transcribed to create element occurrence records in MNFI's statewide biodiversity conservation database (MNFI 2023). Tracks and GPS points collected during the field visits were transposed on aerial imagery to facilitate the generation of natural community boundaries for new element occurrences. This natural community element occurrence mapping is distinct from the preliminary delineation of natural community types that was based solely on GIS analysis and aerial photo interpretation and was used strictly for planning purposes. Data compiled from the field surveys were used to produce site descriptions, threat assessments, and management recommendations for each natural community element occurrence, which appear within the **Survey Results** section.

For each natural community element occurrence, floristic data were compiled into the Universal Floristic Quality Assessment Calculator (Andreas et al. 2004, Freyman et al. 2016) to determine the Floristic Quality Index (FQI). The floristic quality assessment is derived from a mean coefficient of conservatism and floristic quality index. Each native species is assigned a coefficient of conservatism, a value of 0 to 10 based on probability of its occurrence in a natural versus degraded habitat. Species restricted to a specialized or undisturbed habitat are assigned a value of 10, implying the species has extremely strong fidelity to a specific habitat. Native species that are not particular or indicative of natural conditions are assigned a low value of 0 or 1. The coefficient of conservatism is determined by experts on the flora of a region, and so may vary for a given plant species from region to region. We employed a

Soil texture and chemistry were evaluated for each natural community type. Across the island, soils are alkaline resulting from their derivation from limestone bedrock and the copius and sustained inputs of the colonial nesting waterbirds. Pictured above is a soil sample from the limestone lakeshore cliff. These soils are shallow (0-1 cm), alkaline (pH 7.5-7.8) organics that are restricted to cracks and crevices in the limestone. Photo by Joshua G. Cohen.

regionally appropriate FQA for Ohio (Andreas et al. 2004). From the total list of plant species for an area, a mean C value is calculated and then multiplied by the square root of the total number of plant species to calculate the FQI. As a point of reference, Michigan sites with an FQI of 35 or greater possess sufficient conservatism and richness that they are considered floristically important from a statewide perspective (Herman et al. 2001). Species lists for each natural community element occurrence are provided in Appendix 2. Nomenclature of plant species follows Michigan Flora (Voss and Reznicek 2012).

In addition to these natural community surveys, MNFI conducted two distinct and concurrent surveys in 2022 on West Sister Island. This included rare plant and invasive species mapping and forest plot sampling. The plot sampling included evaluation of soil texture and moisture, aging representative canopy trees, measuring tree diameters, and quantifying floristic composition and coverage by stratum (USFWS 2021a). Data gathered from these survey efforts were also used to inform the documentation and description of natural communities on West Sister Island. For details on rare plant and invasive species survey efforts please refer to USFWS 2021b and Bassett et al. 2023.

Natural Community Stewardship Prioritization

MNFI developed a scoring matrix for 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 an invasive index. We used the element occurrence rank to determine the ecological integrity rank, with higher scores for higher-ranked element occurrences. The rarity index was calculated by assigning a score for each natural community type's state rank (based on Michigan ranks since no contemporary classification for Ohio natural communities is available) and global rank (Appendix 1) and averaging the two scores. For both state and global ranks, higher scores were assigned to rarer types. The invasive index was derived by calculating the average of an invasive threat severity index and a treatment feasibility index. The threat severity index incorporates knowledge of impacts of invasive plant species to natural community types and site-specific information gained during surveys on invasive infestations. Higher scores for the threat severity index correspond to increased degradation due to invasive infestation. The treatment feasibility index was derived by assigning a score to each natural community element occurrence based on the ease of treating the invasive species recorded within that site. Higher scores for the treatment feasibility index correspond to a greater likelihood of successful treatment and control of targeted invasive species. The threat severity index and treatment feasibility index were assigned based on professional judgement and familiarity with species, systems, and ecological regions. Each index was scored on a scale of 0 to 5. For each natural community element occurrence, the sum of the scores for the ecological integrity index, rarity index, and invasive index was calculated to sort the natural community element occurrences by their stewardship prioritization score (Figure 4). Higher scores indicate a higher priority for stewardship intervention. The stewardship prioritization for the natural community element occurrences is presented in the **Stewardship Prioritization Results** section.

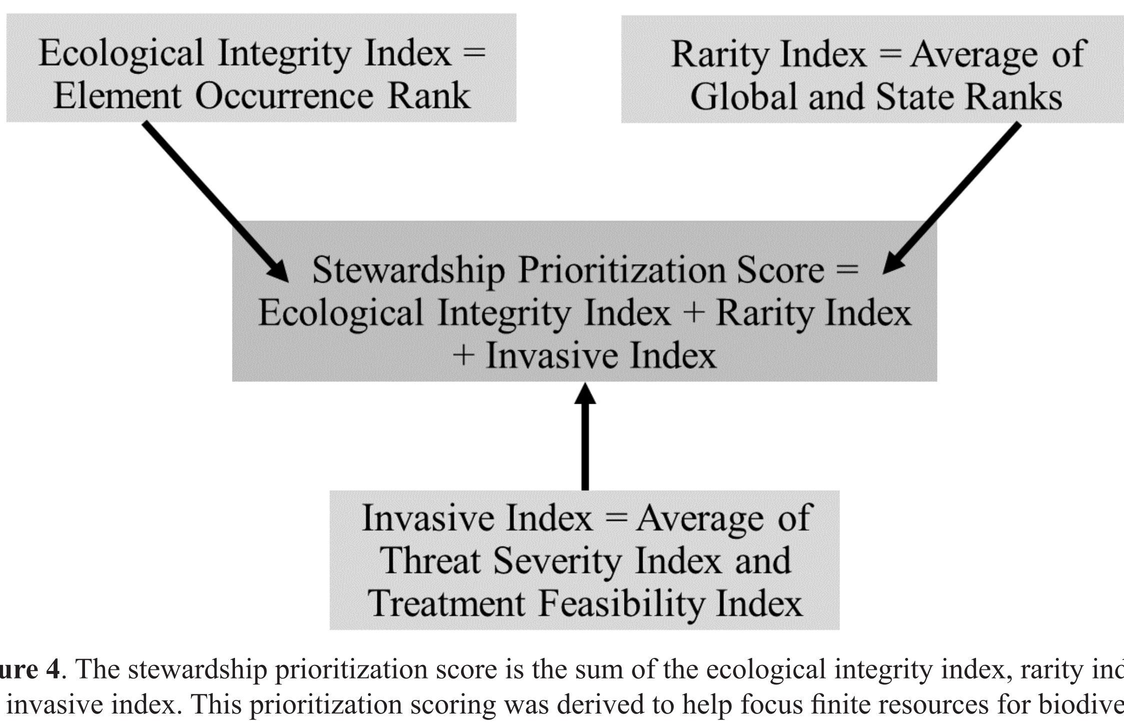

Figure 4. The stewardship prioritization score is the sum of the ecological integrity index, rarity index, and invasive index. This prioritization scoring was derived to help focus finite resources for biodiversity stewardship.

Survey Results

The following results section is organized alphabetically by natural community type. We provide detailed **Site Summaries** for each of the natural community element occurrences documented on the island.

Three natural community element occurrences were documented on West Sister Island including limestone bedrock lakeshore, limestone lakeshore cliff, and mesic southern forest. Table 1 lists the visited sites, their element occurrence ranks, and their acreage. Mapped natural community boundaries are provided for each natural community element occurrence in Figure 5. The following site summaries detail threats and management recommendations for each of the three natural community element occurrences visited in 2022 organized alphabetically by community type. Appendix 3 provides an overview of the natural community types adapted from MNFI's natural community classification (Kost et al. 2007, Cohen et al. 2015) and an accompanying ecoregional distribution map for each natural community type in Michigan (Albert et al. 2008). Unfortunately, no natural community classification, state ranking, and distribution maps exist for Ohio.

For each site summary, we provide the following information:

a) site name

b) natural community type

c) global and Michigan state rank (see Appendix 1 for ranking criteria)

d) current element occurrence rank

e) size

f) locational information

g) digital photographs

h) site description

i) threat assessment

j) management recommendations

Limestone lakeshore cliff, West Sister Island. Photo by Joshua G. Cohen.

Table 1. Natural community element occurrences (EOs) surveyed in 2022 on West Sister Island. EO rank abbreviations are as follows: C, fair estimated viability; and CD, fair to poor estimated viability.

Community Type	EO ID	Acreage	EO RANK
Limestone Bedrock Lakeshore	26266	1.2	C
Limestone Lakeshore Cliff	26269	2.1	C
Mesic Southern Forest	26268	73.3	CD


The shoreline of West Sister Island is characterized by limestone bedrock lakeshore along the western shoreline (above left) and limestone lakeshore cliff along the eastern shoreline (above right). The interior of the island supports mesic southern forest dominated by hackberry. Photos by Joshua G. Cohen.

Figure 5. Natural community element occurrences on West Sister Island.

SITE SUMMARIES

1. West Sister Island - Limestone Bedrock Lakeshore

Natural Community Type: Limestone Bedrock Lakeshore
Rank: G3 S2, globally vulnerable and imperiled in Michigan
Element Occurrence Rank: C
Size: 1.2 acres
Location: West Sister Island, Ottawa Wildlife Refuge, Lake Erie
Element Occurrence Identification Number: 26266

Site Description: Approximately 0.4 miles of limestone bedrock lakeshore occurs along the western shoreline of West Sister Island. Limestone bedrock lakeshore intergrades locally with limestone lakeshore cliff, which occurs primarily along the eastern shore of the island. In addition, small pockets of sand and gravel beach and limestone cobble shore also occur intermixed with the limestone bedrock lakeshore. These shoreline ecosystems are backed by mesic southern forest in the interior of the island dominated by hackberry (*Celtis occidentalis*). The interior of the island supports thousands of nesting colonial shorebirds.

The soils of the limestone bedrock lakeshore are characterized by shallow (0-1 cm), alkaline (pH 7.5-7.8) organics restricted to depressions and crevices in the limestone. Shallow pools of water or splash pools occur locally on the limestone bedrock lakeshore and have been enriched with bird guano. These pools frequently have a reddish hue, likely from algae that are causing the slow dissolution of the bedrock. Much of the limestone bedrock lakeshore is white-washed with bird guano.

West Sister Island limestone bedrock lakeshore. Photo by Joshua G. Cohen.

West Sister Island limestone bedrock lakeshore delineated in yellow on 2020 aerial imagery.

Limestone bedrock lakeshore 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. West Sister Island is subject to frequent storm events. Storm waves frequently disturb limestone bedrock lakeshore, removing fine mineral sediments and organic soils. Winter storms scour vegetation from limestone bedrock lakeshore. Long-term cyclic fluctuations of Great Lakes water levels significantly influence vegetation patterns of limestone bedrock lakeshore, with vegetation and organic soils becoming established during low-water periods and reduced or eliminated during high-water periods. The limestone bedrock lakeshore was surveyed in 2022 after five years of high Great Lakes water levels (from 2016 through 2020) resulting in the decrease in the extent of the limestone bedrock lakeshore. High water levels and increased wave activity have likely reduced the overall cover of vegetation. The western shore of West Sister Island is exposed to 18 miles of open Lake Erie to the west and 9 miles of open water to the southwest and is therefore subject to high energy disturbance in the form of frequent storms, high wave activity, and ice scour. This frequent disturbance contributes to the absence of soil accumulation and vegetative establishment along the limestone bedrock lakeshore.

The limestone bedrock lakeshore is sparsely vegetated with scattered tree and herbaceous cover (1-2%) restricted to the inland edge and including hackberry (*Celtis occidentalis*), stinging nettle (*Urtica dioica*), lambs-quarters (*Chenopodium album*), and motherwort (*Leonurus cardiaca*).

The West Sister Island limestone bedrock lakeshore was surveyed from July 18th through July 20th, 2022. Twenty-three plant species were documented with 14 native species and 9 non-native species (Appendix 2.1). The total FQI was 8.6.

Threats: Species composition and structure are patterned by natural processes. Non-native species recorded along the limestone bedrock lakeshore include lambs-quarters (*Chenopodium album*), motherwort (*Leonurus cardiaca*), white mulberry (*Morus alba*), and annual bluegrass (*Poa annua*).

Management Recommendations: The main management recommendations are to allow natural processes to operate unhindered, retain an intact buffer of natural communities surrounding the limestone bedrock lakeshore, control the non-native species, and monitor control efforts.

West Sister Island limestone bedrock lakeshore. Photo by Joshua G. Cohen.

2. West Sister Island - Limestone Lakeshore Cliff
Natural Community Type: Limestone Lakeshore Cliff
Rank: G4G5 S1, apparently secure to secure globally and critically imperiled within Michigan
Element Occurrence Rank: C
Size: 2.1 acres
Location: West Sister Island, Ottawa Wildlife Refuge, Lake Erie
Element Occurrence Identification Number: 26269

Site Description: Approximately 0.7 miles of limestone lakeshore cliff occurs along the eastern shoreline of West Sister Island. Limestone lakeshore cliff intergrades locally with limestone bedrock lakeshore, which occurs primarily along the western shore of the island. In addition, small pockets of sand and gravel beach and limestone cobble shore also occur intermixed with the limestone bedrock lakeshore. These shoreline ecosystems are backed by mesic southern forest in the interior of the island dominated by hackberry (*Celtis occidentalis*). The interior of the island supports thousands of nesting colonial shorebirds and nesting cormorant are concentrated in the hackberry along the upper margin of the limestone lakeshore cliff and along the edge of the mesic southern forest.

The cliffs are low in stature ranging from 2 to 5 meters tall. Thin soils, cold winter temperatures, steady winds, and summer droughts make for harsh growing conditions for vegetation. The soils of the limestone lakeshore cliff are characterized by shallow (0-1 cm), alkaline (pH 7.5-7.8) organics restricted to cracks and crevices in the limestone. The upper margin of the limestone lakeshore cliff is white-washed with bird guano.

West Sister Island limestone lakeshore cliff. Photo by Joshua G. Cohen.

West Sister Island limestone lakeshore cliff delineated in yellow on 2020 aerial imagery.

West Sister Island is subject to frequent storm events. Storm waves frequently disturb limestone lakeshore cliff, removing fine mineral sediments and organic soils. In addition, winter storms scour vegetation from limestone lakeshore cliff. Long-term cyclic fluctuations of Great Lakes water levels significantly influence vegetation patterns of limestone lakeshore cliff, with vegetation and organic soils becoming established during low-water periods and reduced or eliminated during high-water periods. The limestone lakeshore cliff was surveyed in 2022 after five years of high Great Lakes water levels (from 2016 through 2020). High water levels and increased wave activity have likely reduced the overall cover of vegetation. The eastern shore of West Sister Island is exposed to 21 miles of open Lake Erie water to the east and is therefore subject to high energy disturbance in the form of frequent storms, high wave activity, and ice scour. This frequent disturbance contributes to the absence of soil accumulation and vegetative establishment along the limestone lakeshore cliff.

The vertical structure of cliffs facilitates constant erosion and restricts soil development to the cliff edge, cracks, ledges, and the base of the cliff where organic matter and soil particles can accumulate. The thin soils and direct exposure to wind, ice, and sun produce desiccating conditions that limit plant growth. Weathering results in the gradual exfoliation of exposed limestone along the cliff face, which adds to the instability of the ecosystem, reducing dependable habitat for plant establishment. As portions of the bedrock slough off, they form talus slopes of boulders and slabs along the base of cliffs and expose fresh, bare rock substrates along the cliff face.

Vegetation is sparse, being generally restricted to the flat, exposed bedrock at the upper edge of the cliff (i.e., lip), cracks and joints in the cliff face, ledges along the cliff face, and along the cliff base where limestone chunks are occasional between the cliff and the open water. Significant areas of vertical cliff face are bare of all vegetation. Sparse herbaceous cover (2-4%) includes flat-topped goldenrod (*Euthamia graminifolia*) and yarrow (*Achillea millefolium*) and numerous non-native species including common burdock (*Arctium minus*), lambs-quarters (*Chenopodium album*), motherwort (*Leonurus cardiaca*), catnip (*Nepeta cataria*), Canada bluegrass (*Poa compressa*), bittersweet nightshade (*Solanum dulcamara*), and common mullein (*Verbascum thapsus*). Scattered and often stunted hackberry (*Celtis occidentalis*) (1-2%) occur along the lip of the cliff. Staghorn sumac (*Rhus typhina*) occurs locally along the margin of the cliff.

West Sister Island limestone lakeshore cliff. Photo by Joshua G. Cohen.

The West Sister Island limestone lakeshore cliff was surveyed from July 18th through July 20th, 2022. Thirty-seven plant species were documented with 18 native species and 19 non-native species (Appendix 2.2). The total FQI was 6.1.

Threats: Species composition and structure are patterned by natural processes. Non-native species are locally common and include garlic mustard (*Alliaria petiolata*), common burdock (*Arctium minus*), black mustard (*Brassica nigra*), lambs-quarters (*Chenopodium album*), prickly lettuce (*Lactuca serriola*), motherwort (*Leonurus cardiaca*), catnip (*Nepeta cataria*), lady's thumb (*Persicaria maculosa*), Canada bluegrass (*Poa compressa*), common knotweed (*Polygonum aviculare*), common purslane (*Portulaca oleracea*), curly dock (*Rumex crispus*), bittersweet nightshade (*Solanum dulcamara*), common sow-thistle (*Sonchus oleraceus*), lesser chickweed (*Stellaria pallida*), common dandelion (*Taraxacum officinale*), field penny cress (*Thlaspi arvense*), and common mullein (*Verbascum thapsus*). A single white mulberry (*Morus alba*) was documented along the ecotone between the limestone lakeshore cliff and the mesic southern forest. Defoliation of hackberry (*Celtis occidentalis*) along the top lip of the cliffs from guano burns could contribute to localized tree mortality.

Management Recommendations: The main management recommendations are to allow natural processes to operate unhindered, retain an intact buffer of natural communities surrounding the limestone lakeshore cliff, control the non-native species, and monitor control efforts. As noted above, a single white mulberry was observed during the surveys and prompt action can eradicate this species from the island. All future management adjacent to the shoreline should include a significant buffer (e.g., a minimum of 100 ft).

In addition to walking along the upper margin of the limestone lakeshore cliff, MNFI scientists also used a pack raft to survey the limestone lakeshore cliff from the water. Photo by Joshua G. Cohen.

3. West Sister Island - Mesic Southern Forest
Natural Community Type: Mesic Southern Forest
Rank: G2G3 S3, imperiled to vulnerable globally and vulnerable within Michigan
Element Occurrence Rank: C
Size: 73.3 acres
Location: West Sister Island, Ottawa Wildlife Refuge, Lake Erie
Element Occurrence Identification Number: 26268

Site Description: Mesic southern forest on West Sister Island occurs on nutrient-enriched loams overlying Silurian-aged limestone bedrock. The forest is flat to gently rolling, occurs across the interior of the island, and is flanked on the shoreline by limestone lakeshore cliff, limestone bedrock lakeshore, and limestone cobble shore. The forest tends to gently slope down to Lake Erie and the elevation is highest in the interior of the island.

West Sister Island is subject to frequent storm events. Windthrow is common within the mesic southern forest, which is characterized by moderate volumes of coarse woody debris composed of hackberry (*Celtis occidentalis*). The majority of windthrown hackberry have been snapped three to six feet up their boles with only one root tipped overstory hackberry observed on the island. Scattered light gaps occur throughout the forest.

The spongey soils are characterized by nutrient enriched loams overlying limestone bedrock. High organic inputs fertilize the loams with nesting colonial shorebirds enriching the loams with guano, egg shells, vomit, and decomposing fish and dead birds. In addition, fine branches and leaves knocked to the forest floor by nesting birds contribute to the organic matter. The loams are fine-textured and slightly acidic to alkaline (pH 6.0-7.7) with an average pH of 7.4 across 20 plots. Measured depth of mineral soil over limestone bedrock ranged from 15 to 45 cm with average depth across 20 soil plots being 30.4 cm.


The soils of the mesic southern forest are enriched by organic inputs from the thousands of nesting birds that utilize the forest. Inputs include guano, vomitted fish (left), and dead birds (right). Photos by Joshua G. Cohen.

West Sister Island mesic southern forest delineated in yellow on 2020 aerial imagery. The mesic southern forest covers almost the full extent of the interior of the island (shaded yellow) with areas of coppiced forest excluded in the southern portion of the island.

Numerous canopy dominants were cored across the mesic southern forest to help determine the age range of canopy trees in the uneven-aged mesic southern forest. Thirteen overstory hackberry were cored in 20 overstory plots and the average age of canopy dominants is 81 years with estimated canopy ages ranging from 53 to 130 years. Many of the canopy hackberry had rotten centers and estimating canopy age across all plots was not possible. Canopy age of hackberry was observed to be youngest near the lighthouse with that land having reverted to forest more recently. In addition, there is a higher turnover of canopy hackberry along the margins of the island along the limestone lakeshore cliff and limestone bedrock lakeshore where the double-crested cormorant nesting is concentrated. Trees along the margin of the mesic southern forest and shoreline have been white-washed with cormorant guano and these portions of forest consistently have smaller-diameter trees.

The overwhelming dominance of hackberry is unusual in forested systems, at least in adjacent Michigan. We have observed it just one other time, on Little Charity Island in Lake Huron, another island supporting prodigious quantities of colonial nesting birds. The preponderance of hackberry as the canopy dominant on Little Charity and West Sister Islands suggests that this tree species is highly adapted to disturbance caused by colonial nesting shorebirds. Observed canopy mortality on northern white-cedar (*Thuja occidentalis*) on other Great Lakes islands of similar size and nesting densities is significantly higher (at or near 100% in some instances). Many other tree species die when exposed to the disturbance caused by nesting birds but the hackberry on West Sister Island appears to be thriving. Some reasons why hackberry is so successful on this island include its propensity to be readily dispersed by birds; its capacity for fast growth; its tolerance of intermediate shade condition; and its tolerance of high nutrient conditions in the soil. Hackberry sheds its lower branches and has warty bark which may be beneficial to nesting birds since these traits may help reduce predation. Hackberry offers nesting habitat for a diversity of bird species with its lower branches being suitable for great white egret, young canopy trees providing habitat for great white egret and double-crested cormorant, and large older trees providing habitat for great blue heron.

The mesic southern forest on West Sister Island is overwhelmingly dominated by hackberry. Photo by Joshua G. Cohen.

The mesic southern forest on West Sister Island is overwhelmingly dominated by hackberry with infrequent canopy associates including American elm (*Ulmus americana*), Kentucky coffee-tree (*Gymnocladus dioicus*), swamp white oak (*Quercus bicolor*), and honey locust (*Gleditsia triacanthos*). Of the 442 canopy trees measured in 20 overstory plots 99% of those trees were hackberry (438 hackberry and just four Kentucky coffee-tree). Canopy coverage typically ranges from 70 to 90% with some local patches having more open canopy (60-70%) where blowdown is more prevalent. Canopy trees typically range in diameter from 15 to 30 cm with older and larger hackberry frequently reaching 40 to 60 cm. The average diameter of measured canopy trees was 21 cm (n = 442). The subcanopy ranges from 10 to 20% and is characterized by hackberry with infrequent Kentucky coffee-tree. The understory layer is sparse (5-10%) with hackberry and infrequent Kentucky coffee-tree, American elm, and choke cherry (*Prunus virginiana*). The low shrub layer is sparse (2-5%) with poison-ivy (*Toxicodendron radicans*) and choke cherry and scattered seedlings of hackberry and less frequently Kentucky coffee-tree and choke cherry.

The ground cover is dense (50-75%) and homogenous with dominant species including Short's aster (*Symphyotrichum shortii*), great waterleaf (*Hydrophyllum appendiculatum*), bottlebrush grass (*Elymus hystrix*), giant Solomon seal (*Polygonatum biflorum* var. *commutatum*), and smooth sweet-cicely (*Osmorhiza longistylis*). Additional ground cover species include sedges (*Carex grisea* and *C. laxiflora*), silky wild rye (*Elymus villosus*), nodding fescue (*Festuca subverticillata*), stinging nettle (*Urtica dioca*), carrion-flower (*Smilax lasioneura*), pokeweed (*Phytolacca americana*), false nettle (*Boehmeria cylindrica*), and spotted touch-me-not (*Impatiens capensis*). Garlic mustard (*Alliaria petiolata*) is locally common in the ground cover. The ground cover is likely species depauperate because of the extreme conditions of growing in soils enriched by bird guano, vomit, and decomposing fish and dead birds. Those species that can tolerate these conditions seem to be excelling and are extremely robust. Several seasonally wet openings occur within the mesic southern forest and support localized pockets of wetland plants including false nettle and wood-nettle (*Laportea canadensis*).

The West Sister Island mesic southern forest was surveyed from July 18th through July 20th, 2022. Forty-six plant species were documented with 39 native species and 7 non-native species (Appendix 2.3). The total FQI was 19.

Threats: Species composition and vegetative structure of the mesic southern forest on West Sister Island has been influenced by the interaction of soil texture, depth of soil to limestone substrate, and time and intensity of past disturbance factors including windthrow, clearing, grazing by livestock, and logging. The increased nutrient input by growing populations of double-crested cormorant has been shown to significantly alter soil nutrient characteristics on neighboring islands (Rush et al. 2011) and is likely impacting the floristic composition and vegetative structure on West Sister Island. Earthworms were noted locally in the soil and earthworms have locally impacted soil decomposition processes. Garlic mustard is locally common within the mesic southern forest. Additional non-natives documented in the mesic southern forest include common burdock (*Arctium minus*), lambs-quarters (*Chenopodium album*), multiflora rose (*Rosa multiflora*), and motherwort (*Leonurus cardiaca*).

Management Recommendations: The main management recommendations are to allow natural processes to operate unhindered, retain an intact buffer of natural communities surrounding the mesic southern forest, control the invasive species (especially garlic mustard, common buckthorn, and multiflora rose), and monitor the control efforts. Single individuals of common buckthorn and rosa multiflora were observed during the surveys and prompt action can eradicate these species from the island.

Coppicing to create heterogeneity was observed in the southern portion of the island. These younger stands of regenerating hackberry forest were excluded from the mesic southern forest element occurrence. Within these younger stands, we observed high concentrations of nesting great white egret. Additional mechanical treatment may be beneficial for increasing canopy heterogeneity across the island and generating suitable nesting habitat for different species of nesting shorebirds. Before engaging in this type of management, we recommend implementing quantitative studies to evaluate nesting success within these intensively managed areas compared to unmanaged portions of the forest.

Vegetative monitoring should be continued to evaluate invasive species infestations and the impacts of the nesting colonies on the floristic composition and vegetative structure of the mesic southern forest. The photo above depicts white-washed hackberry and the photo below shows the invasive garlic mustard. Photos by Joshua G. Cohen (above) and Elizabeth A. Haber (below).

Stewardship Prioritization Results and Discussion

The stewardship prioritization scores for each natural community element occurrence within West Sister Island are presented in Table 2. We sorted the element occurrences by their stewardship prioritization scores and assigned them a medium (≥ 9 and < 10; yellow) or low (< 9; blue) stewardship priority. No high (≥ 10) scores were assigned on West Sister Island. The highest ranking natural community element occurrence on West Sister Island is the mesic southern forest, which received a medium priority score. The limestone bedrock lakeshore and limestone lakeshore cliff received low priority scores.

Compared to other islands in the National Wildlife Refuge (Table 3), these are low priority scores reflecting the low integrity ranking of the element occurrences on West Sister Island, the relatively high level of invasive infestation, and the low feasibility of successfully treating invasives given the high level of disturbance from the colonial nesting birds.

The framework for stewardship prioritization presented in this report offers a method for targeting biodiversity management. In addition, it can be used to focus long-term monitoring targets. Futhermore, this method could be catered 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 National Wild Refuge. In addition, other indices could be incorporated into the stewardship prioritization matrix, which focused on invasive plant species management. Additional indices to consider incorporating include indices that incorporate the presence of rare species, priority wildlife species, cultural resources, and the functionality of the landscape surrounding the site. Implementation of stewardship efforts within prioritized areas will also need to be followed by monitoring to gauge the success of biodiversity management and adjust future stewardship prioritization efforts.

Table 2. Stewardship prioritization for natural community element occurrences (EOs) on West Sister Island. EOs are sorted by their stewardship prioritization scores and assigned a medium (yellow) or low (blue) stewardship priority.

EO ID	Natural Community	Island	EO Rank	Ecological Integrity Index	Gobal Rank	Global Rank Score	State Rank	State Rank Score	Rarity Index	Invasive Threat Severity	Treatment Feasability	Invasive Index	Stewardship Priority Score
26268	Mesic Southern Forest	West Sister	C	3	G2G3	3.5	S3	3	3.25	3	4	3.5	9.75
26266	Limestone Bedrock Lakeshore	West Sister	C	3	G3	3	S2	4	3.5	2	2	2	8.5
26269	Limestone Lakeshore Cliff	West Sister	C	3	G4G5	1.5	S1	5	3.25	2	2	2	8.25

Given the low integrity of the natural community types on West Sister Island, the high levels of invasive plant infestations, and the low feasibility of successfully treating these infestations, we suggest that invasive species treatment is a low stewardship priority in comparison to other National Wildlife Refuge islands. Photo by Joshua G. Cohen.

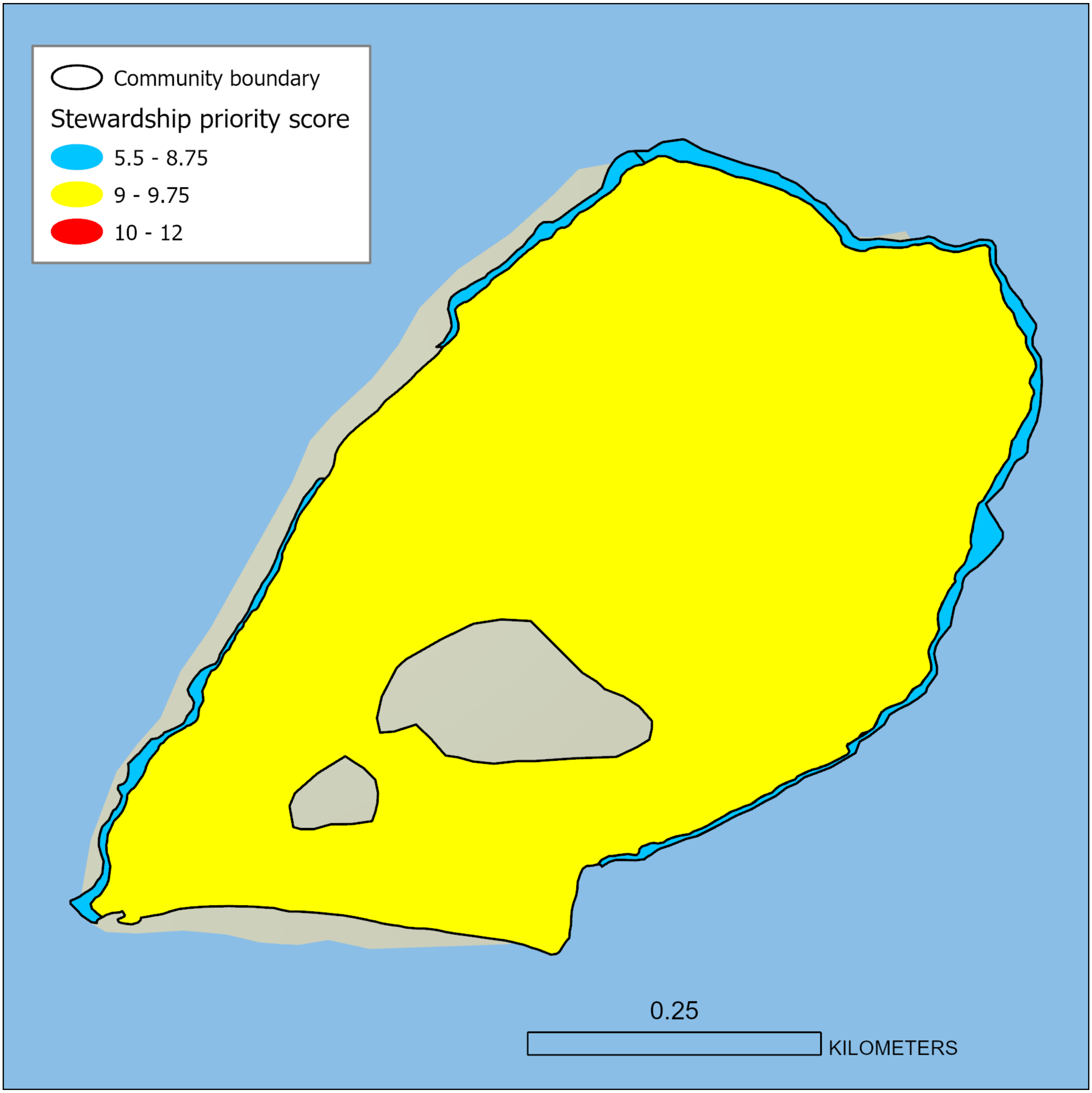

Figure 6. Stewardship prioritization for natural community element occurrences on West Sister Island. Element occurrences are displayed by their stewardship prioritization scores and assigned a medium (yellow) or low (blue) stewardship priority.

Table 3. Stewardship prioritization for all surveyed National Wildlife Refuge islands. This table includes 66 natural community element occurrences (EOs) from 15 islands. EOs are sorted by their stewardship prioritization scores and assigned a high (red), medium (yellow), or low (blue) stewardship priority. The West Sister Island natural community EOs (underlined and in bold) ranked 18th, 46th, and 54th out of the 66 natural community EOs.

EO ID	Natural Community	Island	EO Rank	Ecological Integrity Index	Gobal Rank	Global Rank Score	State Rank	State Rank Score	Rarity Index	Invasive Threat Severity	Treatment Feasability	Invasive Index	Stewardship Priority Score
6682	Great Lakes Marsh	Harbor Island	AB	4.5	G2	4	S3	3	3.5	4	4	4	12
24356	Interdunal Wetland	Crooked Island	BC	3.5	G2?	4	S2	4	4	4	5	4.5	12
24382	Interdunal Wetland	Big Charity Island	C	3	G2?	4	S2	4	4	4	5	4.5	11.5
24355	Open Dunes	Crooked Island	B	4	G3	3	S3	3	3	5	4	4.5	11.5
24358	Great Lakes Marsh	Crooked Island	BC	3.5	G2	4	S3	3	3.5	4	4	4	11
24381	Open Dunes	Big Charity Island	C	3	G3	3	S3	3	3	5	4	4.5	10.5
24365	Great Lakes Marsh	Sugar Island	BC	3.5	G2	4	S3	3	3.5	4	3	3.5	10.5
7488	Boreal Forest	Poverty Island	B	4	GU	3	S3	3	3	3	4	3.5	10.5
4159	Limestone Bedrock Lakeshore	Poverty Island	AB	4.5	G3	3	S2	4	3.5	2	3	2.5	10.5
26246	Granite Bedrock Lakeshore	West Huron Island	AB	4.5	G4G5	1.5	S2	4	2.75	3	3	3	10.25
24354	Coastal Fen	Crooked Island	AB	4.5	G1G2	4.5	S2	4	4.25	1	2	1.5	10.25
26250	Granite Lakeshore Cliff	East Huron Island	A	5	GU	3	S1	5	4	1	1	1	10
26255	Granite Bedrock Glade	West Huron Island	B	4	G3G5	2	S2	4	3	3	3	3	10
26248	Granite Lakeshore Cliff	West Huron Island	A	5	GU	3	S1	5	4	1	1	1	10
24374	Limestone Bedrock Lakeshore	Detroit Island	B	4	G3	3	S2	4	3.5	2	3	2.5	10
1437	Limestone Lakeshore Cliff	Poverty Island	A	5	G4G5	1.5	S2	4	2.75	2	2.5	2.25	10
24348	Limestone Lakeshore Cliff	Saint Martin Island	A	5	G4G5	1.5	S2	4	2.75	2	2.5	2.25	10
26247	Granite Bedrock Lakeshore	Cattle Island	AB	4.5	G4G5	1.5	S2	4	2.75	2	3	2.5	9.75
26245	Granite Bedrock Lakeshore	East Huron Island	AB	4.5	G4G5	1.5	S2	4	2.75	2	3	2.5	9.75
26268	**Mesic Southern Forest**	**West Sister Island**	**C**	**3**	**G2G3**	**3.5**	**S3**	**3**	**3.25**	**3**	**4**	**3.5**	**9.75**
24359	Limestone Cobble Shore	Crooked Island	B	4	G2G3	3.5	S3	3	3.25	2	3	2.5	9.75
24362	Coastal Fen	Sugar Island	C	3	G1G2	4.5	S2	4	4.25	2	3	2.5	9.75
24363	Limestone Cobble Shore	Sugar Island	B	4	G2G3	3.5	S3	3	3.25	2	3	2.5	9.75
26254	Granite Bedrock Glade	Cattle Island	B	4	G3G5	2	S2	4	3	2	3	2.5	9.5
26249	Granite Lakeshore Cliff	Cattle Island	AB	4,5	GU	3	S1	5	4	1	1	1	9.5
26257	Granite Bedrock Glade	East Huron Island	AB	4.5	G3G5	2	S2	4	3	2	2	2	9.5
11688	Mesic Northern Forest	Harbor Island	B	4	G4	2	S3	3	2.5	3	3	3	9.5
1231	Boreal Forest	Harbor Island	BC	3.5	GU	3	S3	3	3	3	3	3	9.5
24384	Sand and Gravel Beach	Big Charity Island	BC	3.5	G3?	3	S3	3	3	3	3	3	9.5
24357	Boreal Forest	Crooked Island	C	3	GU	3	S3	3	3	4	3	3.5	9.5
24361	Limestone Bedrock Lakeshore	Sugar Island	C	3	G3	3	S2	4	3.5	3	3	3	9.5
24375	Limestone Cobble Shore	Detroit Island	BC	3.5	G3	3	S2	4	3.5	2	3	2.5	9.5
26265	Limestone Cobble Shore	Gull Island (Lake Michigan)	C	3	G2G3	3.5	S3	3	3.25	3	3	3	9.25
24385	Limestone Cobble Shore	Big Charity Island	BC	3.5	G2G3	3.5	S3	3	3.25	2	3	3	9.25
24350	Limestone Cliff	Saint Martin Island	B	4	G4G5	1.5	S2	4	2.75	2	3	2.5	9.25
24353	Limestone Cobble Shore	Saint Martin Island	B	4	G2G3	3.5	S3	3	3.25	1	3	2	9.25
26251	Granite Lakeshore Cliff	Gull Island (Lake Superior)	B	4	GU	3	S1	5	4	1	1	1	9
26264	Sand and Gravel Beach	Gull Island (Lake Michigan)	C	3	G3?	3	S3	3	3	3	3	3	9
26260	Dry-Mesic Northern Forest	Harbor Island	BC	3.5	G4	2	S3	3	2.5	2	4	3	9
26259	Rich Conifer Swamp	Harbor Island	BC	3.5	G4	2	S3	3	2.5	3	3	3	9
24367	Great Lakes Marsh	Plum Island	C	3	G4	2	S4	4	3	3	3	3	9
24349	Mesic Northern Forest	Saint Martin Island	BC	3.5	G4	2	S3	3	2.5	3	3	3	9
26244	Granite Bedrock Lakeshore	Gull Island (Lake Superior)	B	4	G4G5	1.5	S2	4	2.75	2	2	2	8.75
26258	Limestone Cobble Shore	Harbor Island	BC	3.5	G2G3	3.5	S3	3	3.25	2	2	2	8.75
24366	Limestone Cobble Shore	Rocky Island	C	3	G2G3	3.5	S3	3	3.25	3	2	2.5	8.75
26252	Granite Bedrock Glade	Gull Island (Lake Superior)	BC	3.5	G3G5	2	S2	4	3	2	2	2	8.5
26256	Boreal Forest	West Huron Island	B	4	GU	3	S3	3	3	2	1	1.5	8.5
26266	**Limestone Bedrock Lakeshore**	**West Sister Island**	**C**	**3**	**G3**	**3**	**S2**	**4**	**3.5**	**2**	**2**	**2**	**8.5**
24370	Limestone Cobble Shore	Plum Island	C	3	G3	3	S2	4	3.5	2	2	2	8.5
24372	Limestone Lakeshore Cliff	Detroit Island	BC	3.5	GNR	3	S4	2	2.5	2	3	2.5	8.5
24368	Limestone Lakeshore Cliff	Plum Island	C	3	GNR	3	S4	2	2.5	4	2	3	8.5
24352	Northern Hardwood Swamp	Saint Martin Island	C	3	G4	2	S3	3	2.5	3	3	3	8.5
24351	Boreal Forest	Saint Martin Island	B	4	GU	3	S3	3	3	1	2	1.5	8.5
26269	**Limestone Lakeshore Cliff**	**West Sister Island**	**C**	**3**	**G4G5**	**1.5**	**S1**	**5**	**3.25**	**2**	**2**	**2**	**8.25**
26263	Boreal Forest	Gull Island (Lake Michigan)	C	3	GU	3	S3	3	3	2	2	2	8
24379	Northern Hardwood Swamp	Big Charity Island	C	3	G4	2	S3	3	2.5	2	3	2.5	8
24360	Boreal Forest	Sugar Island	B	4	GU	3	S3	3	3	1	1	1	8
24369	Mesic Northern Forest	Plum Island	D	2	G4	2	S3	3	2.5	5	2	3.5	8
26253	Boreal Forest	East Huron Island	AB	4.5	GU	3	S3	3	3	0	NA	0	7.5
24373	Limestone Cliff	Detroit Island	BC	3.5	G4G5	1.5	S5	1	1.25	2	3	2.5	7.25
24387	Sand and Gravel Beach	Detroit Island	BC	3.5	G3?	3	S2	4	3.5	0	NA	0	7
24378	Dry-Mesic Northern Forest	Big Charity Island	C	3	G4	2	S3	3	2.5	1	1	1	6.5
24380	Limestone Bedrock Lakeshore	Big Charity Island	C	3	G3	3	S2	4	3.5	0	NA	0	6.5
26262	Mesic Northern Forest	Gull Island (Lake Michigan)	C	3	G4	2	S3	3	2.5	0	NA	0	5.5
24377	Mesic Northern Forest	Big Charity Island	C	3	G4	2	S3	3	2.5	0	NA	0	5.5
24364	Mesic Northern Forest	Sugar Island	CD	2.5	G4	2	S3	3	2.5	0	NA	0	5

Conclusion

Through this project we evaluated the ecological integrity of natural communities on West Sister Island. We documented three new element occurrences including limestone bedrock lakeshore, limestone lakeshore cliff, and mesic southern forest. This report provides site-based assessments of these three natural community element occurrences. Threats, management needs, and restoration opportunities specific to each individual site have been discussed. The baseline information presented in this report provides resource managers with an ecological foundation for prescribing site-level biodiversity stewardship, monitoring these management activities, and implementing island-wide biodiversity planning to prioritize management efforts. The framework for prioritizing stewardship and monitoring efforts across sites will help facilitate difficult decisions regarding the distribution of finite stewardship resources for site-based management. Based on our stewardship prioritization framework, if invasive species control efforts are to be enacted on West Sister Island, we recommend focusing control efforts on reducing the garlic mustard infestation within the mesic southern forest.

Nesting great white egrets within the mesic southern forest on West Sister Island. Photo by Joshua G. Cohen.

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Appendix 1 - Global and State Element Ranking Criteria

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.

GNR = Global rank not yet assessed. Unranked.

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.

SNR = rank not yet assessed. Unranked.

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.

Appendix 2 - Floristic Quality Assessments

For each high-quality natural community, floristic data were compiled into the Universal Floristic Quality Assessment Calculator (Andreas et al. 2004, Freyman et al. 2016) to determine the Floristic Quality Index (FQI) for each natural community element occurrence. The floristic quality assessment is derived from a mean coefficient of conservatism and floristic quality index. Each native species is assigned a coefficient of conservatism, a value of 0 to 10 based on probability of its occurrence in a natural versus degraded habitat. Species restricted to a specialized or undisturbed habitat are assigned a value of 10, implying the species has extremely strong fidelity to a specific habitat. Native species that are not particular or indicative of natural conditions are assigned a low value of 0 or 1. The coefficient of conservatism is determined by experts on the flora of a region, and so may vary for a given plant species from region to region. We employed regionally appropriate FQA for Ohio (Andreas et al. 2004). From the total list of plant species for an area, a mean C value is calculated and then multiplied by the square root of the total number of plant species to calculate the FQI. In addition, each species is assigned a coefficient of wetness (W) based on its affinity to wetland or upland habitat. As a point of reference, Michigan sites with an FQI of 35 or greater possess sufficient conservatism and richness that they are considered floristically important from a statewide perspective (Herman et al. 2001).

For each high-quality natural community element occurrence, we generated a floristic quality assessment (FQA). The FQA includes a comprehensive list of the species documented in the element occurrence along with each species C and W values. In addition, for each site we present the accompanying conservatism-based metrics, species richness, species wetness, physiognomy metrics, and duration metrics. Within the plant lists for each natural community element occurrence, non-native species have been highlighted in bold.

We used the Ohio FQA (Andreas et al. 2004) and nomenclature within the species lists follows Michigan Flora (Voss and Reznicek 2012).

Appendix 2.1. West Sister Island Limestone Bedrock Lakeshore FQA

Conservatism-Based Metrics:

Total Mean C:	1.8
Native Mean C:	3
Total FQI:	8.6
Native FQI:	11.2
Adjusted FQI:	23.4
% C value 0:	39.1
% C value 1-3:	34.8
% C value 4-6:	21.7
% C value 7-10:	4.3
Native Tree Mean C:	3.3
Native Shrub Mean C:	n/a
Native Herbaceous Mean C:	2.9

Species Richness:

Total Species:	23	
Native Species:	14	60.90%
Non-native Species:	9	39.10%

Species Wetness:

Mean Wetness:	2.8
Native Mean Wetness:	1.9

Physiognomy Metrics:

Tree:	5	21.70%
Shrub:	0	0.00%
Vine:	2	8.70%
Forb:	15	65.20%
Grass:	1	4.30%
Sedge:	0	0.00%
Rush:	0	0%
Fern:	0	0.00%
Bryophyte:	0	0%

Duration Metrics:

Annual:	6	26.10%
Perennial:	14	60.90%
Biennial:	3	13.00%
Native Annual:	1	4.30%
Native Perennial:	12	52.20%
Native Biennial:	1	4.30%

Appendix 2.1. West Sister Island Limestone Bedrock Lakeshore FQA (continued)

Scientific Name	Common Name	Acronym	Native?	C	W
Abutilon theophrasti	**velvetleaf**	**ABUTHE**	**non-native**	**0**	**5**
Alliaria petiolata	**garlic mustard**	**ALLPET**	**non-native**	**0**	**4**
Arctium minus	**common burdock**	**ARCMIN**	**non-native**	**0**	**4**
Celtis occidentalis	hackberry	CELOCC	native	4	3
Chenopodium album	**lambs-quarters**	**CHEALB**	**non-native**	**0**	**2**
Geum canadense	white avens	GEUCAN	native	2	3
Gleditsia triacanthos	honey locust	GLETRI	native	4	1
Gymnocladus dioicus	kentucky coffee-tree	GYMDIO	native	3	5
Leonurus cardiaca	**common motherwort**	**LEOCAR**	**non-native**	**0**	**5**
Malva neglecta	**cheese mallow**	**MALNEG**	**non-native**	**0**	**5**
Morus alba	**white mulberry**	**MORALB**	**non-native**	**0**	**5**
Oenothera biennis	common evening-primrose	OENBIE	native	1	4
Parietaria pensylvanica	pellitory	PARPEN	native	4	4
Phytolacca americana	pokeweed	PHYAME	native	1	2
Poa annua	**annual bluegrass**	**POAANN**	**non-native**	**0**	**3**
Prunus virginiana	choke cherry	PRUVIR	native	2	3
Scrophularia marilandica	maryland figwort	SCRMAR	native	4	4
Stellaria pallida	**lesser chickweed**	**STEPAL**	**non-native**	**0**	**5**
Symphyotrichum shortii	shorts aster	SYMSHO	native	4	5
Toxicodendron radicans	poison-ivy	TOXRAD	native	1	0
Urtica dioica l. var. procera	american stinging nettle	URTIDIOP	native	1	1
Vallisneria americana	water-celery	VALAME	native	8	-5
Vitis riparia	riverbank grape	VITRIP	native	3	-3

Appendix 2.2. West Sister Island Limestone Lakeshore Cliff FQA

Conservatism-Based Metrics:

Total Mean C:	1
Native Mean C:	2
Total FQI:	6.1
Native FQI:	8.5
Adjusted FQI:	13.9
% C value 0:	59.5
% C value 1-3:	29.7
% C value 4-6:	10.8
% C value 7-10:	0
Native Tree Mean C:	2.7
Native Shrub Mean C:	2
Native Herbaceous Mean C:	1.9

Species Richness:

Total Species:	37	
Native Species:	18	48.60%
Non-native Species:	19	51.40%

Species Wetness:

Mean Wetness:	2.6
Native Mean Wetness:	2.1

Physiognomy Metrics:

Tree:	4	10.80%
Shrub:	1	2.70%
Vine:	3	8.10%
Forb:	27	73.00%
Grass:	2	5.40%
Sedge:	0	0.00%
Rush:	0	0%
Fern:	0	0.00%
Bryophyte:	0	0%

Duration Metrics:

Annual:	11	29.70%
Perennial:	20	54.10%
Biennial:	6	16.20%
Native Annual:	3	8.10%
Native Perennial:	13	35.10%
Native Biennial:	2	5.40%

Appendix 2.2. West Sister Island Limestone Lakeshore Cliff FQA (continued)

Scientific Name	Common Name	Acronym	Native?	C	W
Achillea millefolium	yarrow	ACHMIL	native	1	3
Alliaria petiolata	**garlic mustard**	**ALLPET**	**non-native**	**0**	**4**
Ambrosia artemisiifolia	common ragweed	AMBART	native	0	3
Arctium minus	**common burdock**	**ARCMIN**	**non-native**	**0**	**4**
Brassica nigra	**black mustard**	**BRANIG**	**non-native**	**0**	**5**
Celtis occidentalis	hackberry	CELOCC	native	4	3
Chenopodium album	**lambs-quarters**	**CHEALB**	**non-native**	**0**	**2**
Conyza canadensis	horseweed	CONCAN	native	0	5
Elymus villosus	hairy wild rye	ELYVIL	native	4	4
Epilobium ciliatum	northern willow-herb	EPICIL	native	4	1
Erigeron philadelphicus	philadelphia fleabane	ERIPHI	native	2	3
Euthamia graminifolia	flat-topped goldenrod	EUTGRA	native	2	0
Geum canadense	white avens	GEUCAN	native	2	3
Lactuca serriola	**prickly lettuce**	**LACSER**	**non-native**	**0**	**1**
Leonurus cardiaca	**common motherwort**	**LEOCAR**	**non-native**	**0**	**5**
Morus alba	**white mulberry**	**MORALB**	**non-native**	**0**	**5**
Nepeta cataria	**catnip**	**NEPCAT**	**non-native**	**0**	**3**
Oenothera biennis	common evening-primrose	OENBIE	native	1	4
Parthenocissus quinquefolia	virginia creeper	PARQUI	native	2	3
Persicaria maculosa	**ladys thumb**	**PERMAC**	**non-native**	**0**	**-3**
Persicaria pensylvanica	pinkweed	PERPEN	native	0	-3
Poa compressa	**canada bluegrass**	**POACOM**	**non-native**	**0**	**3**
Polygonum aviculare	**common knotweed**	**PLGAVI**	**non-native**	**0**	**3**
Portulaca oleracea	**common purslane**	**POROLE**	**non-native**	**0**	**0**
Prunus virginiana	choke cherry	PRUVIR	native	2	3
Rhus typhina	staghorn sumac	RHUTYP	native	2	5
Rumex crispus	**curly dock**	**RUMCRI**	**non-native**	**0**	**3**
Scrophularia marilandica	maryland figwort	SCRMAR	native	4	4
Solanum dulcamara	**bittersweet nightshade**	**SLMDUL**	**non-native**	**0**	**1**
Sonchus oleraceus	**common sow-thistle**	**SONOLE**	**non-native**	**0**	**5**
Stellaria pallida	**lesser chickweed**	**STEPAL**	**non-native**	**0**	**5**
Taraxacum officinale	**common dandelion**	**TAROFF**	**non-native**	**0**	**4**
Thlaspi arvense	**field penny cress**	**THLARV**	**non-native**	**0**	**5**
Ulmus americana	american elm	ULMAME	native	2	-2
Urtica dioica l. var. procera	american stinging nettle	URTIDIOP	native	1	1
Verbascum thapsus	**common mullein**	**VERTHA**	**non-native**	**0**	**5**
Vitis riparia	riverbank grape	VITRIP	native	3	-3

Appendix 2.3. West Sister Island Mesic Southern Forest FQA

Conservatism-Based Metrics:

Total Mean C:	2.8
Native Mean C:	3.3
Total FQI:	19
Native FQI:	20.6
Adjusted FQI:	30.4
% C value 0:	17.4
% C value 1-3:	41.3
% C value 4-6:	34.8
% C value 7-10:	6.5
Native Tree Mean C:	3.7
Native Shrub Mean C:	2.5
Native Herbaceous Mean C:	3.3

Species Richness:

Total Species:	46	
Native Species:	39	84.80%
Non-native Species:	7	15.20%

Species Wetness:

Mean Wetness:	1.5
Native Mean Wetness:	1.2

Physiognomy Metrics:

Tree:	7	15.20%
Shrub:	3	6.50%
Vine:	4	8.70%
Forb:	26	56.50%
Grass:	3	6.50%
Sedge:	3	6.50%
Rush:	0	0%
Fern:	0	0.00%
Bryophyte:	0	0%

Duration Metrics:

Annual:	6	13.00%
Perennial:	37	80.40%
Biennial:	3	6.50%
Native Annual:	5	10.90%
Native Perennial:	33	71.70%
Native Biennial:	1	2.20%

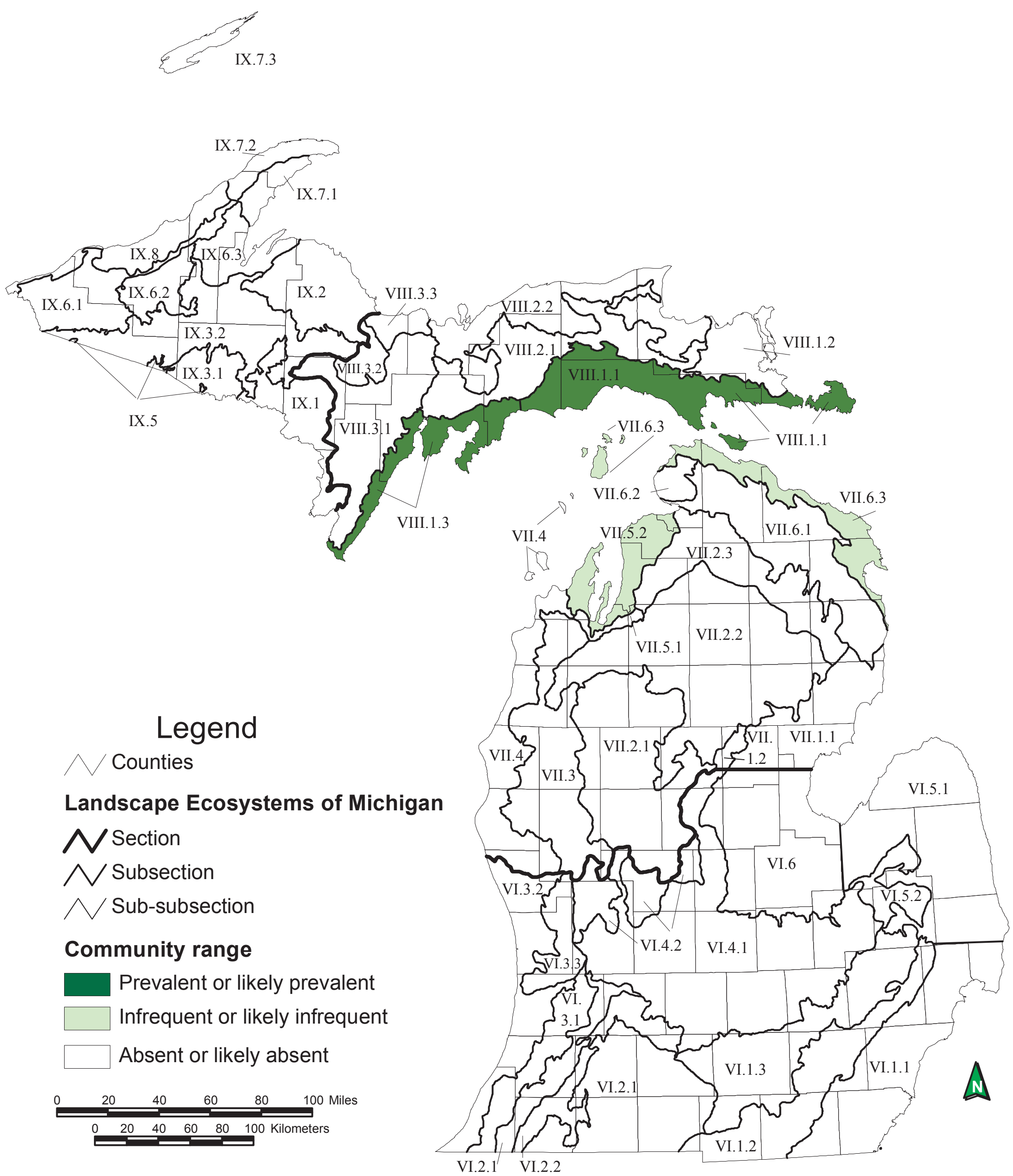
Appendix 2.3. West Sister Island Mesic Southern Forest FQA (continued)

Scientific Name	Common Name	Acronym	Native?	C	W
Alliaria petiolata	**garlic mustard**	**ALLPET**	**non-native**	**0**	**4**
Arctium minus	**common burdock**	**ARCMIN**	**non-native**	**0**	**4**
Arisaema triphyllum (l.) schott subsp. stewardsonii	swamp jack-in-the-pulpit	ARITRIS	native	7	-2
Asparagus officinalis	**asparagus**	**ASPOFF**	**non-native**	**0**	**3**
Boehmeria cylindrica	false nettle	BOECYL	native	4	-4
Carex communis	beech sedge	CXCOMM	native	4	5
Carex grisea	narrow-leaved sedge	CXGRIS	native	4	0
Carex laxiflora	two-edged wood sedge	CXLAXF	native	3	3
Celtis occidentalis	hackberry	CELOCC	native	4	3
Chenopodium album	**lambs-quarters**	**CHEALB**	**non-native**	**0**	**2**
Echinocystis lobata	wild cucumber	ECHLOB	native	2	0
Elymus hystrix	bottlebrush grass	ELYHYS	native	4	5
Elymus villosus	hairy wild rye	ELYVIL	native	4	4
Festuca subverticillata	nodding fescue	FESSUB	native	5	3
Galium aparine	cleavers	GALAPA	native	0	3
Geum canadense	white avens	GEUCAN	native	2	3
Gleditsia triacanthos	honey locust	GLETRI	native	4	1
Gymnocladus dioicus	kentucky coffee-tree	GYMDIO	native	3	5
Hydrophyllum appendiculatum	appendaged waterleaf	HYDAPP	native	5	5
Impatiens capensis	spotted touch-me-not	IMPCAP	native	2	-3
Laportea canadensis	wood-nettle	LAPCAN	native	5	-3
Leonurus cardiaca	**common motherwort**	**LEOCAR**	**non-native**	**0**	**5**
Maianthemum stellatum	starry false solomons-seal	MAISTE	native	7	-3
Mentha arvensis	field mint	MENARV	native	2	-3
Osmorhiza longistylis	smooth sweet cicely	OSMOLO	native	4	3
Parietaria pensylvanica	pellitory	PARPEN	native	4	4
Parthenocissus quinquefolia	virginia creeper	PARQUI	native	2	3
Phytolacca americana	pokeweed	PHYAME	native	1	2
Pilea pumila	canadian clearweed	PILPUM	native	2	-3
Polygonatum biflorum	smooth solomons-seal	POLBIF	native	4	3
Prunus virginiana	choke cherry	PRUVIR	native	2	3
Quercus bicolor	swamp white oak	QUEBIC	native	7	-4
Rhamnus cathartica	**european buckthorn**	**RHACAT**	**non-native**	**0**	**2**
Rhus typhina	staghorn sumac	RHUTYP	native	2	5
Rosa multiflora	**multiflora rose**	**ROSMUL**	**non-native**	**0**	**3**
Sambucus canadensis	common elderberry	SAMCAN	native	3	-2
Sanicula canadensis	short-styled snakeroot	SANICAN	native	3	5
Scrophularia marilandica	maryland figwort	SCRMAR	native	4	4
Smilax lasioneura	pale carrion-flower	SMXLAS	native	6	0
Symphyotrichum lateriflorum	calico aster	SYMLAT	native	2	-2
Symphyotrichum shortii	shorts aster	SYMSHO	native	4	5
Toxicodendron radicans	poison-ivy	TOXRAD	native	1	0
Ulmus americana	american elm	ULMAME	native	2	-2
Urtica dioica l. var. procera	american stinging nettle	URTIDIOP	native	1	1
Viola sororia	common blue violet	VIOSOR	native	1	1
Vitis riparia	riverbank grape	VITRIP	native	3	-3

Appendix 3 - Natural Community Overviews and Distribution Maps

LIMESTONE BEDROCK LAKESHORE

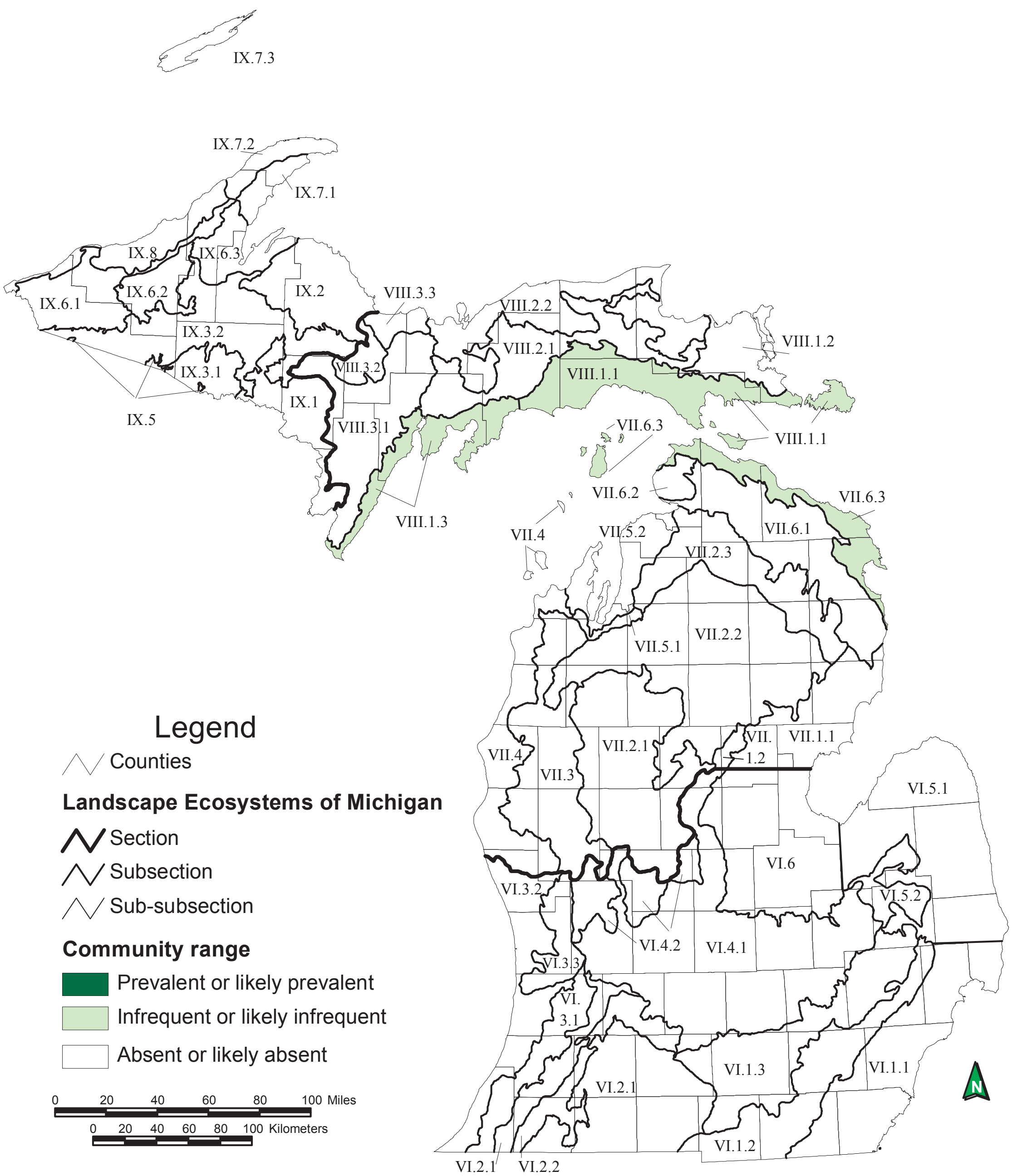
Overview: Limestone bedrock lakeshore is a sparsely vegetated natural community dominated by lichens, mosses, and herbaceous vegetation. This community, which is also referred to as alvar pavement and limestone pavement lakeshore, occurs along the shorelines of northern Lake Michigan and Lake Huron on broad, flat, horizontally bedded expanses of limestone or dolomite bedrock. On the Lake Michigan shoreline, limestone bedrock lakeshore is concentrated along the Garden Peninsula and adjacent islands and also occurs along the southern part of Schoolcraft County. Along Lake Huron, it is located east of the Les Cheneaux Islands, on Drummond Island, and on islands in Thunder Bay. Limestone bedrock lakeshore 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 bedrock lakeshore, removing fine mineral sediments and organic soils. Winter storms scour vegetation from limestone bedrock lakeshore. Long-term cyclic fluctuations of Great Lakes water levels significantly influence vegetation patterns of limestone bedrock lakeshore, with vegetation and organic soils becoming well established during low-water periods and reduced or eliminated during high-water periods (Kost et al. 2007, Cohen et al. 2015).



Map 1. Distribution of limestone bedrock lakeshore in Michigan (Albert et al. 2008).

LIMESTONE LAKESHORE CLIFF

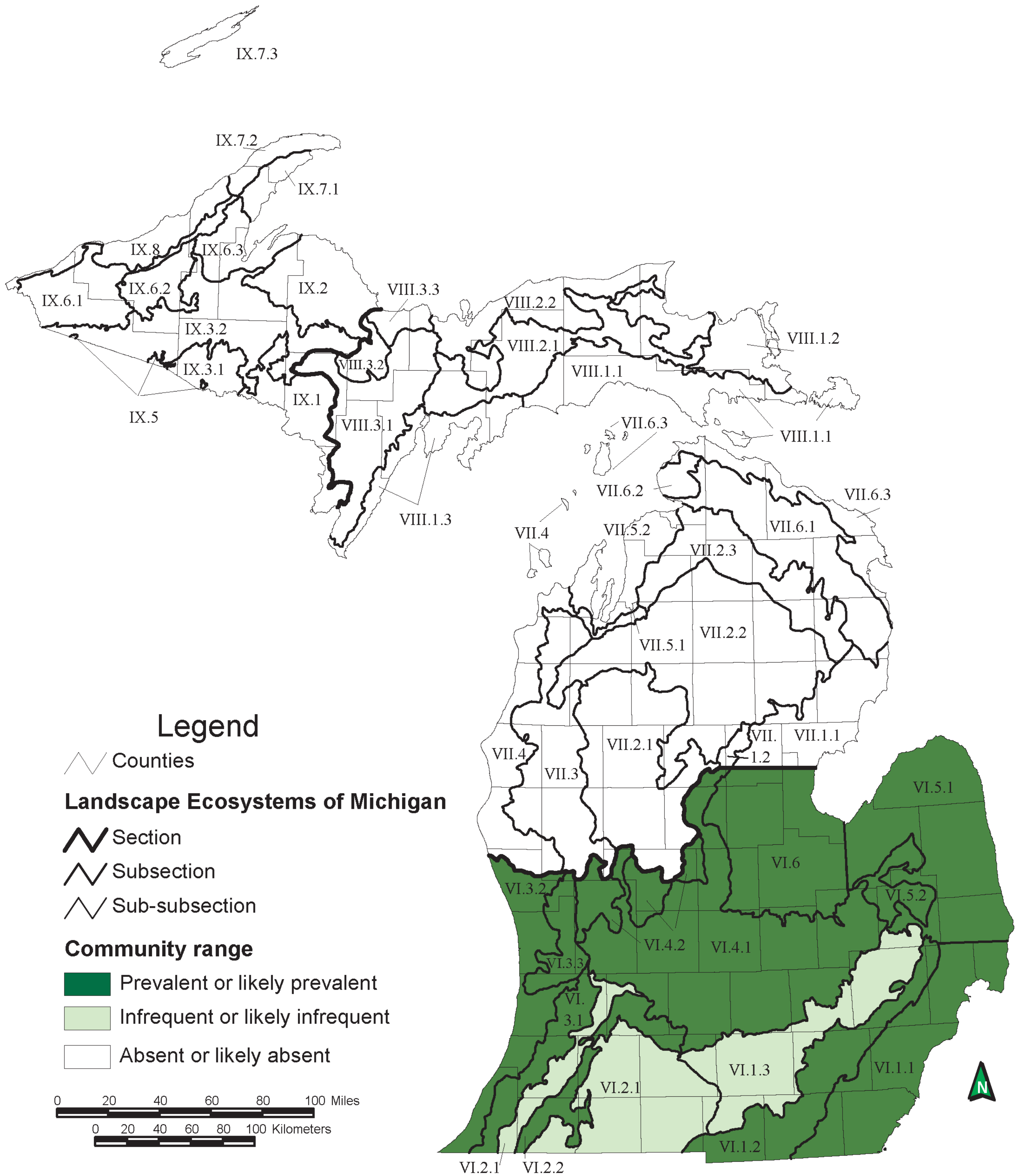
Overview: Limestone lakeshore cliff consists of vertical or near-vertical exposures of bedrock, which typically support less than 25% vascular plant coverage, although some rock surfaces can be densely covered with lichens, mosses, and liverworts. The community occurs in the Upper Peninsula along the shorelines of Lake Michigan and Lake Huron. Like all of Michigan's lakeshore cliffs, vegetation cover is sparse but abundant cracks and crevices combined with calcareous conditions result in greater plant diversity and coverage than on most other cliff types. Limestone lakeshore cliffs are characterized by high site moisture due to the proximity to the Great Lakes and a stressed and unstable environment because of severe waves, wind, and winter ice. The vertical structure of cliffs causes constant erosion and restricts soil development to the cliff edge, cracks, ledges, and the base of the cliff where organic matter and soil particles can accumulate. The thin soils and direct exposure to wind, ice, and sun produce desiccating conditions that limit plant growth. Weathering results in the gradual exfoliation of exposed limestone along the cliff face, which adds to the instability of the ecosystem, reducing dependable habitat for plant establishment. As portions of the bedrock slough off, they form talus slopes of boulders and slabs along the base of cliffs and expose fresh, bare rock substrates along the cliff face. Windthrow of canopy trees along the cliff escarpment is common due to the thin soils, unstable substrate, and high wind activity. Windblown trees along ledges and at the base of the cliff provide localized areas for soil accumulation (Kost et al. 2007, Cohen et al. 2015).



Map 2. Distribution of limestone lakeshore cliff in Michigan (Albert et al. 2008).

MESIC SOUTHERN FOREST

Overview: Mesic southern forest is an American beech- and sugar maple-dominated forest distributed south of the climatic tension zone and found on flat to rolling topography with predominantly loam soils. The natural disturbance regime is characterized by gap-phase dynamics; frequent, small windthrow gaps allow for the regeneration of shade-tolerant, canopy species. Historically, mesic southern forest occurred as a matrix system, dominating vast areas of rolling to level, loamy uplands of the Great Lakes region. These forests were multi-generational, with old-growth conditions lasting many centuries (Kost et al. 2007, Cohen et al. 2015).



Map 3. Distribution of mesic southern forest in Michigan (Albert et al. 2008).