Rare and Invasive Plant Surveys of West Sister National Wildlife Refuge

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Cover Photo: Limestone cobble shore along the southeastern shore of West Sister Island. Photo by Joshua G. Cohen.

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Disembarking onto West Sister Island. Boat captain Jim Mitchell and assistant pictured. 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 more than 32,000 islands occurs across the Great Lakes plus 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 existing natural communities to support the needs of priority and migratory bird species, threatened and endangered species, and resident wildlife and provide valuable 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. Despite limited access, these islands still face a variety of anthropogenic pressures including the establishment and spread of invasive plant and animal species and the impacts of climate change. Unfortunately, most biodiversity data are limited or outdated, which hinders effective management and decision-making.

To address this critical information gap, the USFWS contracted Michigan Natural Features Inventory (MNFI) to conduct botanical surveys, including rare and invasive plant species mapping and floristic surveys of natural communities; and ecological surveys, including qualitative natural community surveys and quantitative forest sampling. In 2021, botanical and ecological surveys were conducted in Michigan Islands NWR in Lake Huron (Bassett et al. 2022a, Cohen et al. 2022a) and Gravel Island and Green Bay NWRs in Lake Michigan (Bassett et al. 2022b, Cohen et al. 2022b). In 2022, botanical and ecological surveys were conducted in Huron NWR in Lake Superior (Bassett et al. 2023a, Cohen et al. 2023a), Harbor Island NWR in Lake Huron (Bassett et al. 2023b, Cohen et al. 2023b), Michigan Islands NWR in Lake Michigan (Bassett et al. 2023c, Cohen et al. 2023c), and West Sister Island NWR in Lake Erie (*this report*, Cohen et al. 2023d). Botanical surveys were also conducted in 2022 in Detroit River International Wildlife Refuge (Bassett et al. 2023d). This report focuses on the botanical surveys conducted in 2022 in West Sister Island NWR.

Limestone lakeshore cliff on West Sister Island. Note dense colonial nesting water birds. Photo by Scott M. Warner.

There are 615 rare vascular plant species in Ohio that are tracked in the Ohio Natural Heritage Database (Ohio DNR 2022). This included species listed at the state- and federal-levels as threatened and endangered in Ohio that are legally protected. Potentially threatened species are also tracked and include species that are considered at risk of declining but are not legally protected. There are an additional 24 species under review for inclusion on this list. Managing populations of these species and their habitat is a high conservation priority. These species are frequently associated with high-quality ecosystems, or natural communities, that further warrant prioritized management.

A critical goal of this project was to collect updated and new data for rare plant species occurrences to provide natural resource managers and planners with accurate, detailed, standardized baseline information on the viability and extent of rare species populations and the condition of their habitat on these islands. An equally critical goal of this project was to collect updated and new data for invasive species that potentially threaten the viability of rare plant species and high-quality natural communities on these islands. This baseline information facilitates site-level decisions about biodiversity stewardship; prioritizing protection, management and restoration decisions; monitoring the success of management and restoration; and informing landscape-level biodiversity planning efforts. Data on the location and extent of rare plant species and natural communities enables invasive plant species management to better protect these targets of high conservation value. This report summarizes the findings of MNFI's rare and invasive plant surveys on West Sister Island in West Sister Island National Wildlife Refuge of the Ottawa National Wildlife Refuge Complex.

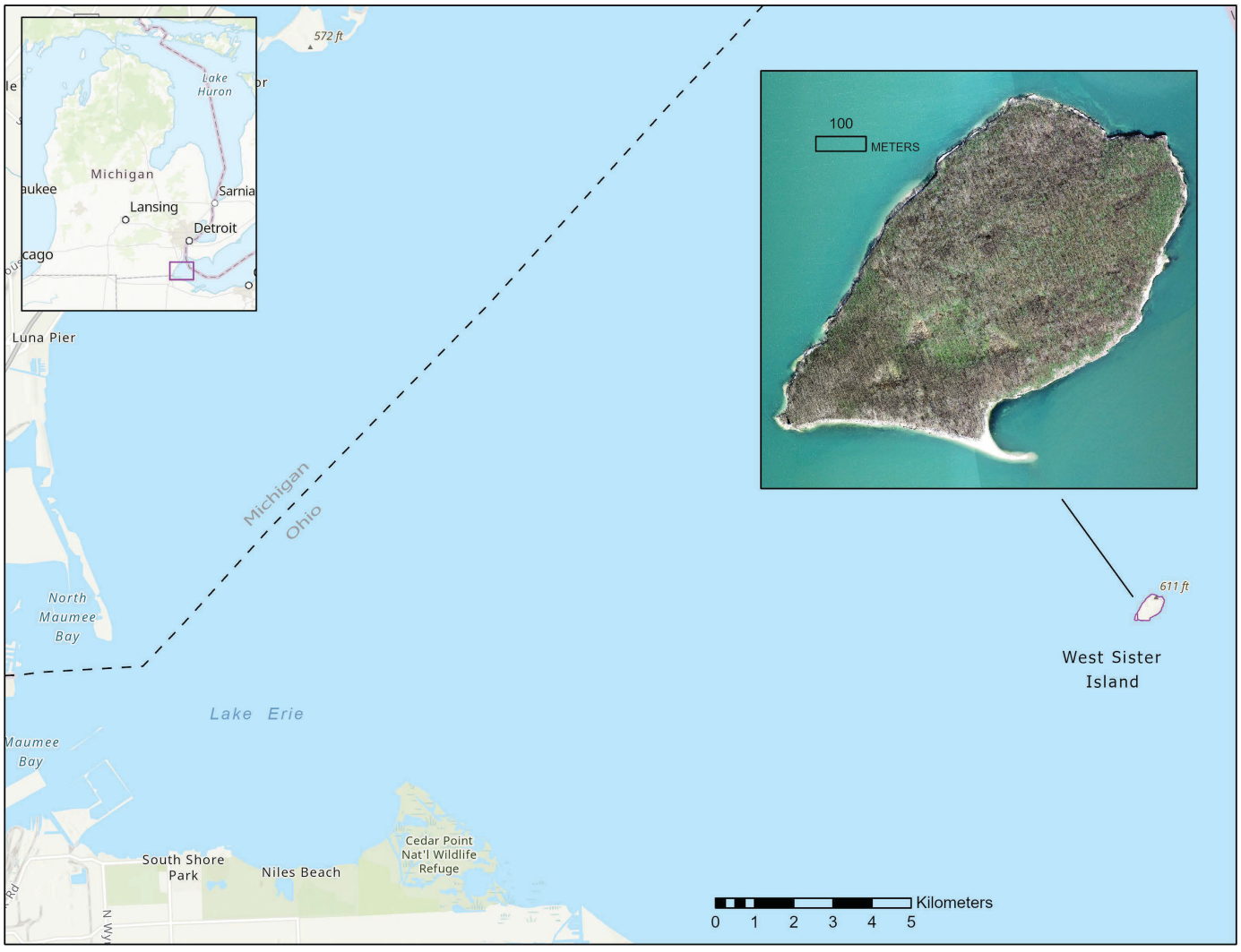

Figure 1. West sister Island in Lake Erie.

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 from 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.

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).

Prioritization and survey targets

Prior to conducting rare and invasive plant surveys, we reviewed previous data and generated target species lists to focus survey effort on known locations and potential habitat for these species. Invasive plant species targets are prioritized by USFWS for the Great Lakes region (see Table 1). We prioritized survey effort by reviewing natural community delineations and evaluating the conservation status (G- and S-ranks; Appendix 1.1) of each natural community (Table 2; Appendix 1.1; Cohen et al 2023b). Rare plant survey targets included species with previously documented element occurrences (EOs) from West Sister Island and in the Ohio Natural Heritage Database and also reported in primary and gray literature (Table 3; R.L. Gardner, pers comm; Gardner 2005, Stuckey and Duncan 2010, Duncan et al. 2011). There are several rare species reported only from quarries on Kelleys Island that were not specifically targeted because they were not known from coastal limestone communities, although many are known from limestone bedrock lakeshore elsewhere (e.g., *Carex*

Table 1. USFWS Great Lakes Region target invasive species.

Scientific Name	Common Name
Alliaria petiolata	Garlic mustard
Alnus glutinosa	Black alder
Berberis thunbergii	Japanese barberry
Butomus umbellatus	Flowering rush
Celastrus orbiculatus	Oriental bittersweet
Centaurea stoebe	Spotted knapweed
Cirsium arvense	Canada thistle
Dioscorea polystachya	Chinese yam
Dipsacus fullonum	Wild teasel
Dipsacus laciniatus	Cut-leaf teasel
Eichhornia crassipes	Water hyacinth
Elaeagnus umbellata	Autumn olive
Fallopia japonica	Japanese knotweed
Fallopia sachalinensis	Giant knotweed
Frangula alnus (syn. *Rhamnus frangula*)	Glossy buckthorn
Hesperis matronalis	Dame's rocket
Hydrocharis morsus-ranae	European frog-bit
Iris pseudacorus	Yellow flag iris
Ligustrum vulgare	Common privet
Lonicera spp.	Bush honeysuckle
Ludwigia peploides	Floating primrose willow
Myriophyllum aquaticum	Parrot-feather milfoil
Phalaris arundinacea	Reed canary grass
Phragmites australis subsp. *australis*	Invasive reed
Pistia stratiotes	Water lettuce
Populus alba	White poplar
Rhamnus cathartica	Common buckthorn
Robinia pseudoacacia	Black locust
Rosa multiflora	Multiflora rose
Vincetoxicum nigrum (syn. *Cynanchum louiseae*)	Black swallow-wort
Vincetoxicum rossicum (syn. *Cynanchum rossicum*)	Dog-strangling vine

Table 2. Natural community types targeted for surveys on West Sister Island. Natural community delineations are based on Michigan Natural Features Inventory Classification System, were determined remotely, and may differ from natural communities observed during field surveys. (Cohen et al. 2020). Global and State Rank (G- and S-Rank) values are based on NatureServe 2002 (see Appendix 1).

Natural community	Global rank	State rank
Limestone bedrock lakeshore	G3	S2
Limestone cobble shore	G2G3	S3
Limestone lakeshore cliff	G4G5	S1
Mesic southern forest	G2G3	S3
Sand and gravel beach	G3?	S3
Southern hardwood swamp	G3	S3

garberi, Clinopodium arkansanum, Packera paupercula; Duncan et al. 2011). An EO is an area of land or water where a significant element of biodiversity including rare species and natural communities currently occurs or historically occurred. Each EO may be comprised of multiple observations of a species or community through space or time, and is given a unique numeric identifier, an EOID.

Field surveys

We conducted meander surveys on West Sister Island, using the following approach to maximize the probability of encountering targets and incidental observations of rare and invasive plant species. This approach was repeated across all the NWRs surveyed by MNFI in 2021-2022 (Bassett et al. 2022a, 2022b, 2023a, 2023b, 2023c, 2023d). We surveyed the entire perimeter of the island, as a potential entry point for invasive plant species and due to the high probability of encountering rare species in the unique primary limestone communities. We also conducted meanders through the interior of the island, crossing through each natural community as delineated prior to surveys (USFWS 2021). The survey route adequately covered the natural community and micro-habitats or areas of non-homogenous habitat within each community type. These were noted in either aerial imagery and other GIS data prior to the survey, or while meandering during the survey. We conducted floristic surveys during the course of meanders. We generated a species list for each natural community on West Sister Island. If a natural community was represented by multiple patches or polygons on an island, we pooled species lists across these for that island. Botanical surveys were conducted on West Sister Island from July 18th through July 20th, 2022.

We collected data on rare and invasive plant species using applications on a Samsung tablet, augmented by hand-written field notes. For rare species we used a custom Survey123 form, "MNFI Rare Species App Form" (see Appendix E in USFWS 2021). IIn this form, we collected data on population parameters including an estimate of abundance and proportion of fertile plants; habitat, including natural community designation and dominant species; any notable microhabitat features; and threats such as invasive species. Refuge staff have access to rare plant species data through the USFWS subscription to the Michigan Natural Heritage Database. Floristic surveys were completed by recording species lists in a field notebook. Nomenclature follows Voss and Reznicek (2012).

For target and select non-target invasive plant species in high-quality natural communities, and for select

Table 3. Rare plant species targets for West Sister Island. Species reported previously from West Sister Island (Hawkins 1977, Gardner 2005, Stuckey and Duncan 2010) noted with a numeric EOID (*Arabis pycnocarpa* var. *pycnocarpa* reported from West Sister Island but not in Natural Heritage Database). Other species with EOID = NA have been reported from Bass Islands to the east in Lake Erie (Duncan et al. 2011). G/S and EO Ranks defined in Appendix 1.

Scientific Name	Common Name	State Status	G/S Rank	EOID	EO Rank	Year Last Observed	Natural Communities
Arabis pycnocarpa var. pycnocarpa	Hairy rock cress	X	G5T5/SH	NA	NA	1977	Limestone lakeshore cliff
Boechera stricta	Drummond crock cress	E	GNR/S1	12877	F	1996	Limestone lakeshore cliff
Campanula rotunndifolia	Harebell	T	G5/S2	NA	NA	NA	Limestone lakeshore cliff
Euthamia caroliniana	Slender goldentop	T	G5/S2	10545	H	1981	Limestone lakeshore cliff
Symphyotrichum drummondii	Drummond's aster	T	G5/S2	11972	E	2004	Mesic southern forest
Viola neprophylla	Northern bog violet	T	G5/S2	NA	NA	NA	Limestone bedrock lakeshore

invasive species occurrences outside high-quality natural communities, we mapped invasive plant species occurrences as a point, line, or polygon using the ArcCollector Web Map "R3 Invasive and Weed Observations layer" managed by the USFWS (see Appendix F in USFWS 2021). In this form, we estimated the percent of mapped area occupied by each invasive plant species, and observer data (e.g., name of observer, observation date). We also noted the presence and abundance of target and select non-target invasive plant species occurring in degraded areas in field notebooks. Refuge staff have access to invasive plant species data through the USFWS R3 portal on ArcGIS Online.

Ranking and assessment

We assessed the viability of each rare plant EO using standard Natural Heritage Methodology (NatureServe 2002). According to this methodology, each EO is assigned a rank from A (excellent estimated viability/ecological integrity) to D (poor estimated viability/ecological integrity) when sufficient data is available to assess a rank. When data is not available and for instances where an EO is not located, additional ranks include E (Verified extant), F (Failed to find), H (Historical), and X (Extirpated). See Appendix 1.2 for EO Rank definitions.

Finally, we conducted Floristic Quality Assessments (FQAs) for each natural community on the island (Andreas et al. 2004). The FQA utilizes plant species composition to derive the Floristic Quality Index (FQI), a quantitative metric of habitat quality that can be used as a relatively objective comparison among natural community occurrences of the same type. Drawing upon expert consensus among botanists familiar with the flora of Ohio, each vascular plant species in Ohio has been assigned an a priori coefficient of conservatism (C-value) that ranges from 0 to 10 on a scale of increasing conservatism or fidelity to pre-European colonization habitats (Andreas et al. 2004). Plant species with a C-value of 7 to 10 are considered highly conservative (Herman et al. 2001). A C-value of 4 to 6 indicates moderate conservatism and a C-value of 1 to 3 indicates low or no conservatism (e.g., ruderal species). Non-native species were given a C-value of 0 for these calculations. We calculated FQI for each natural community occurrence as

$$FQI = \bar{C} \times \sqrt{n}$$

where $\bar{C}$ = mean C-value and n = species richness. Sites with an FQI of 35 or greater are generally considered to be florstically important from a statewide perspective (Herman et al. 2001).

Botanist Scott Warner conducting a survey on limestone lakeshore cliff. Photo by E. Haber.

Botanist Elizabeth Haber conducting a survey in mesic southern forest. Photo by Scott M. Warner.

Ruderal plant community along limestone lakeshore cliff. Photo by Joshua G. Cohen.

Results and Discussion

We did not document or confirm any rare plant EOs on West Sister Island (Table 3). We conducted FQAs in three natural community occurrences (Table 4), and documented occurrences of three target invasive plant species (Table 5).

We recorded 73 plant species in three natural communities on West Sister Island, with a mean coefficient of conservatism of 2.0 (Table 4, Appendix 2.1). Three natural community element occurrences were surveyed on West Sister Island including limestone bedrock lakeshore, limestone lakeshore cliff, and mesic southern forest (Appendix 2.2-2.4; Cohen et al. 2023d). High soil nutrient levels and other disturbances associated with dense nesting waterbird colonies appear to limit floristic diversity on the island. Mesic southern forest was the most species-rich community with 46 species documented, 85% of which were native species. A large proportion of these native species were disturbance-adapted rather than conservative (hence mean C =2.3). The primary limestone communities were less diverse with a much lower native component than mesic southern forest on West Sister Island, and lower than similar limestone communities recently surveyed in the Great Lakes in northern Lakes Michigan and Huron (Bassett et al. 2022a, 2022b, 2023b). We documented 37 vascular plant species (49% native) in limestone lakeshore cliff, and 23 species (61% native) in limestone bedrock lakeshore. We did not document any rare plant species on West Sister Island (Table 3).

We mapped three priority target invasive plant species on West Sister Island (Table 5, Figure 2). We considered garlic mustard (*Alliaria petiolata*), multiflora rose (*Rosa multiflora*), and common buckthorn (*Rhamnus cathartica*) to be significant threats to the island's three natural communities. Common buckthorn and multiflora rose were each detected in one location. Currently their abundance is low enough to consider eradication as a viable management goal. Garlic mustard was abundant across the island's three natural communities, far more so than our mapping would indicate. Limited time on the island prevented us from mapping all patches. Bittersweet nightshade (*Solanum dulcamara*) and white mulberry (*Morus alba*), neither of which are target invasive species, were both mapped on West Sister Island. These species, however, may be "passengers" rather than "drivers" of ecological change (MacDougall and Turkington 2005). Rather than degrading ecological integrity, bittersweet nightshade and white mulberry may be examples of species that are abundant instead in response to the disturbances associated with high bird density.

Table 4. Floristic quality summaries for West Sister Island. SR = species richness (% native), C = coefficient of conservatism, FQI = floristic quality index.

		Limestone Bedrock Lakeshore	Limestone Lakeshore Cliff	Mesic Southern Forest	Whole Island
West Sister	SR	23 (61%)	37 (49%)	46 (85%)	73 (66%)
	C	1.8	1	2.8	2
	FQI	8.6	6.1	19	

We observed 21 other non-native species on the island, which we did not consider to be a management priorities so did not map. These included lambs-quarters (*Chenopodium album*), catnip (*Nepeta cataria*), curly dock (*Rumex crispus*), penny cress (*Thlaspi arvense*), and motherwort (*Leonurus cardiaca*) (Appendix 2.1).

The stewardship prioritization ranking of natural communities on West Sister Island surveyed by MNFI that was included in Cohen et al. (2023d) may provide additional direction when considering invasive plant species management. We recommend using the principles of integrated pest management to guide the investment of resources (USFWS Cal-IPC 2018), and coordinating with local Cooperative Invasive Species Management Areas.

Table 5. Invasive species documented at West Sister Island during our surveys, and abundance estimates. All species are USFWS Great Lakes Region target species. Abundance estimate in **bold** is very common.

Scientific Name	Common Name	West Sister
Alliaria petiolata	Garlic mustard	**abundant**
Rhamnus cathartica	Common buckthorn	rare
Rosa multiflora	Multiflora rose	rare

Hackberry (*Celtis occidentalis*), the canopy dominant in mesic southern forest. Photo by Joshua G. Cohen.

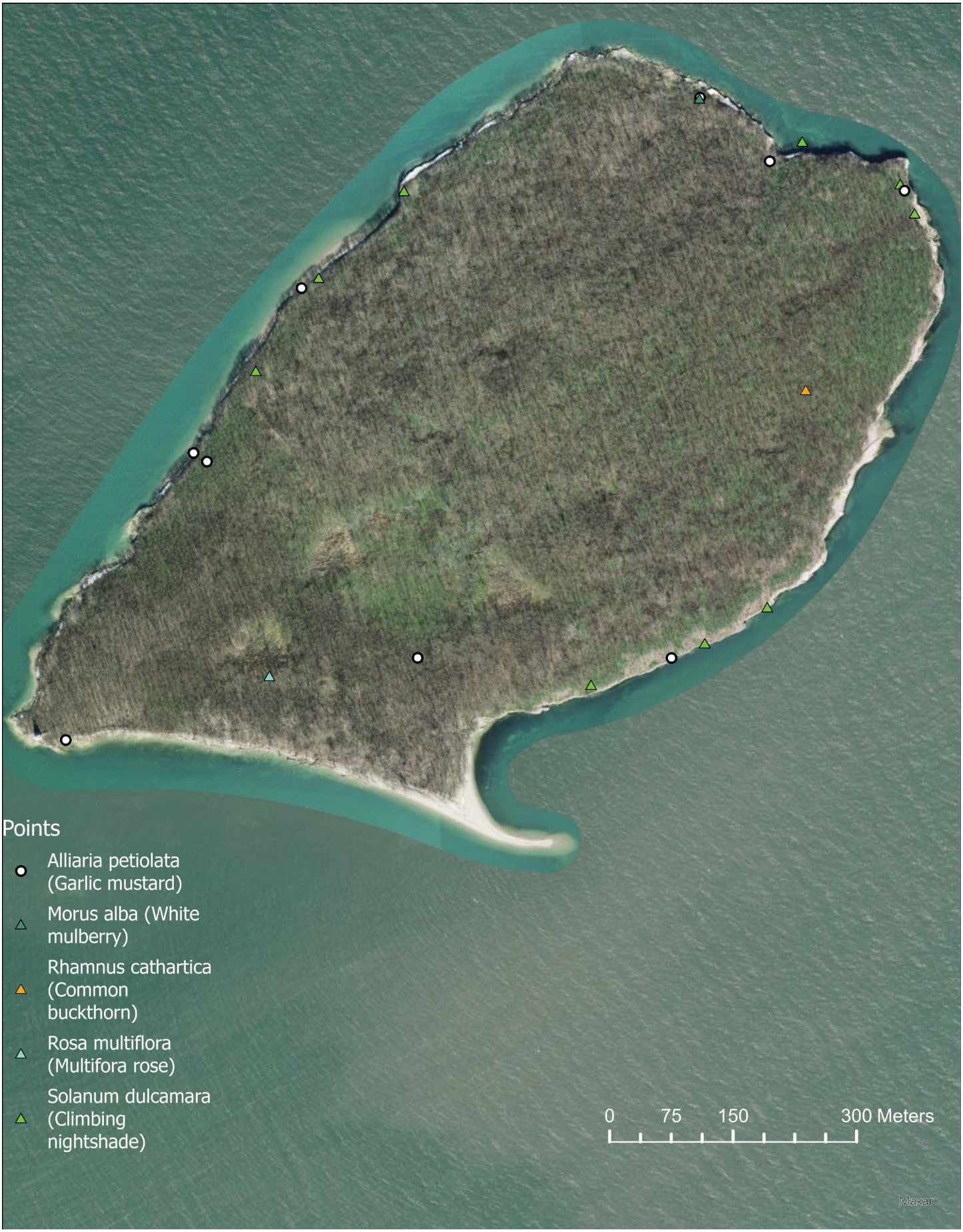

Figure 2. Invasive plant species mapped on West sister Island during our study.

Conclusion

We conducted botanical surveys on West Sister Island in the West Sister Island NWR to collect updated and new data for rare and invasive plant species occurrences. Data on the extent and distribution of these occurrences were collected to guide management prioritization and serve as a baseline for tracking the efficacy of that management. We also conducted natural community surveys on West Sister Island, and a separate report outlines a management prioritization across the natural community EOs (Cohen et al. 2023d). The scope of botanical surveys differs from natural community surveys with the inclusion of degraded areas outside of natural community EOs and the focus on rare plant species as a conservation priority. Here, we summarize these priorities.

Gardner (2005) reported 114 taxa from West Sister Island in 2004, compared to the 73 taxa we report here. Gardner's list includes 53 of his own observations (including 41 collections) from a June 16, 2004 survey, and reports from Hawkins (1977). Possible reasons for our observing lower species richness than Gardner's (2005) and Hawkins' (1977) collective efforts include seasonality and nesting bird abundance. We visited the island one month later (July 18 – 20) than Gardner. It is possible that by Gardner's 2004 survey, the acidifying and nutrient-enriching effects of the cormorants' guano had not yet accumulated sufficiently to degrade the island's flora, but that they had by the time of our 2022 survey. The long-term influence of colonial nesting waterbirds may influence phenology, such as early fruit-set and senescence.

Gardner (2005) reported six currently state-listed species during his or Hawkins' (1977) surveys. Two species that Hawkins reported, round-leaved dogwood (*Cornus rugosa*, Potentially Threatened) and prairie wedgegrass (*Sphenopholis obtusata* var. *obtusata*, State Endangered), are likely misidentifications (R.L. Gardner, pers comm). One species, hairy rock cress (*Arabis pycnocarpa* var. *pycnocarpa*), is now presumed extirpated in Ohio. The three other species that were previously reported from West Sister Island, but were not found in 2022, were Drummond rock cress (*Boechera stricta*, State Endangered; last observed 1996), slender goldentop (*Euthamia caroliniana*, State Threatened), and Drummond's aster (*Symphyotrichum drummondii*, State Threatened). Future surveys should continue to target these three species, as well as hairy rock cress. The present survey could have overlooked these species due to their persisting at low abundance, or low detectability due to phenology or occurrence in the most inaccessible portions of the limestone shoreline.

Mesic southern forest on West Sister Island, showing canopy dominated by hackberry (*Celtis occidentalis*), and understory dominated by great waterfleaf (*Hydrophyllum appendiculatum*). Photo by Elizabeth A. Haber.

Floristic quality of natural community types can help managers to prioritize systems with the greatest native plant diversity. Natural community occurrences with an FQI above 35 are considered management priorities with exceptional floristic quality (Herman et al. 2001). Floristic quality was consistently low in natural communities on West Sister Island (Table 4). Floristic quality in mesic southern forest was notably higher than either limestone bedrock lakeshore or limestone lakeshore cliff (Table 4). The calculation of FQI, however, does not take species abundance into account, so a higher FQI can be misleading if invasive species abundances are high and conservative species abundances are low. The interpretation of FQA results should be weighed against the more in-depth considerations of ecological integrity provided in the natural community descriptions in Cohen et al. (2023d).

The species lists in this report are associated with overlapping, yet often different areas than in Cohen et al. (2023d; Appendix 2). Different surveyors may interpret community boundaries differently and include species that are associated with species of neighboring natural communities, and here our descriptions are more inclusive as they are not limited to EO boundaries. For example, we included species observed in disturbed portions of mesic southern forest that were not included in the natural community EOs (Cohen et al. 2023d).

West Sister Island has supported a massive colony of wading birds for at least several decades. Pierce (1985) summarized nine nest censuses taken between 1959 and 1983. In 1959 and 1982, only black-crowned night heron nests were observed, but in all other years upwards from 600 great blue heron and upwards from 50 great white egret nests were observed in a given year. In 1992, double-crested cormorants began to nest on the island, where they quickly found great success to the detriment of other colonial nesting birds and vegetation (Shieldcastle 1997). Judziewicz (2001) reports similar floristic degradation in the wake of cormorant colonization, which we confirmed in 2021 on Pilot Island in Green Bay NWR in Lake Michigan (Bassett et al. 2022a). Pilot Island once supported a white cedar (*Thuja occidentalis*) forest, but by 2021 was reduced to ruderal ground cover supporting mostly weeds such as bittersweet nightshade, field sow-thistle (*Sonchus arvensis*), and cheeseweed (*Malva neglecta*) (Bassett et al. 2022a).

The prioritization of invasive species management is best focused on conserving high-quality natural communities and rare species. There were few yet widespread invasive plant species on the island. West Sister Island faces continual disturbance from colonial nesting birds, leading to the ruderal nature of the plant communities. However, rare plant species have been observed there in recent decades. Invasive species management may support the recovery of plant species diversity, perhaps including rare plant species.

Great waterleaf (*Hydrophyllum appendiculatum*) in mesic southern forest. Photo by Elizabeth A. Haber.

Black snakeroot (*Sanicula canadensis*) in mesic southern forest. Photo by Elizabeth A. Haber.

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Appendix 1. Element and Element Occurrence Ranking Criteria

Appendix 1.1. Subnational (State) and Global element ranking criteria.

Subnational Rank		DEFINITION
S1	Critically Imperiled	At very high risk of extirpation in the jurisdiction due to very restricted range, very few populations or occurrences, very steep declines, severe threats, or other factors.
S2	Imperiled	At high risk of extirpation in the jurisdiction due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors.
S3	Vulnerable	At moderate risk of extirpation in the jurisdiction due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors.
S4	Apparently Secure	At a fairly low risk of extirpation in the jurisdiction due to an extensive range and/or many populations or occurrences, but with possible cause for some concern as a result of local recent declines, threats, or other factors.
S5	Secure	At very low or no risk of extirpation in the jurisdiction due to a very extensive range, abundant populations or occurrences, with little to no concern from declines or threats.
Global Rank		**DEFINITION**
G1	Critically Imperiled	At very high risk of extinction or elimination due to very restricted range, very few populations or occurrences, very steep declines, very severe threats, or other factors.
G2	Imperiled	At high risk of extinction or elimination due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors.
G3	Vulnerable	At moderate risk of extinction or elimination due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors.
G4	Apparently Secure	At fairly low risk of extinction or elimination due to an extensive range and/or many populations or occurrences, but with possible cause for some concern as a result of local recent declines, threats, or other factors.
G5	Secure	At very low risk or extinction or elimination due to a very extensive range, abundant populations or occurrences, and little to no concern from declines or threats.
GU	Unrankable	Currently unrankable due to lack of information or due to substantially conflicting information about status or trends. NOTE: Whenever possible (when the range of uncertainty is three consecutive ranks or less), a range rank (e.g., G2G3) should be used to delineate the limits (range) of uncertainty.

Appendix 1.2. Element occurrence ranking criteria.

Rank	Definition
A	**Excellent estimated viability** - Based on current information on EO rank factors (i.e., condition, size, and landscape context) for the EO, it is believed to have an excellent probability of persisting, if current conditions prevail, for a defined period of time, typically 20-100 years (for communities, persistence within the bounds of natural disturbance regimes).
B	**Good estimated viability** - Based on current information on EO rank factors (i.e., condition, size, and Iandscape context) for the EO, it is believed to have a good probability of persisting, if current conditions prevail, for a defined period of time, typically 20-100 years (for communities, persistence within the bounds of natural disturbance regimes).
C	**Fair estimated viability** - Based on current information on EO rank factors (i.e., condition, size, and landscape context) for the EO, it is believed to have a fair probability of persisting, if current conditions prevail, for a defined period of time, typically 20-100 years (for communities, persistence within the bounds of natural disturbance regimes).
D	**Poor estimated viability** - Based on current information on EO rank factors (i.e., condition, size, and landscape context) for the EO, it is believed to have a poor probability of persisting, if current conditions prevail, for a defined period of time, typically 20-100 years (for communities, persistence within the bounds of natural disturbance regimes).
E	**Verified Extant** - EO has been recently verified as still existing, but sufficient information on the factors used to estimate viability of the occurrence has not yet been obtained. Use of the E rank should be reserved for those situations where the occurrence is thought to be extant, but an A, B, C, D, or range rank cannot be assigned.
H	**Historical** - There is a lack of recent[1] field information verifying the continued existence of the EO, such as when the occurrence is based only on historical collections data, or when the occurrence was ranked A, B, C, D, or E at one time and is later, without field survey work, considered to be possibly extirpated due to general habitat loss or degradation of the environment in the area.
F	**Failed to find** - EO has not been found despite a search by an experienced observer at a time and under conditions appropriate for the Element at a Iocation where it was previously reported, but that still might be confirmed to exist at that location with additional field survey efforts. For EOs with vague locational information, the search must include areas of appropriate habitat within the range of locational uncertainty. An F rank, when applicable, supersedes an A, B, C, D, E, or H rank.
X	**Extirpated** - There is documented destruction of the habitat or environment of the EO, or persuasive evidence of its eradication based on adequate survey (i .e. , thorough or repeated survey efforts by one or more experienced observers at times and under conditions appropriate for the Element at that location).
U	**Unrankable** - An EO rank cannot be assigned due to lack of sufficient information on the occurrence.
NR	**Not Ranked** - An EO rank has not yet been assigned to the occurrence.

Appendix 2. Floristic Quality Assessments

We conducted Floristic Quality Assessments (FQAs) for each natural community on the island (Andreas et al. 2004). The FQA utilizes plant species composition to derive the Floristic Quality Index (FQI), a quantitative metric of habitat quality that can be used as a relatively objective comparison among natural community occurrences of the same type. Drawing upon expert consensus among botanists familiar with the flora of Ohio, each vascular plant species in Ohio has been assigned an a priori coefficient of conservatism (C-value) that ranges from 0 to 10 on a scale of increasing conservatism or fidelity to pre-European colonization habitats (Andreas et al. 2004). Plant species with a C-value of 7 to 10 are considered highly conservative (Herman et al. 2001). A C-value of 4 to 6 indicates moderate conservatism and a C-value of 1 to 3 indicates low or no conservatism (e.g., ruderal species). Non-native species were given a C-value of 0 for these calculations. We calculated FQI for each natural community occurrence as

$$FQI = \bar{C} \times \sqrt{n}$$

where $\bar{C}$ = mean C-value and n = species richness. Sites with an FQI of 35 or greater are generally considered to be florstically important from a statewide perspective (Herman et al. 2001).

Appendix 2.1. West Sister Island FQA.

Conservatism-Based Metrics:

Total Mean C:	2
Native Mean C:	3.1
Total FQI:	17.1
Native FQI:	21.5
Adjusted FQI:	25.1
% C value 0:	38.4
% C value 1-3:	32.9
% C value 4-6:	23.3
% C value 7-10:	5.5
Native Tree Mean C:	3.7
Native Shrub Mean C:	2.5
Native Herbaceous Mean C:	3

Species Richness:

Total Species:	73	
Native Species:	48	65.80%
Non-native Species:	25	34.20%

Species Wetness:

Mean Wetness:	1.9
Native Mean Wetness:	1.1

Physiognomy Metrics:

Tree:	8	11%
Shrub:	3	4.10%
Vine:	5	6.80%
Forb:	49	67.10%
Grass:	5	6.80%
Sedge:	3	4.10%
Rush:	0	0%
Fern:	0	0%
Bryophyte:	0	0%

Duration Metrics:

Annual:	19	26%
Perennial:	47	64.40%
Biennial:	7	9.60%
Native Annual:	8	11%
Native Perennial:	37	50.70%
Native Biennial:	3	4.10%

Appendix 2.1. West Sister Island FQA, continued.

Scientific Name	Common Name	Acronym	Native?	C	W
Abutilon theophrasti	velvetleaf	ABUTHE	non-native	0	5
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
Arisaema triphyllum	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
Brassica nigra	black mustard	BRANIG	non-native	0	5
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
Conyza canadensis	horseweed	CONCAN	native	0	5
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
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
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
Lactuca serriola	prickly lettuce	LACSER	non-native	0	1
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
Malva neglecta	cheese mallow	MALNEG	non-native	0	5
Mentha arvensis	field mint	MENARV	native	2	-3
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
Osmorhiza longistylis	smooth sweet cicely	OSMOLO	native	4	3
Parietaria pensylvanica	pellitory	PARPEN	native	4	4
Parthenocissus quinquefolia	virginia creeper	PARQUI	native	2	3
Persicaria lapathifolium	dock-leaved smartweed	PERLAP	native	1	-4
Persicaria maculosa	ladys thumb	PERMAC	non-native	0	-3
Phytolacca americana	pokeweed	PHYAME	native	1	2
Pilea pumila	canadian clearweed	PILPUM	native	2	-3
Poa annua	annual bluegrass	POAANN	non-native	0	3
Poa compressa	canada bluegrass	POACOM	non-native	0	3

Appendix 2.1. West Sister Island FQA, continued.

Scientific Name	Common Name	Acronym	Native?	C	W
Polygonatum biflorum	smooth solomons-seal	POLBIF	native	4	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
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
Rumex crispus	curly dock	RUMCRI	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
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
Symphyotrichum lateriflorum	calico aster	SYMLAT	native	2	-2
Symphyotrichum shortii	shorts aster	SYMSHO	native	4	5
Taraxacum officinale	common dandelion	TAROFF	non-native	0	4
Thlaspi arvense	field penny cress	THLARV	non-native	0	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
Vallisneria americana	water-celery	VALAME	native	8	-5
Verbascum thapsus	common mullein	VERTHA	non-native	0	5
Viola sororia	common blue violet	VIOSOR	native	1	1
Vitis riparia	riverbank grape	VITRIP	native	3	-3

Appendix 2.2. 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%
Vine:	2	8.70%
Forb:	15	65.20%
Grass:	1	4.30%
Sedge:	0	0%
Rush:	0	0%
Fern:	0	0%
Bryophyte:	0	0%

Duration Metrics:

Annual:	6	26.10%
Perennial:	14	60.90%
Biennial:	3	13%
Native Annual:	1	4.30%
Native Perennial:	12	52.20%
Native Biennial:	1	4.30%

Appendix 2.2. 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 2.3. West Sister Island Limestone Lakeshore Cliff FQA.

Conservatism-Based Metrics:

Total Mean C:	1
Native Mean C:	2.1
Total FQI:	6.1
Native FQI:	8.9
Adjusted FQI:	14.6
% C value 0:	56.8
% C value 1-3:	32.4
% 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

Physiognomy Metrics:

Tree:	4	10.80%
Shrub:	1	2.70%
Vine:	3	8.10%
Forb:	27	73%
Grass:	2	5.40%
Sedge:	0	0%
Rush:	0	0%
Fern:	0	0%
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 2.3. 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 lapathifolium	dock-leaved smartweed	PERLAP	native	1	-4
Persicaria maculosa	ladys thumb	PERMAC	non-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 2.4. 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%
Bryophyte:	0	0%

Duration Metrics:

Annual:	6	13%
Perennial:	37	80.40%
Biennial:	3	6.50%
Native Annual:	5	10.90%
Native Perennial:	33	71.70%
Native Biennial:	1	2.20%

Appendix 2.4. 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	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