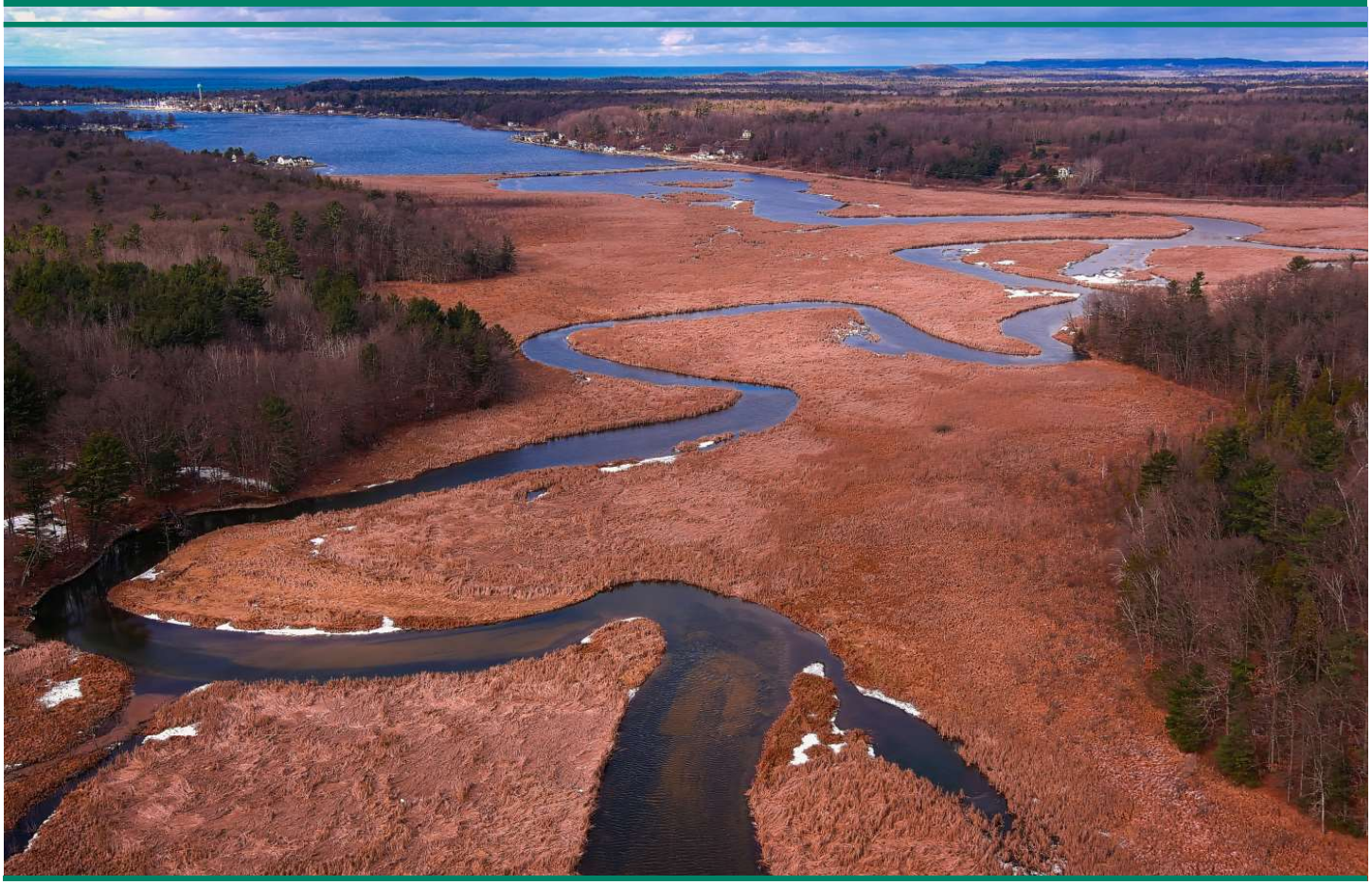
Natural Features Inventory and Management Recommendations for Pentwater State Game Area



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Michigan Natural Features Inventory

MICHIGAN STATE UNIVERSITY | Extension

Michigan Natural Features Inventory

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We collectively acknowledge that Michigan State University occupies the ancestral, traditional, and contemporary Lands of the Anishinaabeg – Three Fires Confederacy of Ojibwe, Odawa, and Potawatomi peoples. In particular, the University resides on Land ceded in the 1819 Treaty of Saginaw. We recognize, support, and advocate for the sovereignty of Michigan's twelve federally recognized Indian nations, for historic Indigenous communities in Michigan, for Indigenous individuals and communities who live here now, and for those who were forcibly removed from their Homelands. By offering this Land Acknowledgement, we affirm Indigenous sovereignty and will work to hold Michigan State University more accountable to the needs of American Indian and Indigenous peoples.

Cover Photo: Pentwater Great Lakes Marsh. Photo by J. M. Lincoln.

ACKNOWLEDGEMENTS

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A special thanks to Jeff Chandonnet and family for lodging during natural community surveys. We also thank Will and Keeley Lent who accompanied us on surveys of the dry-mesic northern forest.

DNR Wildlife Biologist Pete Kailing and Wildlife Technician Rachel Kanaziz assisted during field surveys. Photo by J.M. Lincoln.

EXECUTIVE SUMMARY

The Pentwater State Game Area (SGA) is a block of semi-contiguous public land in west Michigan, consisting of 2,585 acres in Oceana County. Pentwater SGA is important ecologically because it provides critical habitat for a myriad of game and non-game species and supports 1,784 acres of upland forest, 301 acres of forested wetland, and 295 acres of non-forested wetlands and lakes. The extensive forests and various wetlands are especially prominent features of Pentwater SGA and the natural cover within the game area supports a diversity of rare herptiles (reptiles and amphibians), plants, birds, insects, and mollusks.

Michigan Natural Features Inventory (MNFI) conducted Stage 1 Michigan Forest Inventory (MiFI) in 2015 and surveys for high-quality natural communities and rare animals were conducted in 2022 and 2023 as part of the Integrated Inventory Project. This project is part of a long-term effort by MNFI to document areas of high conservation significance on state lands and provide information to the Michigan Department of Natural Resources, Wildlife Division regarding sustainable management of those important areas.

MNFI scientists documented six new natural community Element Occurrences (EOs) and 6 new rare animal EOs and provided information for updating three existing EOs. In total, 17 EOs have been documented in Pentwater SGA including eight animal EOs, two plant EOs, and seven natural community EOs.

A Great Lakes marsh in Pentwater Lake was initially documented in 1988 and was re-evaluated in 2022. During the 2022 field season MNFI ecologists also documented six additional new natural communities, including a bog, a dry-mesic northern forest, two intermittent wetlands, a mesic northern forest, and a wet-mesic sand prairie. The two species of rare plants, meadow-beauty (*Rhexia virginica*; State Special Concern) and waterthread pondweed (*Potamogeton bicupulatus*; State Threatened), were found in the intermittent wetlands. Together, these high-quality communities represent 24.3% of the game area, harbor populations of two rare plants species, and provide critical habitat for several populations of rare animals found within the game area.

Given the presence of mature forest and marsh we focused bird surveys in the game area on rare songbirds, marsh birds, nocturnal birds, and raptors. We conducted forest songbird surveys at 29 points. No rare forest songbirds were detected. During marsh bird surveys we recorded two least bitterns (*Ixobrychus exilis*, State Threatened) and two marsh wrens (*Cistothorus palustris,* State Special Concern) within the Great Lakes marsh along the eastern end of Pentwater Lake. Three eastern whip-poor-will (*Antrostomus vociferus*) were recorded during nocturnal bird surveys. Red-shouldered hawks (*Buteo lineatus*, State Special Concern) were detected at four points though we did not record any active nests within the vicinity of these detections. Three additional bird species detected have are DNR featured species, including pileated woodpecker (*Dryocopus pileatus*), wood thrush (*Hylocichla mustelina*), and wild turkey (*Meleagris gallopavo*). Wood thrush are also a species of greatest conservation need and a focal species for conservation efforts under the Landbird Habitat Conservation Strategy of the Upper Mississippi River and Great Lakes Region Joint Venture.

MNFI scientists conducted visual encounter surveys for rare reptiles throughout the game area with a focus along the Pentwater River. The Blanding's turtle (*Emydoidea blandingii*; State Special Concern) was the only rare herptile found during the surveys. Surveys targeting wood turtles (*Glyptemys insculpta*, State Threatened) along the Pentwater River were unsuccessful, despite suitable habitat.

Two types of rare insect surveys were conducted at Pentwater SGA targeting Great Plains spittlebug (*Lepyronia gibbosa*, State Special Concern) and the Federally Endangered Hine's emerald dragonfly (*Somatochlora hineana*, State Endangered). We documented a single occurrence of Great Plains spittlebug in one of the wet-mesic sand prairie openings, and despite suitable habitat, we did not find any Hine's emerald dragonflies.

We identified two stands for land snail surveys based on the presence of mature, relatively high-quality forest. We documented the median striate (*Striatura meridionalis*, State Special Concern) in litter surveys at two plots, comprising two new element occurrences. We also documented additional species with uncertain conservation status that may be rare in Michigan but have not been assessed. We found 10 individuals of the carved glyph (*Glyphyalinia indentata*, Vulnerable in Ontario); 11 individuals of the small spot (*Punctum minutissimum*, Imperiled in Indiana); and three black striates (*Striatura ferrea*, Vulnerable in Minnesota and Ontario and Imperiled in Wisconsin).

Aquatic surveys were performed at four sites in the Pentwater River within Pentwater SGA. A total of three unionid mussel species were found including fatmucket (*Lampsilis siliquoidea*), white heelsplitter (*Lasmigona complanata*), and giant floater (*Pyganodon grandis*). Though no state threatened or endangered mussel species or species of special concern were found, the presence of young white heelsplitter indicates recent reproduction. Zebra mussels (*Dreissena polymorpha*) are having a negative impact on native mussel populations within the game area.

We provide the following management recommendations to protect native biodiversity and ecosystem integrity in order of importance: 1) establish Priority Conservation Areas (PCAs) around the natural communities identified in this report, populations of rare taxa, and areas of relatively unfragmented forests that can serve as future old growth; 2) develop and prioritize stewardship actions within those PCAs with the aim of improving or maintaining the condition of natural communities primarily by controlling invasive species, applying prescribed fire, and limiting damage to natural resources by trails; and 3) conduct long term monitoring on the condition of natural communities, populations of rare taxa, and the effectiveness of stewardship actions. Our fundamental recommendations are to minimize degradation of natural areas by limiting fragmentation within PCAs, preventing habitat loss by addressing serious infestations of invasive species, continuing to apply prescribed fire within the highest quality fire-dependent systems, and continually evaluating the effectiveness of stewardship actions.

Mears Barn along the eastern edge of the Great Lakes marsh east of Pentwater Lake.
Photo by J.M. Lincoln.

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INTRODUCTION

The Pentwater State Game Area (SGA) is a relatively large block of semi-contiguous public land in the western Lower Peninsula of Michigan, consisting of 2,585 acres (1,045 ha) in Oceana County (Figure 1). The land is owned and managed by the Wildlife Division of Michigan's Department of Natural Resources (DNR) and was purchased by funds secured by the Pittman-Robertson Federal Aid in Wildlife Restoration Act administered by the DNR's Wildlife Division (WLD). Pentwater SGA is important ecologically because it has extensive unfragmented mature forests and an example of Great Lakes marsh which provide habitat for a myriad of game and non-game species and natural cover in an area characterized by increasing rural development and extensive agriculture.

Michigan Natural Features Inventory (MNFI) is Michigan's natural heritage program and maintains a geospatial database of populations of rare and declining species and benchmark natural communities. MNFI and the DNR WLD have been collaborating since 2009 to provide comprehensive ecological evaluation of state lands through an "Integrated Inventory" project which is also funded through the Pittman-Robertson Act. As part of the DNR's Integrated Inventory Project, in 2015 MNFI conducted Michigan Forest Inventory (MiFI) habitat cover type mapping process within the Pentwater SGA. Surveys for high-quality natural communities and rare animals were conducted in 2022 and 2023. This project is part of a long-term effort by MNFI to document areas of high conservation significance on state lands and provide the DNR WLD with information to inform the sustainable management of those areas. This project addresses MNFI's mission to guide the conservation of Michigan's biodiversity for current and future generations by providing the highest quality scientific expertise and information and the DNR WLD's complementary mission to enhance,

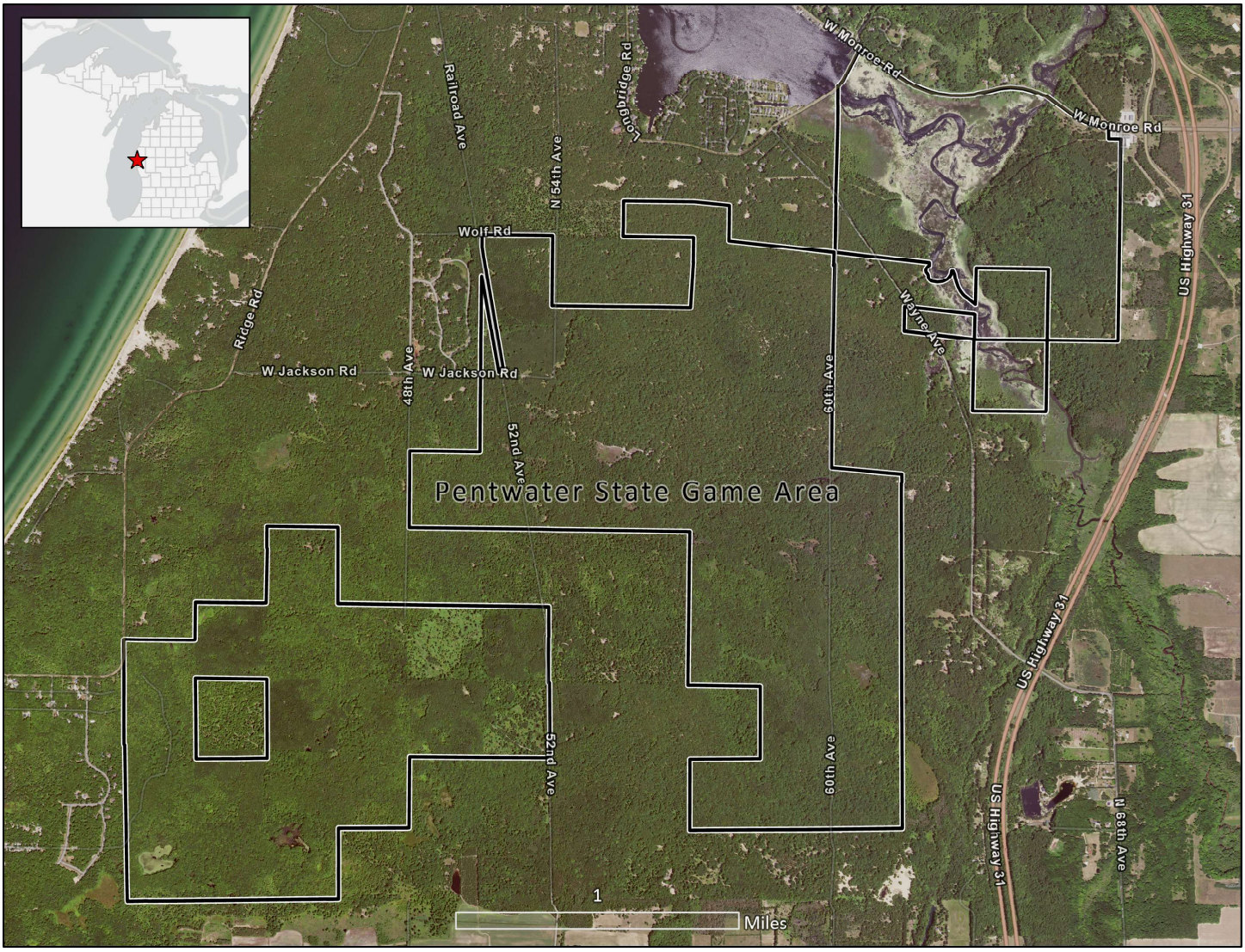


Figure 1. Imagery of Pentwater State Game Area (ESRI 2020).

restore and conserve the State's wildlife resources, natural communities, and ecosystems for the benefit of Michigan's citizens, visitors, and future generations.

The primary goal of this Integrated Inventory is to provide resource managers and planners with standardized, baseline information on each natural community and rare species occurrences and identify the most critical places on state lands for biodiversity stewardship. This baseline information is vital for informing landscape-level biodiversity planning efforts; prioritizing protection, management, and restoration objectives; facilitating site-level decisions about biodiversity stewardship; and monitoring the success of management and restoration.

This report provides an overview of the landscape and historical context of Pentwater SGA, summarizes the findings of MNFI's surveys for high-quality natural communities and rare animal species, and identifies stewardship priorities within the game area. Because the landscape surrounding Pentwater SGA is characterized by agricultural and rural development, the area of natural cover within the game area serves as an important reservoir of biodiversity for the region. Pentwater SGA supports rare plant, avian, reptile, snail, and insect species. During the natural features inventory of this game area, MNFI scientists documented or updated element occurrences of three rare bird species, two rare plants, one rare turtle, one rare insect, one rare land snail, and seven high-quality natural communities representing six natural community types.

Management recommendations are provided for rare species, specific natural communities, and the game area in general.

One of the most visible features of the game area is the Great Lakes marsh along the eastern portion of Pentwater Lake. This wetland provides many ecosystem services such as habitat for migratory birds and spawning fish as well as sequestering of nutrients, improving water quality, and hunting and recreation opportunities. Photo by J.M. Lincoln.

Landscape and Historical Context

Ecoregions

Michigan has been subdivided into ecoregions based on climate, glacial features, physiography, soils, and characteristic ecosystems (Albert 1995). This classification system provides a framework for understanding the distribution patterns of species, natural communities, natural disturbance regimes, and anthropogenic activities. The classification is structured with three levels, from broad landscape regions called Sections, down to smaller Subsections and Sub-Subsections. Pentwater SGA occurs in southern lower Michigan in Section VII within the Manistee Subsection (VII.4) (Albert 1995) (Figure 2). The Manistee Subsection lies along the west coast of the state and is moderated by Lake Michigan with sandy lake plain, areas of outwash, end moraine, small dune fields, and large dunes along Lake Michigan (Figure 3). Most of the game area occurs on outwash-over-lakeplain where there is a series of small dunes (Figure 4). This dune field supports a matrix of oak-pine forest on a series of old dune ridges with several small, isolated wetlands occurring between the dunes. These appear to be old interdunal wetlands that now support various types of wetland community types including intermittent wetland, wet-mesic sand prairie, bog, and northern shrub thicket (Albert 1995).

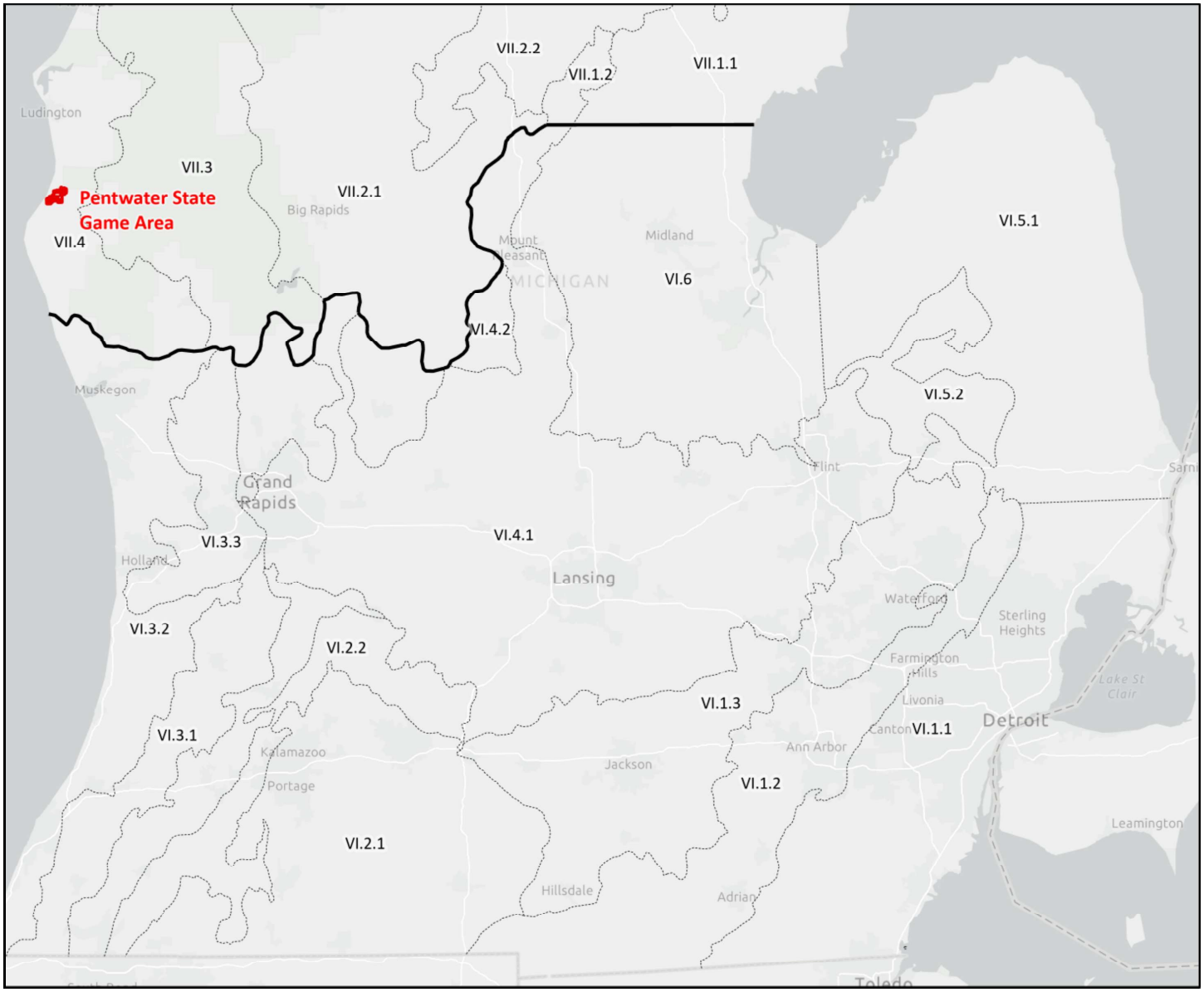


Figure 2. Ecoregions of southern Michigan. Pentwater SGA occurs within the Manistee Subsection (VII.4) of the ecoregions of the western lower peninsula of Michigan (Albert 1995).

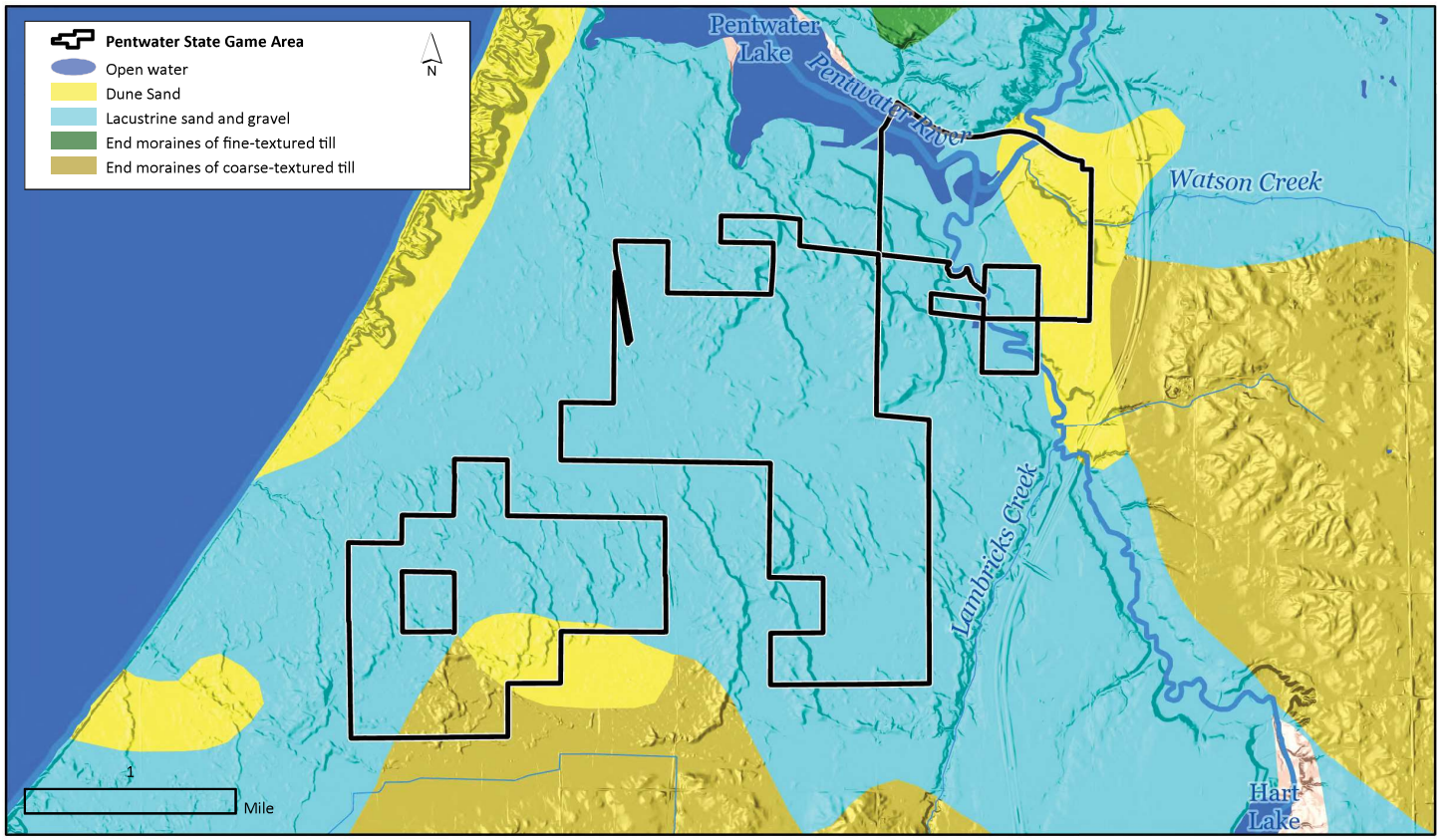


Figure 3. Surficial geology of the Pentwater State Game Area.

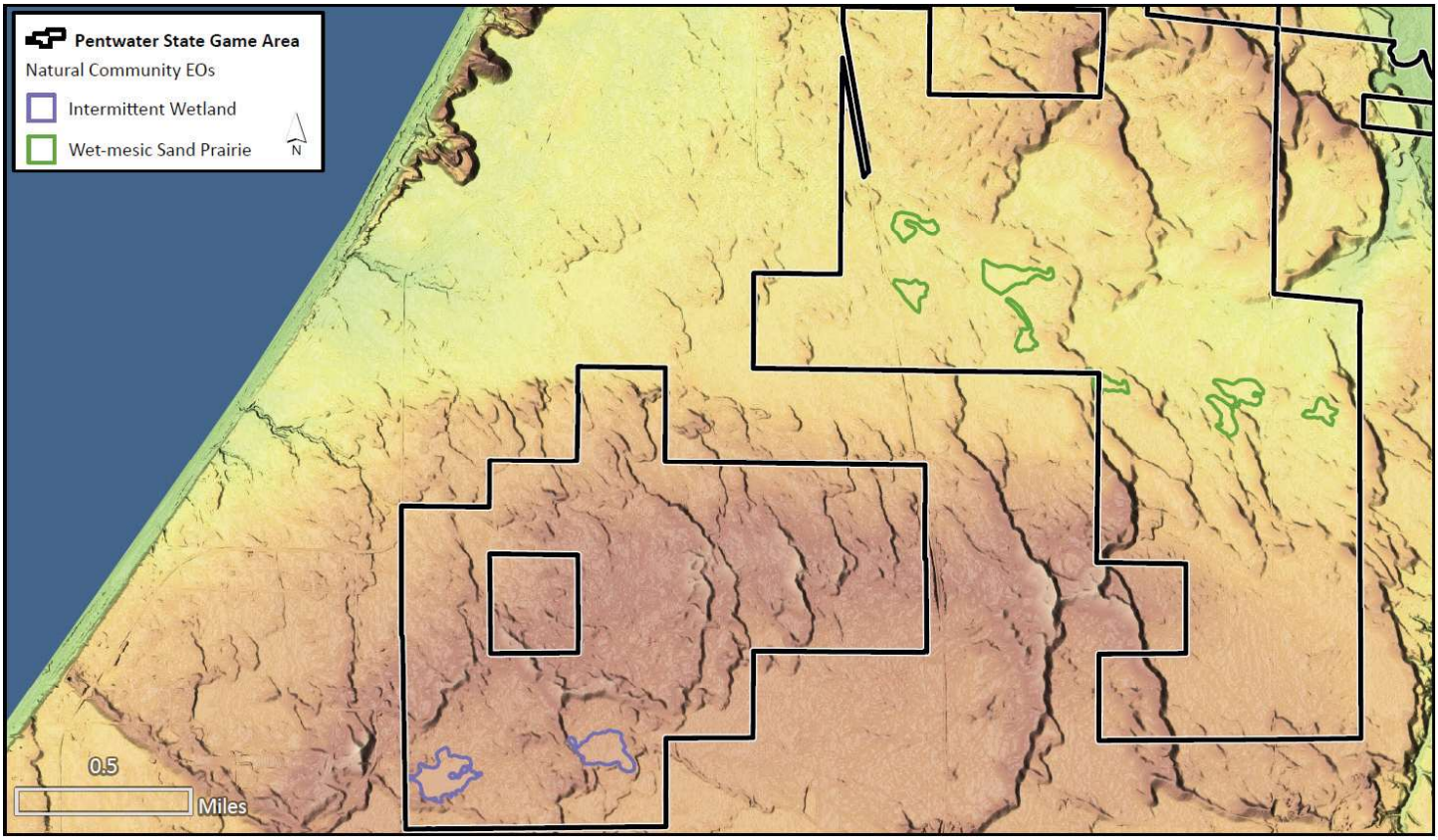


Figure 4. A digital elevation model of Pentwater State Game Area. This shows the large coastal dunes along the lake and a series of smaller dunes inland that form the unique topography of the game area. The dune field is characterized by a matrix of oak-pine forest with small wetlands between dunes. The intermittent wetlands and wet-mesic sand prairies documented during MNFI's natural community surveys occur between these dune features as small, isolated wetlands.

Circa-1800 Vegetation

Interpretations of the General Land Office (GLO) surveyor notes by MNFI ecologists indicated that the Pentwater SGA and surrounding area contained several distinct vegetation assemblages in the 1800s (Comer et al. 1995) (Figure 5). The GLO surveys of this part of Oceana County were conducted by John Mullett in 1838. He recorded information on tree species composition, tree size, and general condition of the lands within and surrounding Pentwater SGA. At the time of the first surveys, the upland portions of the game area was predominantly white pine-mixed hardwood forest (51.5%) and beech-sugar maple-hemlock forest (37.1%). There were small areas of mixed conifer swamp (3.2%), with emergent marsh (6.1%) and open water (1.6%) along the eastern portion of Pentwater Lake.

We evaluated the surveyor's notes within the game area and in the immediate vicinity of the game area to provide a summary of the composition and structure of the land in 1838. The most prevalent species across the game area was white pine (*Pinus strobus;* 41%) with beech (*Fagus grandifolia*; 22%), maple (*Acer spp.*; 10%), and eastern hemlock (*Tsuga canadensis*; 10%) as the other prevalent species. Red pine (*Pinus resinosa*; 7%) and white oak (*Quercus alba*; 7%) were relatively infrequent and recorded from areas of drier dune ridges. Recorded diameters of trees ranged widely from 12.7 to 91.4 cm (5 to 36 in) with an average of 36 cm (14.1 in; N = 58).

Michigan's natural community classification provides a useful framework for understanding and documenting the natural communities across the state. Based on the historic vegetation descriptions in the GLO notes, we have ascribed modern community types to what is now the Pentwater State Game Area, including dry-mesic northern forest, mesic northern forest, hardwood-conifer swamp, Great Lakes marsh, and small inclusions of other community types. The GLO notes made no mention of the prairies, bog, and intermittent wetlands that were documented by MNFI during the ecological surveys. These community types are relatively small and were regularly omitted from the GLO survey notes due to the coarse scale of the surveys and the surveyor's focus on timber.

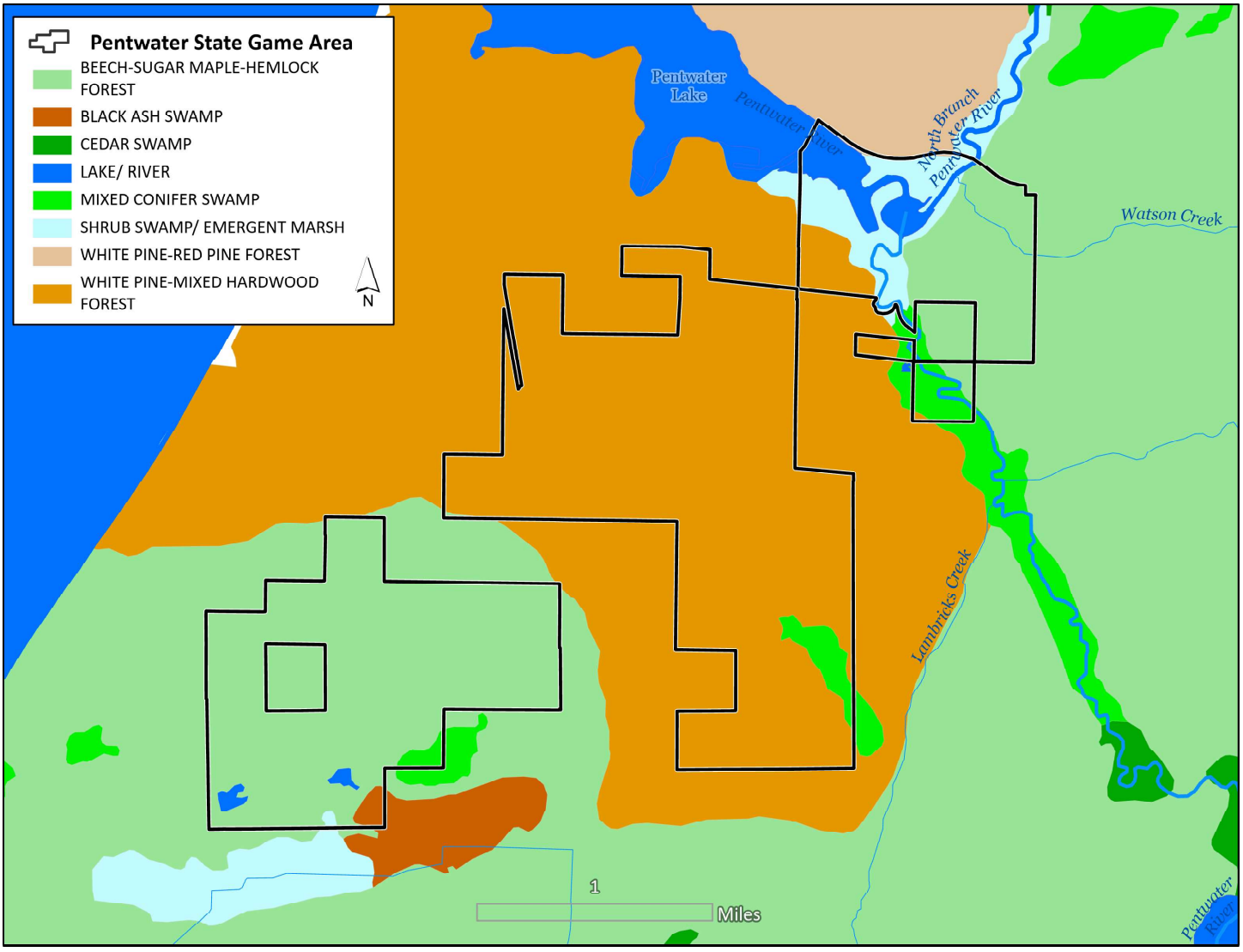


Figure 5. Vegetation of Pentwater State Game Area circa 1800 (Comer et al. 1995).

Pentwater SGA has several forests that have small wetland features known as vernal pools. These are extremely important for salamanders and other invertebrates. Photo by J.M. Lincoln.

One of the prevalent features of Pentwater SGA is the extensive forests. Though the land was logged in the 1800s, the game area retains an unusual degree of its historic character, compared to most of southern Michigan. Photo by J.M. Lincoln.

Changes in Land Cover

Though there is clear evidence of occupation by Indigenous Peoples in the Pentwater area dating back to the early 1600s, it is likely that the area was continuously occupied through the late woodland period (1500 to 900 years before present) (Hartwick and Tuller 1890, Quimby 1968). However, we do not know the full extent of their settlement or their full influence on the landscape. Euro-colonization brought removal of Indigenous Peoples, resettlement of other tribes, and fire suppression. This was followed by land clearing which meant logging, elimination of wildlife, agriculture, and hydrologic alterations. More recently tree diseases, non-native insect outbreaks, and invasive species infestations are altering the composition of the composition of the landscape. Excerpts from *Oceana County: Pioneers and Business Men* (Hartwick and Tuller 1890) provide first-hand accounts from the first European settlers of the county.

"In 1855 a treaty was made by which the tribes mentioned surrendered their land on Grand River and agreed to select a reservation to the north, and accordingly in 1857-1858 they shipped their shattered bands, seventeen in all, at Grand Haven, on board the steamer *Ottawa*, and *Charles Mears*, a large propeller, owned by Mr. Mears, came to Pentwater, the young men riding their ponies along the beach and made their way from Pentwater to their reservation in "Injun" Town."

"In the spring they made astonishing quantities of maple sugar… The county clerk in one season purchased six tons of maple sugar and 1500 gallons of syrup. In one day he bought 50 bushels of huckleberries, 15 bear skins, twenty wolf, and buck skins by the ton."

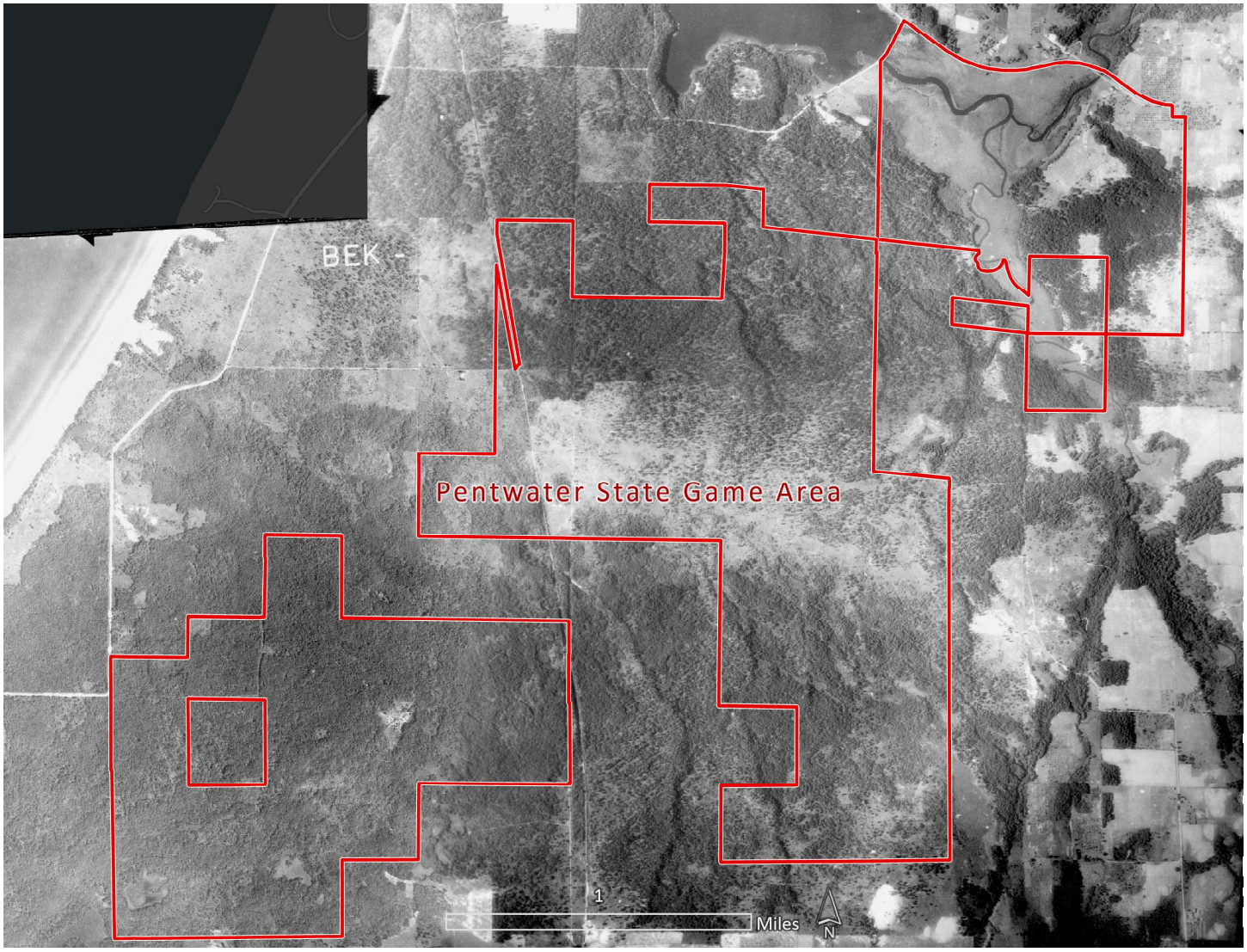


Figure 6. Mosaic of 1938 aerial photographs of Pentwater State Game Area. This resource can inform managers about important conservation targets because areas that were forested in the picture (typically the darker hues) tend to be dominated by native vegetation, have the oldest trees, and exhibit the lowest levels of invasive species. Therefore, these areas generally have the highest conservation value.

> “Wolves were numerous” and “as showing the number of wild pigeon [passenger pigeon] that came into Pentwater when the Indians were there, it is said that for nearly a mile along the shore, the Indians beat them down in windrows with brush, the squaws picking up the birds, and the White men, tired of shooting, took to killing with the butt of their guns.”

Another data point to the past that we have is from 1938 when planes were flown over the state as part of an effort to evaluate resources. Aerial photographs from 1938 (Figure 6) show how logging and the expansion of agriculture have contributed to habitat fragmentation and ecological degradation across the landscape. The imagery from 1938 is particularly useful for the identification of the highest quality forest remaining on the landscape. Unlike much of the surrounding landscape, most of the uplands in the game area were not cleared for agriculture. Despite being logged in the 1850s and 1860s, many forests in the Pentwater SGA have retained aspects of their historic character to an extent infrequently observed in southern Michigan. While several areas of Pentwater SGA have been logged since the state has assumed ownership, many have not. These areas of forest that were intact in the historic imagery are prominent in our conservation planning efforts outlined in this document.

To gauge landscape integrity, MNFI has developed a land use integrity index that is based on the proportion of land use in a buffer surrounding an area of interest (Figure 7). Stands surrounded by intensive land use (e.g., row crops and residences) receive lower scores and stands surrounded by natural cover (e.g., hardwood-conifer swamp and prairie fen) receive higher scores. Pentwater SGA is characterized by high land use index scores across the game area and especially in comparison with areas of agricultural operations to the south of the game area and the town of Pentwater to the north.

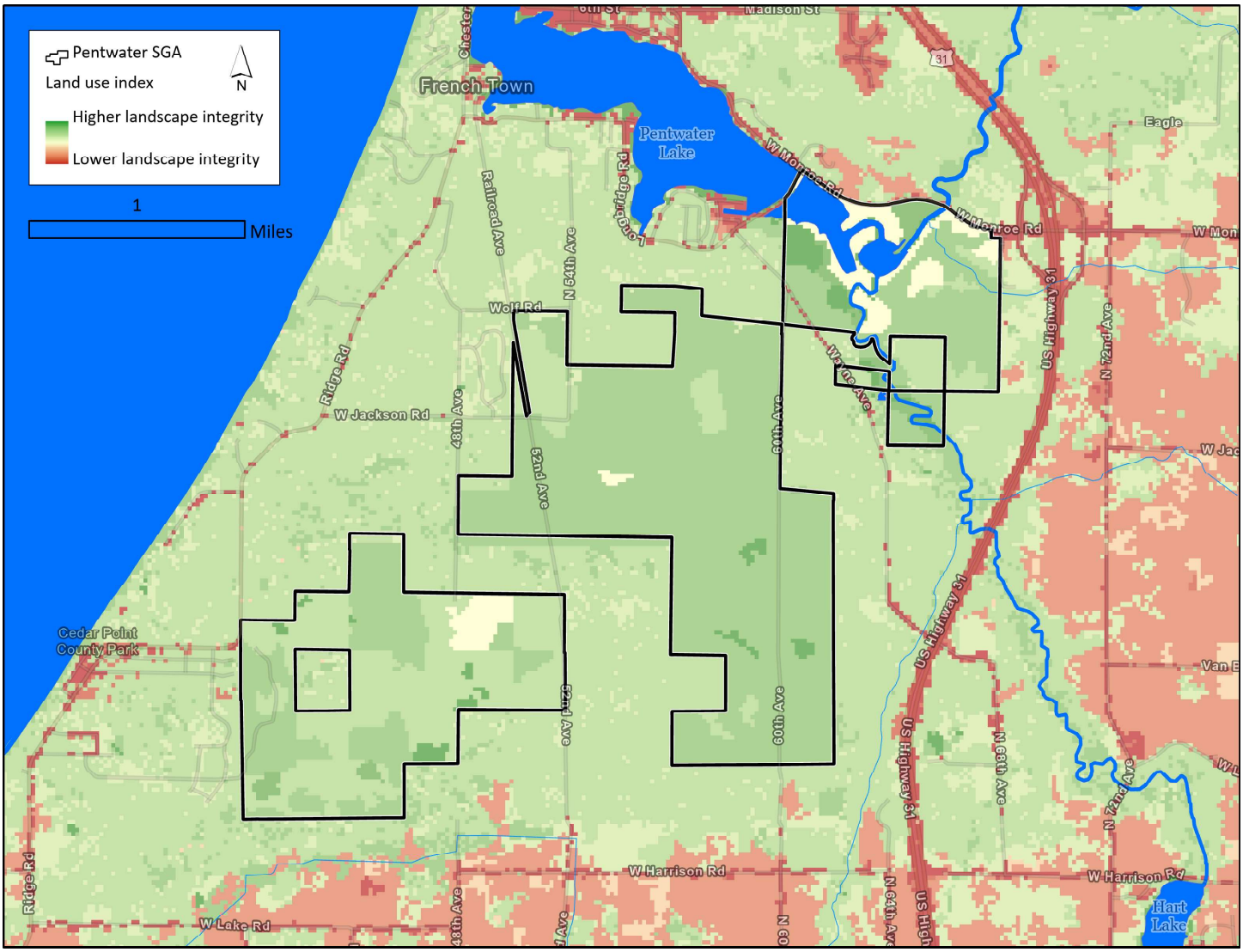


Figure 7. A land use index of Pentwater State Game Area. The land use index is based on the proportion of development and natural cover in an area of interest. Pentwater SGA is characterized by high landscape integrity index scores especially in contrast to the surrounding areas of agriculture and public lands.

The Manistee Subsection (VII.4) is 24% agriculture, 5% developed, and 46% forested. In comparison, the game area is currently 81% forested. Despite the dramatic shifts in composition from anthropogenic disturbance in the surrounding landscape, abundant natural cover remains within Pentwater SGA with 95% of the game area constituting natural cover and 24.3% (630.6 ac) documented as high-quality natural communities. In addition, Pentwater SGA remains predominantly unfragmented, especially in comparison with the surrounding land.

Looking at this historic and landscape context helps frame management options and contextualize the importance of the game area as a refuge for native biodiversity. While the GLO notes do not provide us the certainty of knowing exactly what the landscape looked like in the past, available descriptions depict a landscape with extensive oak-pine forest, similar to what is on the game area today. Land clearing has shifted the composition of the game area and the forests are likely much younger than they were historically and are in a more fire-suppressed state. Additionally, recently introduced tree diseases and new forest pests are altering composition of regional forests. Dutch elm disease, emerald ash borer, beech bark disease, and hemlock wooly adelgid have impacted the forests of the region and their effects are still unfolding. Despite changes to the landscape and threats to the health of our future forests, the game area currently supports extensive mature forest with excellent potential to develop into old growth that retains much if its historic character. This is particularly true given the DNR's approach to allowing the oldest forests to continue maturing and regularly applying prescribed fire in the highest quality examples of fire-dependent forests. This report is intended to provide information on Pentwater's remaining ecological assets to promote the conservation of the game area's unique natural heritage for current and future generations.

Though much has changed over the past 200 years, there are extensive areas of mature forest throughout much of Pentwater SGA. Photo by J.M. Lincoln.

METHODS

Throughout this report, natural community types and rare species are referred to as “elements” and their documented occurrences at specific location are referred to as element occurrences or “EOs”. Ecological and rare species surveys relied on a variety of data resources to determine if potential habitat occurs within the game area, including existing natural community EOs, MiFI cover types, aerial photography, and on-the-ground observations. The documentation of new high-quality natural communities was especially dependent on areas identified during the 2015 MiFI surveys. The combination of MiFI surveys and targeted natural community surveys helped inform subsequent rare species surveys and the development of management recommendations.

Species targeted for rare animal surveys were identified using historical distribution within Michigan, past occurrences in or near Pentwater SGA, and the presence of potential habitat as determined by MiFI and natural community surveys. Based on these criteria, rare animal surveys focused on rare nocturnal birds, woodland raptors, forest interior songbirds, and secretive marsh birds; reptiles and amphibians; several insect groups; rare land snails; and unionid mussels. Surveys for target animal species were conducted in appropriate habitats during time periods when targeted elements were expected to be most active and detectable (e.g., breeding season). Surveys were conducted to identify new occurrences, update or expand existing occurrences, and revisit historical occurrences of select rare species. Michigan’s Wildlife Action Plan (Derosier et al. 2015) identifies species of greatest conservation need (SGCN) and observations of these species were recorded when encountered.

Natural Community Surveys

MNFI’s natural community classification recognizes 77 natural community types in Michigan (Kost et al. 2007, Cohen et al. 2015). 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, such as timber harvest, alterations to hydrology, and fire suppression. Indigenous peoples have been integral to Michigan’s landscapes with many natural community types shaped by native land tending practices such as cultural burning, seeding, planting, and harvesting of plants and wildlife. The interactions between Indigenous cultures and their landscape were widespread, sophisticated, and central to maintaining historical abundances of biodiversity (Anderton 1999, Kimmerer and Lake 2001, Stewart 2009).

MNFI Entomologist, David Cuthrell surveys for the Federally Endangered Hine’s emerald dragonfly in sedge meadow along Watson Creek. Photo by L.M. Rowe.

The natural community EOs were evaluated employing Natural Heritage and MNFI methodology, which considers three factors to assess a natural community's ecological integrity or quality: size, landscape context, and condition (Faber-Langendoen et al. 2008, 2015). These Ecological Integrity Assessments provide a standard "biophysical exam" that assesses vegetative composition, soil attributes, hydrology, size, and interactions with the surrounding landscape. Evaluating ecological integrity or condition of natural communities provides resource managers with critical information on factors that may be degrading ecosystems and what conservation actions should be taken to safeguard native biodiversity. If a site meets defined requirements for the three criteria of size, landscape context, and condition (MNFI 1988), it is categorized as a high-quality example of that specific natural community type, entered into MNFI's database as an EO, and given a rank of A to D based on how well it meets the above criteria. MNFI scientists utilized a combination of field surveys, aerial photographic interpretation, and Geographic Information System (GIS) analysis to assess natural community size and landscape context.

Natural community surveys detailed the vegetative structure and composition, ecological boundaries, and landscape and abiotic context of exemplary natural communities. These surveys also assessed the current ranking, classification, and delineation of these occurrences. Ecological field surveys of Pentwater SGA were implemented over the growing season of 2022 and 2024.

Qualitative meander surveys were conducted to assess the natural community classification, ecological boundaries, and ranking of the target sites. Vegetative structure and composition, soils, landscape and abiotic context, threats, management needs, and restoration opportunities were all assessed. This information is critical for informing landscape-level planning efforts, facilitating site-level decisions about prioritizing management objectives to conserve native biodiversity, and evaluating the success of restoration actions.

Methods employed during this survey followed the methodology developed during the initial evaluation of Ecological Reference Areas on State Forest land by MNFI ecologists (Cohen et al. 2008; Cohen et al. 2009).

Carex vesicaria and *Eleocharis elliptica* in Golden Intermittent Wetland. During natural community surveys, MNFI scientists note community structure and composition, as well as threats and past disturbances. Photo by J.M. Lincoln.

The ecological field surveys involved:

- compiling comprehensive plant species lists and noting dominant and representative species and opportunistically documenting rare plant populations
- describing site-specific structural attributes and ecological processes
- measuring tree diameter at breast height (DBH) of representative canopy trees and aging canopy dominants
- analyzing soils and hydrology
- noting anthropogenic disturbances
- evaluating potential threats to ecological integrity
- ground-truthing aerial photographic interpretation using GPS
- taking digital photos and GPS points at significant locations
- evaluating the natural community classification and mapped ecological boundaries
- assigning or updating element occurrence ranks
- noting management needs and restoration opportunities or evaluating past and current restoration activities

Following completion of the field surveys, the collected data were analyzed and transcribed to create new EO records in MNFI's statewide biodiversity conservation database (MNFI 2024). Natural community boundaries were modified or established and information from these surveys was used to develop site descriptions, threat assessments, and management recommendations.

Floristic data from the surveys were compiled into the Universal Floristic Quality (FQA) Assessment Calculator (Reznicek et al. 2014, Freyman et al. 2016). The FQA utilizes plant species composition to derive the Floristic Quality Index (FQI) of the natural community element occurrences within the game area. The FQI is 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 Michigan, each vascular plant species native to Michigan 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 (Reznicek et al. 2014). Plant species with a C-value of 7 to 10 are considered highly conservative with a strong fidelity to specific, quality habitats (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.

FQI for each natural community occurrence was calculated using the following equation:

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

where $\bar{C}$ = *mean C-value* and n = *species richness*.

Michigan sites with an FQI of 35 or greater possess sufficient conservatism and richness that they are considered floristically important from a statewide perspective. FQI scores greater than 50 indicate exceptional sites with extremely high conservation value (Herman et al. 2001). Mean C values may represent a less biased indicator of relative conservation value and are provided with conservation metrics in the Appendices (Matthews et al. 2005, Slaughter et al. 2015). Tracking changes to the FQI or Mean C of a site following biodiversity stewardship is a useful means of evaluating the success of management. Species lists for each natural community EO are provided in the Appendices.

Blue flag iris observed during natural community surveys in the Great Lakes marsh. Photo by J.M. Lincoln.

Rare Bird Surveys

Given the extensive blocks of mature forest and Great Lakes marsh we focused bird surveys in the game area on rare nocturnal birds, songbirds, raptors, and secretive marsh birds. Nocturnal bird surveys targeted common nighthawk (*Chordeiles minor*, State Special Concern) and eastern whip-poor-will (*Antrostomus vociferus*, State Threatened). Rare forest songbird surveys targeted cerulean warbler (*Setophaga cerulea*, State Threatened), hooded warbler (*Setophaga citrina*, State Special Concern), and golden-winged warbler (*Vermivora chrysoptera*, State Threatened). Rare raptor surveys targeted red-shouldered hawk (*Buteo lineatus*, State Threatened) and northern goshawk (*Accipiter gentilis*, State Threatened). Secretive marsh bird surveys targeted least bittern (*Ixobrychus exilis*, State Threatened), American bittern (*Botaurus lentiginosus*, State Special Concern) and marsh wren (*Cistothorus palustris*, State Special Concern).

Nocturnal bird surveys were conducted in the central portion of the state game area within a dry-mesic northern forest covering approximately 150 acres across several stands. Three points were surveyed for eastern whip-poor-will and common nighthawks, since sound travels far at night and there was only a small area of the game area with suitable habitat for these species. The survey points were separated by a minimum of 400 m. Surveys for nocturnal birds started at dusk and lasted through midnight on June 22, 2022.

Forested stands covering at least four hectares (10 acres) were considered potential habitat for target species of forest songbirds and raptors. We generated a 250 m X 250 m grid of survey points overlaid on the survey area (Figure 8). Points were assigned unique identification numbers and uploaded to a tablet computer for field location. Points falling within the survey stands were visited during raptor and songbird surveys. During field surveys some points were deemed “non-suitable” habitat and surveys did not occur at these points. We did not survey points falling within pine plantations, young aspen stands, or farmstead forests.

Forest songbird point counts were conducted at systematically located points within suitable habitat (Figure 8). Ralph et al. (1995) noted that it is usually more desirable to increase the number

Nocturnal bird surveys were conducted for eastern whip-poor-will and common nighthawk (pictured above). Photo by A.P. Kortenhoven.

of independent point-count stations than to conduct repeated surveys at a smaller number of locations, so each point was visited only once. Forest songbird surveys were conducted from sunrise to six hours after sunrise, or until weather condition made it unlikely to detect birds. Forest songbird surveys took place late June 2022. We did not conduct surveys during weather conditions that could reduce bird detectability, such as strong winds (≥ 20 km/hr or 13 mph) and moderate to heavy precipitation. In addition to documenting observations of the targeted rare species, we collected data on all birds seen or heard during each 10-minute point count. We recorded the species and number of individuals observed during three independent periods (2 minutes, 3 minutes, and 5 minutes) for a total of 10 minutes at each station (Ralph et al. 1995). Use of the three survey periods provides flexibility in making comparisons with other surveys (e.g., North American Breeding Bird Surveys) which adhere to these survey protocols. Each bird observation was assigned to one of four distance categories (0-25 m, 25-50 m, 50-100 m, and >100 m) based on the estimated distance of the bird from the observer to facilitate future distance analyses and refinement of density and population estimates.

We conducted two-minute raptor surveys at systematically located point-count stations (Figure 8; Mosher et al. 1990, Anderson 2007, Bruggeman et al. 2011). Each two-minute point count consisted of one-minute broadcasts of either northern goshawk or red-shouldered hawk calls and one minute of silent listening. Surveys were conducted in April 2022. At each station the following data were recorded: whether a red-shouldered hawk or northern goshawk was detected; all other raptor sightings or vocalizations; other bird observations; and other rare animal species detections or potential habitats. If a rare raptor was observed, the vicinity surrounding the point was searched for potential nests. While walking and driving between station locations, we also visually inspected trees for stick nests.

Visual surveys for marsh birds were conducted on June 23, 2022 at randomly chosen points within the Great Lakes marsh along the Pentwater River.

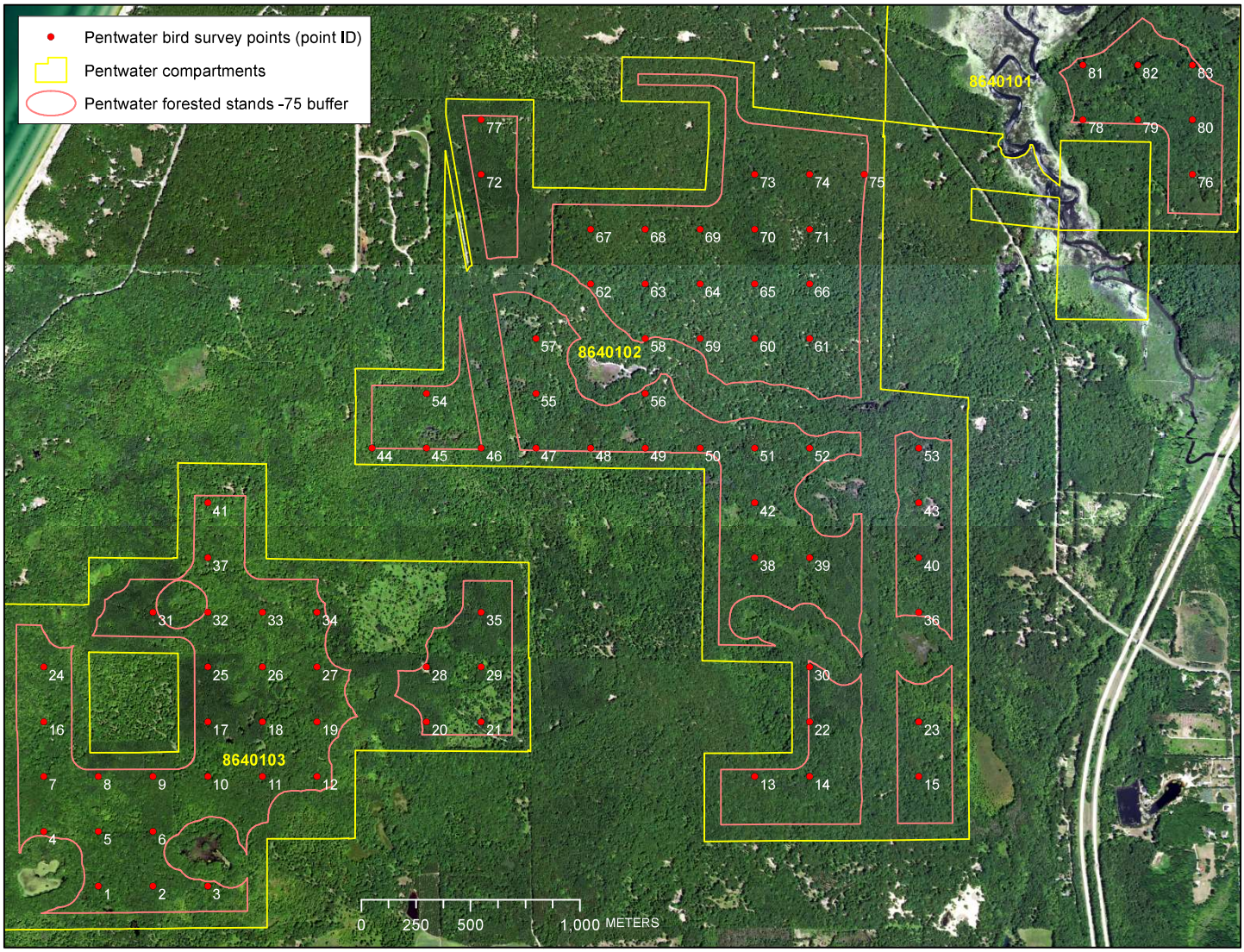


Figure 8. Location of songbird, raptor, and nocturnal bird survey sites in Pentwater State Game Area.

Rare Herptile Surveys

Surveys for rare amphibian and reptile species (i.e., herptiles) in Pentwater SGA in 2022 focused on documenting new occurrences of rare species. We determined which species to survey for based on available habitat and known range of these species. We targeted the following species: Fowler's toad (*Anaxyrus fowleri*, State Special Concern), pickerel frog (*Lithobates palustris*, State Special Concern), Blanding's turtle (*Emydoidea blandingii*, State Special Concern), spotted turtle (*Clemmys guttata*, State Threatened), wood turtle (*Glyptemys insculpta*, State Threatened), and eastern box turtle (*Terrapene carolina carolina*, State Threatened) .

Visual encounter, basking, and aquatic funnel trapping surveys were conducted in areas with suitable habitat for the target species (Figure 9). Surveys were conducted from June 27 to September 22, 2022 during the species' active seasons using standard methods for surveying amphibians and reptiles (Campbell and Christman 1982, Corn and Bury 1990, Crump and Scott 1994, Graeter et al. 2013). Visual encounter surveys were conducted within emergent and shrubby wetlands, vernal pools, adjacent open uplands, and upland and lowland forest stands. Surveys consisted of walking slowly through suitable habitat for target species, overturning cover objects (e.g., logs/woody debris, rocks, etc.), inspecting retreats, and looking for basking, resting, and active individuals on the surface or under cover objects (Campbell and Christman 1982, Corn and Bury 1990, Crump and Scott 1994, Glaudus 2013). Basking surveys were conducted along the Pentwater River within the game area on September 22, 2022 to survey for wood turtle and Blanding's turtle. Basking surveys consisted of two surveyors kayaking slowly down the river looking for turtles swimming or basking on logs and other structures within the river and along the shoreline. Turtles observed during the basking surveys were captured by hand or with a net, when possible, and were measured, weighed, sexed, aged, photographed, and examined for general health condition, injuries, and abnormal shell characteristics. Captured turtles were marked by notching the outer

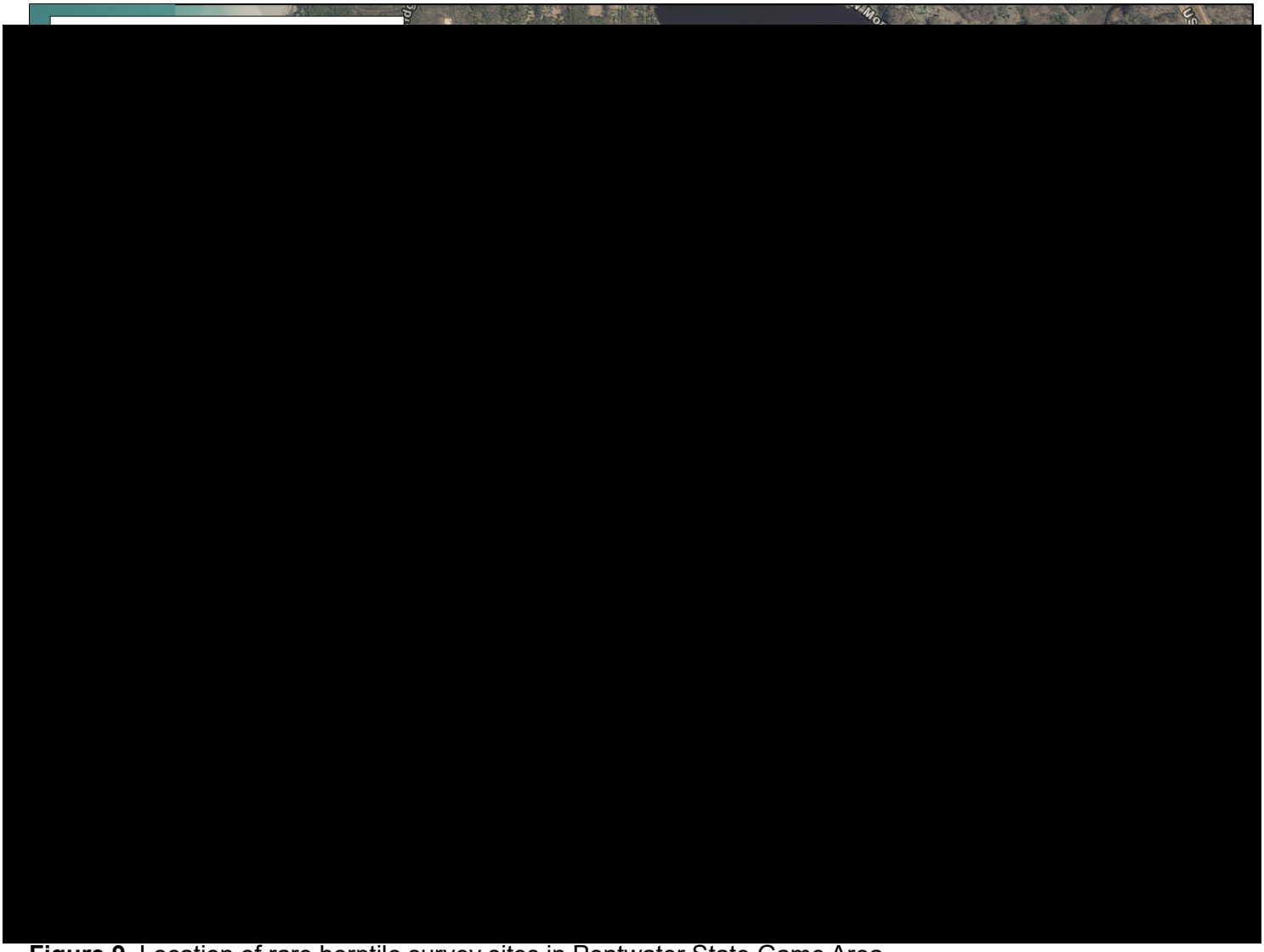


Figure 9. Location of rare herptile survey sites in Pentwater State Game Area.

scutes of the carapace (top turtle shell) with a unique notch code (Nagle et al. 2017). Other herptile species and animal species observed during the basking surveys were recorded. Visual surveys and basking surveys were conducted under appropriate weather conditions when target species were expected to be active and visible (between 60-80°F, wind less than 15 mph, no or light precipitation).

In addition, we used aquatic funnel traps to capture turtles to document the presence, abundance and demographics of turtles in the Pentwater SGA. These surveys consisted of deploying 28 aquatic funnel traps (i.e., Promar collapsible minnow traps and hoop traps) within suitable habitat over four consecutive nights from June 27 through July 1, for a total survey effort of 112 trap nights. These surveys followed standard monitoring protocols for Blanding's and spotted turtles that have been developed and implemented in the Northeast U.S. (Willey and Jones 2014, American Turtle Observatory 2017, Northeast Spotted Turtle Working Group 2019, Cross et al. 2023). Captured turtles were measured, weighed, sexed, aged, photographed, and examined for general health condition, injuries, and abnormal shell characteristics. Captured turtles were marked by notching the outer scutes of the carapace (top turtle shell) with a unique notch code (Nagle et al. 2017). Other herptile species and animal species captured in the traps were recorded. Traps were checked every day and captured animals were released after processing.

Survey data forms were completed for all herptile surveys using the ArcGIS Survey123 mobile application. Survey locations and routes and locations of rare herptile species were recorded using the ArcGIS Survey123 and Field Maps mobile applications on a tablet. We documented all reptiles and amphibians during surveys. The species, number of individuals, age class, location, general habitat, behavior, and time of observation were noted. Weather conditions and survey times also were recorded. When possible, we took photos of species for documentation. All rare species observations were entered into the Michigan Natural Heritage Database.

A Blanding's turtle in an intermittent wetland. This State Special Concern species was a target during herptile surveys in Pentwater SGA. Photo by J.M. Lincoln.

Rare Insect Surveys

Hine's emerald dragonfly (*Somatochlora hineana*; State Endangered) is a species of dragonfly that is recognizable by its large green eyes and can be distinguished from other species of *Somatochlora* by a combination of its dark metallic green thorax with two distinct creamy-yellow lateral lines and its distinctively shaped terminal appendages or genitalia. The species was listed as Federally Endangered under the Endangered Species Act (ESA) in 1995 and currently persists in the Great Lakes region of the United States and in southern Ontario. In Michigan, most occurrences of Hine's emerald dragonfly are isolated in wetland habitats in the upper lower peninsula and southern upper peninsula. Important habitat characteristics of Hine's emerald sites include graminoid dominated wetlands which contain seeps, or slow-moving rivulets; cool, shallow water slowly flowing through vegetation; and open areas in close proximity to forest edge. It is particularly associated with bogs, fens, and marshes where it relies heavily on the refuge provided by crayfish burrows, which the larvae use during the larval development stage, which can last up to four years. Adults are less restricted in forage habitat and will frequently forage outside of the larval habitat boundaries, including roadsides, right-of-ways, and clearings in the habitat where insect prey may be more abundant at different times of the year.

In 2021, two female Hine's emerald dragonflies were collected in Oceana County, Michigan, near Pentwater Lake, expanding the known southern distribution of the species in the state (Craves et al. 2022). These newly documented occurrences are within two miles of Pentwater SGA and provide evidence that Hine's emerald dragonfly may occur within the boundaries of the state game area. In 2023, a survey for Hine's emerald dragonfly were completed at Pentwater SGA to determine if there was suitable habitat for Hine's emerald dragonfly and to document species occurrence.

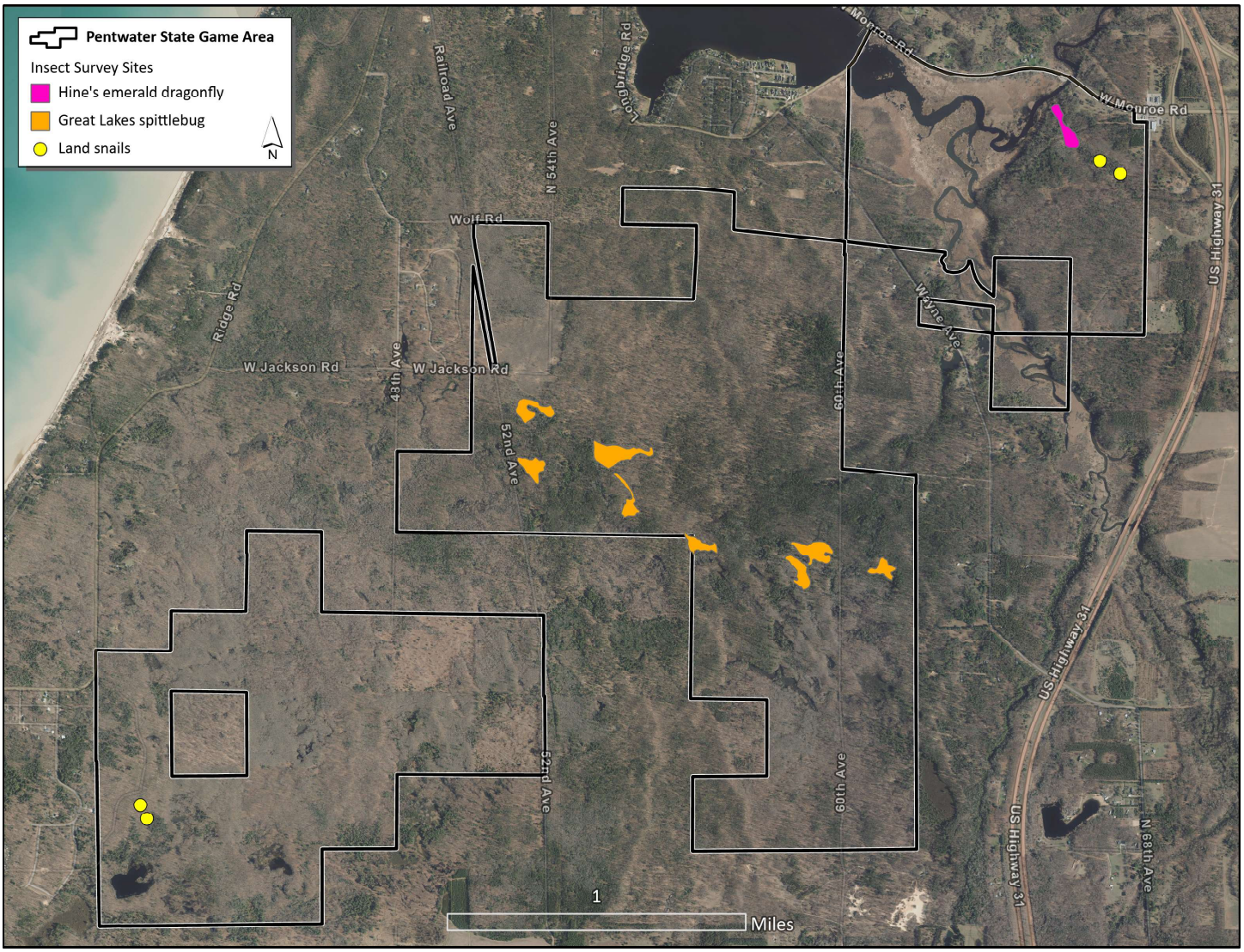


Figure 10. Location of rare insect and land snail survey sites in Pentwater State Game Area.

A four-hour meander survey was implemented on July 21, 2022 along a 250 m stretch of Watson Creek near the main northern connection to Pentwater Lake, within Stand 52 (43.7604, -86.3940). Two surveyors walked the creek bed and adjacent hillside northern wet meadow/sedge meadow to assess habitat quality for Hine's emerald dragonfly. While surveying, any dragonflies that were present were captured for species determination.

Great Plains spittlebug (*Lepyronia gibbosa*; State Special Concern) is a small insect species that can be distinguished from other spittlebugs by forewings with a dark brown V-shaped marking that forms a triangle. This species occurs primarily in dry sand prairies and hillside prairies but has also been documented in old fields, right-of-ways, and forest opening. As nymphs, they feed on a wide variety of plants, but adults are associated with two species of prairie grasses, little bluestem (*Schizachyrium scoparium*) and big bluestem (*Andropogon gerardi*). Great Plains spittlebug often appears in highly restricted populations and has an apparently low tolerance for habitat degredation. Surveys for Great Plains spittlebug were conducted at Pentwater SGA within eight pockets of wet-mesic sand prairie to determine species presence and assess the quality of habitat for this species.

Sweep net surveys for Great Plains spittlebug were completed on July 21 and 22, 2022 within Pentwater SGA. Two surveyors walked the interior of each wet-mesic sand prairie pocket sweep netting on big bluestem for a total of one minute per surveyor. A total of eight pockets were surveyed in 2022. After completing the sweep, all collected specimen were placed in a Ziploc bag for processing in the lab and identified to the family level or otherwise lowest taxonomic level possible.

The Federally Endangered Hine's emerald dragonfly has been recently documented near Pentwater SGA and was the focus of rare insect surveys. The habitat targeted was zones of sedge meadow along Watson Creek. Photo by D. Cuthrell

Rare Land Snail Surveys

We targeted cross vertigo (*Vertigo modesta*, State Endangered) and median striate (*Striatura meridionalis*, State Special Concern) for land snail surveys. Land snails exhibit a wide range of habitat preferences, varying with species and region, but they require a source of calcium for shell building and physiological processes (Burch and Pearce 1990) and are sensitive to disturbance so we focused survey efforts in relatively intact, mature forests. In May 2023 we conducted surveys in two stands at Pentwater SGA: Stand 23 (Compartment 1; Watson Creek Woods) and Stand 25 (Compartment 3; referred to as Birch Avenue Forest) (Figure 10, p. 17). We used two methods to survey each plot: visual searches and ground litter samples. We collected data at two plots in each stand, for a total of four 60-minute visual surveys and 20 leaf-litter samples among all four plots. All plots had leaf litter cover between 80% and 92%, downed woody cover between 5% and 10%, moss cover between 2% and 5%, and bare ground cover between 1% and 9%. One plot was north facing, two were south facing, and one plot was not a slope. The canopy cover at all four plots was between 90% and 95%. Survey plots within a stand were chosen while in the field based on the presence of downed logs, boulders, moss, or other microhabitat suitable for land snails. These microhabitats might be missed in a completely random selection of samples, so presence of these features was favored when establishing sampling plots (Pearce and Örstan 2006).

At each plot we recorded the GPS coordinates, the forest stand number, and the plot identification code.

MNFI zoologist, Ashley Cole-Wick surveys for land snails. Photo by P.J. Badra.

We characterized the groundcover by recording percent cover of leaf litter, downed wood, moss, bare ground, and canopy cover within the surveyed areas. First, we conducted a 60-minute visual search of the microhabitat at each plot, looking for both live snails and spent (empty) shells. All spent shells were collected into vials, and all live snails were preserved in vials with 70% ethanol solution for later identification in a laboratory. Many common and rare snail species are minute, measuring less than 2 mm across. Visual detection of these minute specimens is improbable, so we also collected five ground litter samples per plot, for a total of 20 litter samples, each consisting of approximately 0.75 L of leaves, twigs, moss, soil, and bark. These samples were placed in a paper bag and labeled in the field. We then dehydrated all litter samples at 170 degrees for 1 to 3 hours, or until fully desiccated. Snail shells were then sorted from organic and inorganic particles under a microscope at 10 x magnification. Each shell was separated from litter and placed into a vial for identification. Each bag took approximately two hours to sort, for a total of 40 hours of effort in laboratory time for sorting and an additional eight for identification.

All specimens were identified in the laboratory under a 0-10 x magnification for larger snails (>10 mm), and 20-60 x magnification for smaller snails (<10 mm). We used a variety of resources to identify specimens, including a dichotomous key using shell characters developed by Nekola (2003). Some specimens were too damaged to accurately identify to species and were recorded as unknown. Other partial shells were large enough to clearly identify the sample to species. Some collected snails were immature and had not developed the structures and characteristics necessary to identify to species and were recorded as an unidentifiable immature shell.

Land snail survey area along Watson Creek. Photo by J.M. Lincoln.

Rare Mussel Surveys

Unionid mussels were chosen as a survey target because of the lack of past documented survey effort for this group within Pentwater SGA and for the potential of listed and Special Concern mussel species to occur there. There are no previously known records for unionid mussels in the game area or along Pentwater River, however there are historical records for seven mussel species in Pentwater Lake. These include a 1949 record for the State Extirpated pink papershell (*Potamilus ohiensis*) (UMMZ 2024) and an historical record for lake floater (*Pyganodon lacustris*), a Species of Special Concern with questionable taxonomic status (Harvard 2024). Rare mussel species have been documented in the watersheds adjacent to the Pentwater River, including slippershell (*Alasmidonta viridis*, State Threatened) and creek heelsplitter (*Lasmigona compressa*, Special Concern) in the Pere Marquette watershed to the north, and slippershell, creek heelsplitter, fluted shell (*Lasmigona costata*, Special Concern), paper pondshell (*Utterbackia imbecillis*, Special Concern), and black sandshell (*Ligumia recta*, State Endangered) in the White River watershed to the south. Mussel surveys took place in habitats from ankle to chest deep (0.1 – 1.2m). Snorkel gear was used in deeper habitat sections and glass bottom buckets were used in shallower sections. The search area at each site was estimated to help standardize sampling effort among sites and allow rough mussel density estimates to be made. Live unionid mussels and shells were located with a combination of visual and tactile means.

Table 1. Percentage of each substrate particle size class estimated visually at each mussel survey site. Diameter of each size class: boulder (>256mm), cobble (256-64mm), pebble (64-16mm), gravel (16-2mm), sand (2-0.0625mm), silt/clay (<0.0625mm).

Site #	Boulder	Cobble	Pebble	Gravel	Sand	Silt
1	60*				20	20
2					5	95
3					50	50
4						100

* Boulder sized rip rap

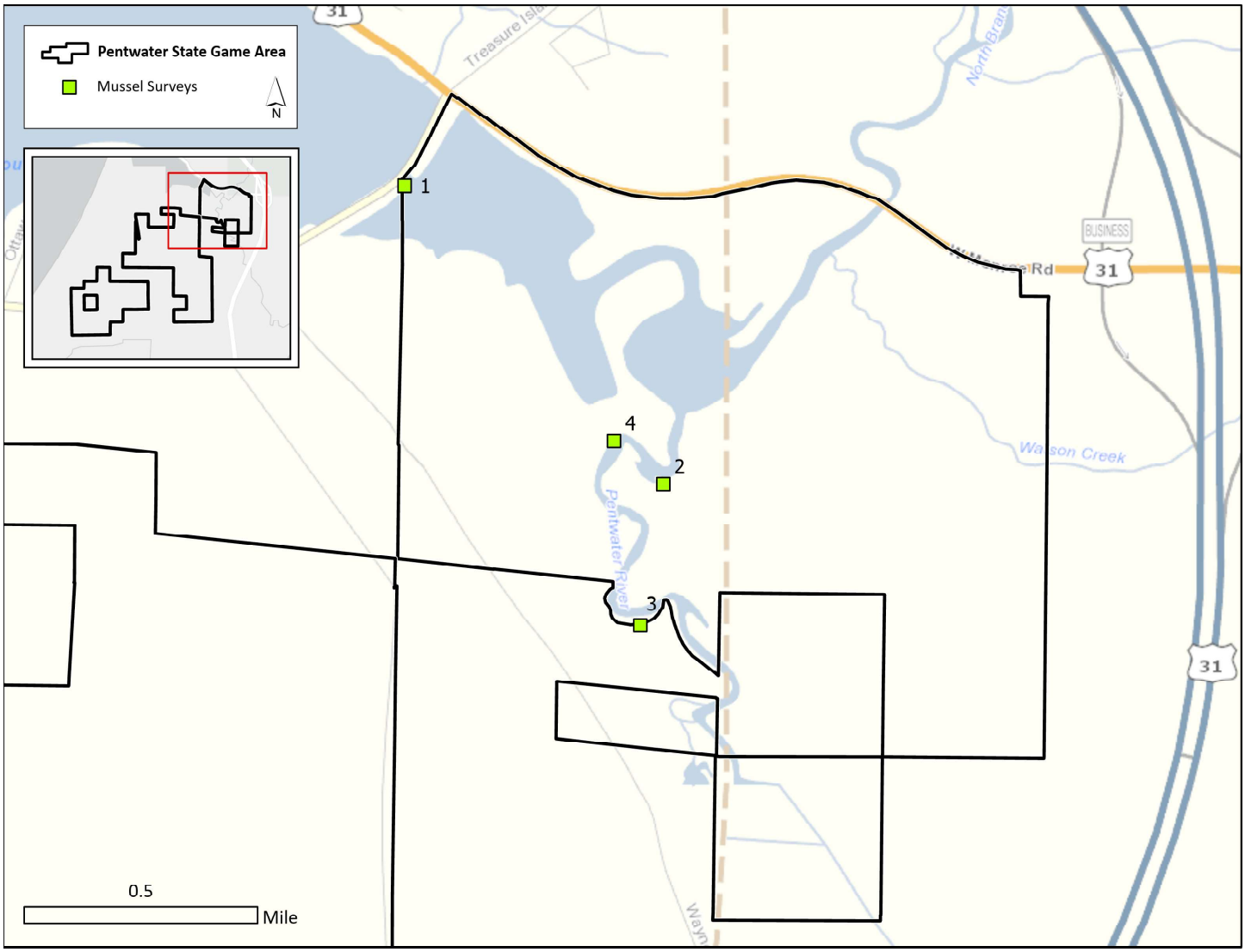


Figure 11. Location of aquatic survey sites in Pentwater State Game Area.

Tactile searches through the substrate were made to help ensure that buried individuals were being detected, including smaller-sized unionid mussels. Live individuals were identified to species and placed back into the substrate anterior end down (siphon end up) in the immediate vicinity of where they were found. Shells were also identified to species. The number of live individuals was determined for each unionid mussel species at each site. The riverbanks were scanned visually for mussel shell middens created by muskrats or other mammalian predators. Aquatic snails, fish, and non-native bivalves including zebra mussels (*Dreissena polymorpha*) and Asian clams (*Corbicula fluminea*) were identified and noted when encountered during mussel surveys.

Latitude and longitude of each survey site was recorded with a handheld Garmin GPS unit. Habitat data were recorded to describe and document stream conditions at the time of the surveys. Substrate within each search area was characterized by estimating percent composition of each of six particle size classes described in Hynes 1970 (Table 1). Woody debris, aquatic vegetation, exposed solid clay substrate, and eroded banks were noted when observed. The percentage of the search area with pool, riffle, and run habitat, and a rough characterization of current speed were estimated visually. Alkalinity and hardness of river water was measured with LaMotte kits (models 4491-DR-01 and 4824-DR-LT-01).

Aquatic survey Site 2 along the Pentwater River. Photo by J.M Lincoln.

RESULTS

MNFI conservation scientists documented 16 element occurrences (EOs) from Pentwater SGA. Of those EOs, 13 were newly documented or updated during the course of the 2022/23 surveys. These new or updated element occurrences are composed of seven natural community and 15 rare species. During surveys completed for the Integrated Inventory project at Pentwater SGA, MNFI scientists documented or updated seven natural community EOs (Table 2, Figure 12), two rare plant EOs (Figure 20, p. 48), three rare bird EOs (Figure 21, p. 49), one herptile EO (Figure 22, p. 51), one insect EO (Figure 23, p. 53), and two rare land snail EOs (Figure 23, p. 53. Data compiled for these EOs were entered into MNFI's Natural Heritage Database (MNFI 2024).

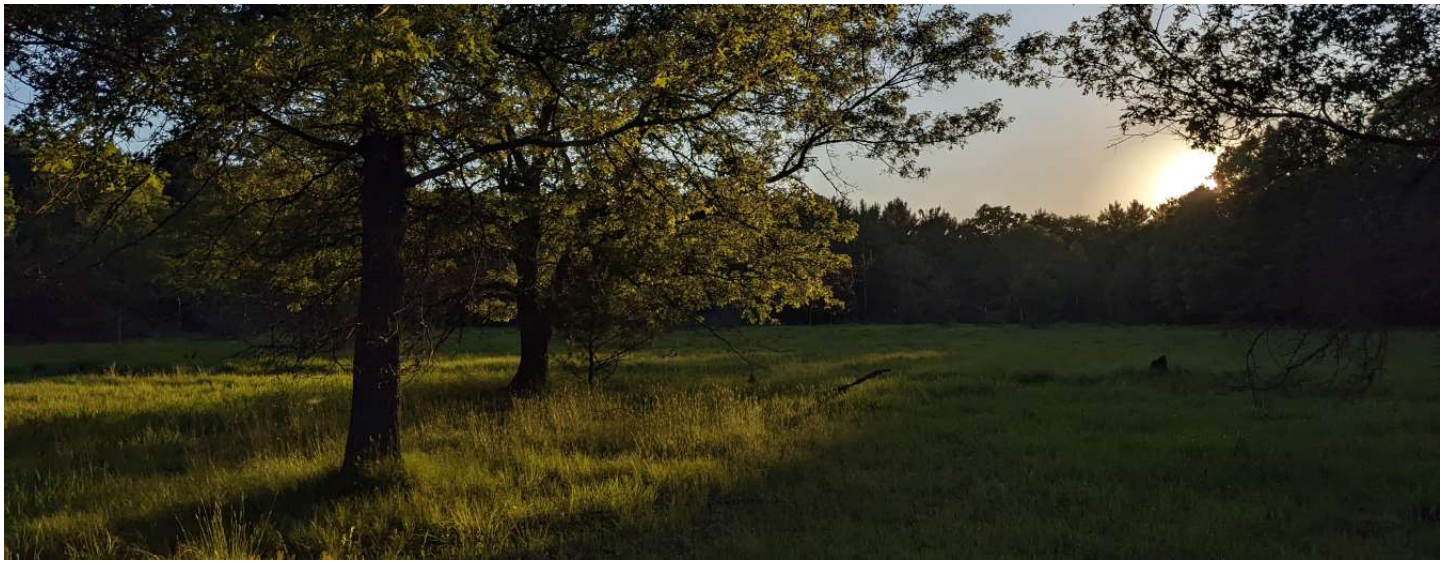
MNFI scientists documented six new natural community Element Occurrences (EOs) and six new rare animal EOs and provided information for updating three existing EOs. In total, 17 EOs have been documented in Pentwater SGA including eight animal EOs, three plant EOs, and seven natural community EOs.

Natural Communities

MNFI ecologists documented six new high-quality natural communities EOs and updated one existing natural community EO in the Pentwater SGA including a bog, a dry-mesic northern forest, a Great Lakes marsh, two intermittent wetlands, a mesic northern forest, and a wet-mesic sand prairie (Table 2, Figure 12). These high-quality natural communities cover 630 acres or 24.3 % of the game area's 2,585 acres. The following site summaries contain a detailed discussion for each of the seven natural community EOs organized alphabetically by natural community type.

Table 2. Natural community element occurrences in the Pentwater State Game Area. EO rank abbreviations are as follows, B - good; BC - good to fair; C - fair; and D - poor.

EO ID	Site Name	Rank	Size (Ac)	First Recognized as EO	Last Visited	Compartment	Stands
	Bog						
25389	Pentwater Bog	B	5.8	2015	2022	2	12
	Dry-mesic Northern Forest						
27471	Pentwater Woods	C	312.3	2024	2024	2	9, 18, 24, 45, 52
	Great Lakes Marsh						
6116	Pentwater Great Lakes Marsh	D	247.7	1989	2024	1	Numerous
	Intermittent Wetland						
26075	Golden Intermittent Wetland	B	7.7	2022	2022	3	7
26074	Pentwater Pond	B	9.5	2022	2022	3	8
	Mesic Northern Forest						
27078	Watson Creek Woods	D	21.4	2022	2022	1	20, 23, 48, 51
	Wet-mesic Sand Prairie						
21677	Pentwater Prairies	BC	26.2	2015	2024	2	4, 7, 8, 22, 23, 40



One of the prairie openings at dawn. Photo by A.P. Kortenhoven.

Table 3. Rare species element occurrences in the Pentwater State Game Area. EO rank abbreviations are as follows, B - good; BC - good to fair; BD - good to poor; C - fair; and E - extant but not fully assessed. Global (G) and State (S) ranks are provided in Appendix 2.

EO ID	Scientific name	Common name	EO Rank	G/S	First Observed	Last Observed
	Birds					
26506	*Antrostomus vociferus*	Eastern whip-poor-will	E	G5/S3	2023	2023
13472	*Cistothorus palustris*	Marsh wren	E	G5/S3	2002	2022
26508	*Ixobrychus exilis*	Least bittern	E	G4/S3	2022	2022
	Herptiles					
27097	*Emydoidea blandingii*	Blanding's turtle	C	G4/S2S3	2022	2023
	Insects					
27136	*Lepyronia gibbosa*	Great Plains spittlebug	BD	G4/S3	2022	2022
	Land Snails					
27074	*Striatura meridionalis*	Median striate	E	G5/SNR	2023	2023
27098	*Striatura meridionalis*	Median striate	E	G5/SNR	2023	2023
	Plants					
27466	*Rhexia virginica*	Meadow-beauty	B	G5/S3	2022	2022
27084	*Potamogeton bicupulatus*	Waterthread pondweed	BC	G4/S2	2022	2022

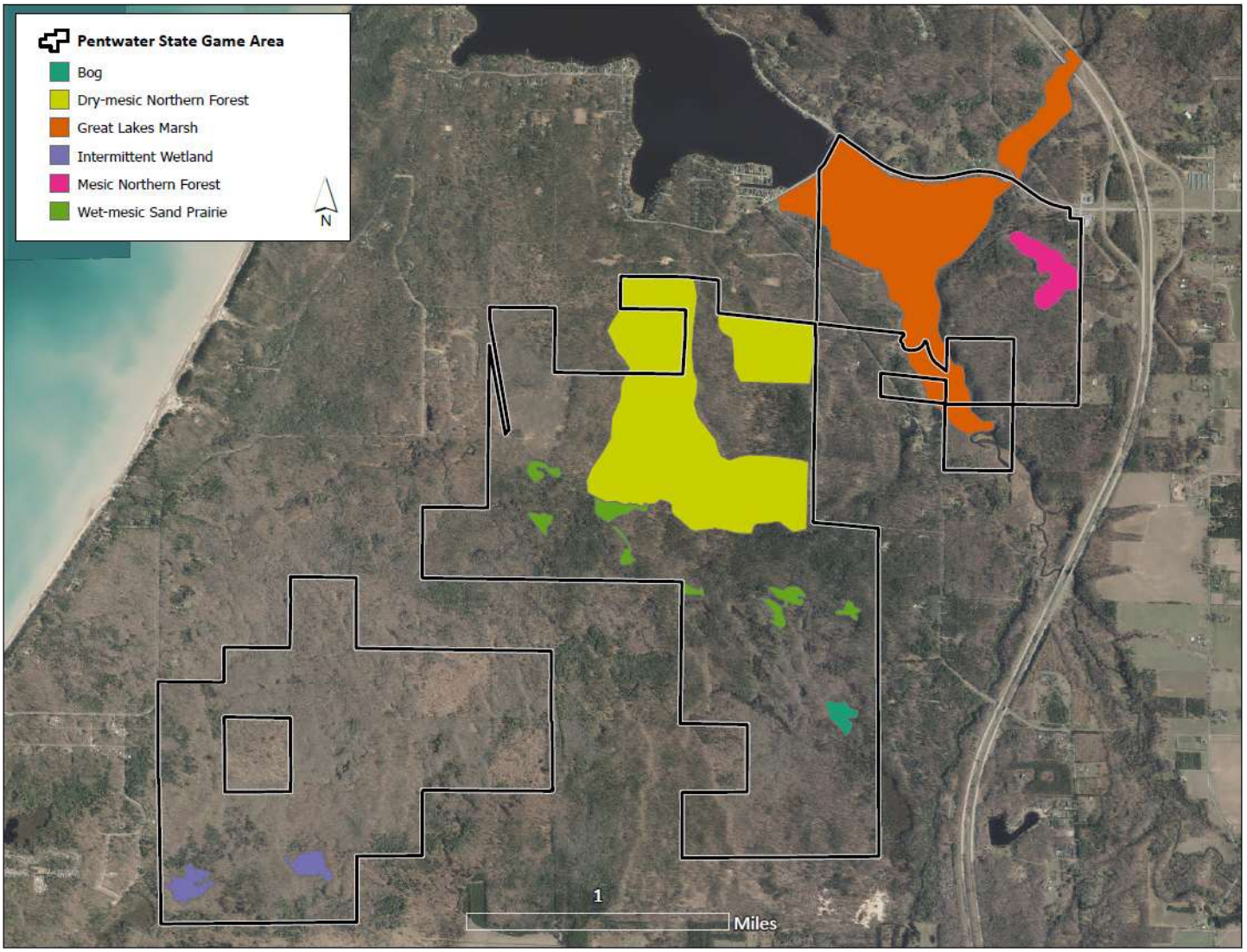


Figure 12. Natural community element occurrences in Pentwater State Game Area.

Natural Community Descriptions
1. Pentwater Bog
Natural Community Type: Bog
Rank: G3G5 S4, vulnerable to secure globally and secure within the state
Element Occurrence Rank: BC
Size: 5.8 acres
Location: Compartment 2; Stand 12
Element Occurrence Identification Number: 25389

This is a small bog in a wetland depression within an old dune field near Lake Michigan. It occurs in a fire-adapted landscape and fires may have historically impacted the bog. This is a low diversity bog and aspects of it are similar to an intermittent wetland with zones of open pooling water and floating sapric peats that feature graminoids. The majority of the bog features mounding fibric peats. The soils are acidic fibric peats (pH 5.5) over very acidic hemic peats (pH 4.5 - 5.5) which overlie acidic (pH 5.0-5.5) saturated coarse sands.

The open sphagnum mat is characterized by low diversity with mounds of sphagnum moss dominated by leatherleaf (*Chamaedaphne calyculata*). The margins feature thickets of Michigan holly (*Ilex verticillata*) and stunted black-gum (*Nyssa sylvatica*). A 23.9 cm diameter black-gum had 59 growth rings. White pine (*Pinus strobus*) and paper birch (*Betula papyrifera*) also occur along the margins and occasionally on the open bog. There are small zones of pooling water with blue-joint (*Calamagrostis canadensis*), spike-rush (*Eleocharis palustris*), wool-grass (*Scirpus cyperinus*), and hardstem bullrush (*Schoenoplectus acutus*).

Pentwater Bog was visited once in June of 2022. Fifteen plant species were observed with no non-

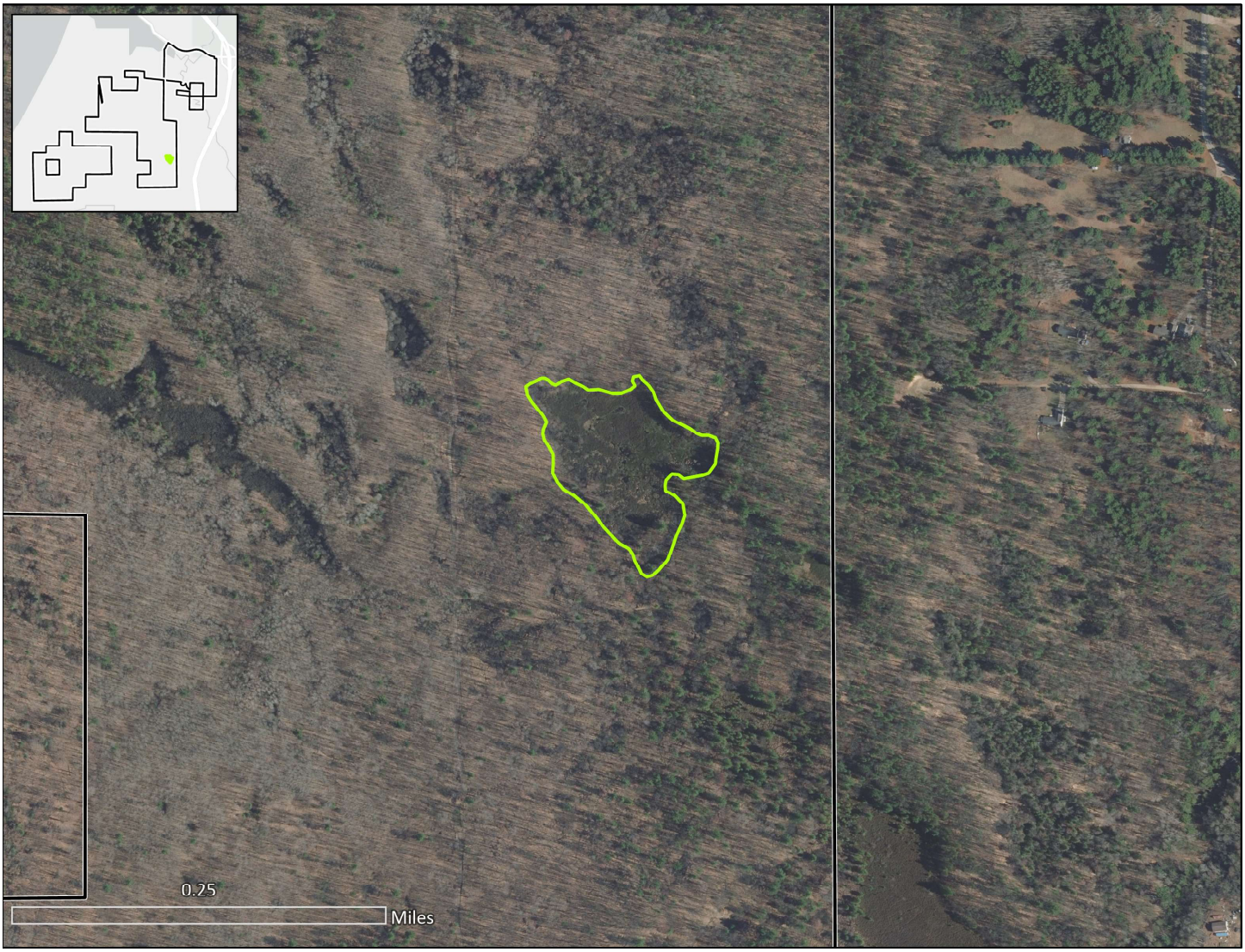


Figure 13. Location of Pentwater Bog (ESRI 2022).

native species recorded. The total FQI was 22.5 and the Total Mean C was 5.8. Conservation metrics for Pentwater Bog and the comprehensive species list are available in Appendix 3.

Threats and Management Recommendations
Alterations to hydrology could fundamentally alter the composition of the wetland and our primary management recommendation is to provide a large, forested buffer between this bog and any forestry operations. We also suggest managers avoid impacts to nearby zones of saturated soils in the forests surrounding the bog. This will help avoid degrading nearby wetland areas and minimize risk of invasive species. No invasive species were recorded within the bog. This is not a fire-dependent natural community type but the surrounding landscape has numerous communities that historically burned and while this site should not be targeted with prescribed fire, we recommend not excluding it from prescribed fires if the surrounding forest becomes a priority for managers to include with prescribed burns.

Pentwater Bog features mounding sphagnum moss with leatherleaf and open zones dominated by spike-rush. Photo by J.M. Lincoln.

2. Pentwater Woods
Natural Community Type: Dry-mesic northern forest
Rank: G4 S3, apparently secure globally and vulnerable within the state
Element Occurrence Rank: C
Size: 312.3 acres
Location: Compartment 2; Stands 9, 18, 24, 45, 52
Element Occurrence Identification Number: 27471

This is a maturing, second-growth oak-pine forest with localized pockets of old-growth trees. The forest occurs on rolling topography that is a series of old dune ridges on an outwash plain. Soils are deep acidic sands.

Black oak (*Quercus velutina*) and northern pin oak (*Q. ellipsoidales*) are the most dominant canopy trees. Black and northern pin oaks typically range from 45 to 70 cm diameter at breast height (dbh) and are mostly around 140 years old. A 56.0 cm dbh black oak had 137 growth rings and was typical of the canopy cohort. Pines are infrequent to locally abundant and white pine (*Pinus strobus*) has developed into the supercanopy and typically ranges between 50 and 90 cm dbh. Red pine (*P. resinosa*) are typically 40 to 55 dbh and were aged between 130 and 180 years old and are just beginning to develop into the supercanopy. Big-tooth aspen (*Populus grandidentata*) is infrequent but locally abundant in younger areas of the forest. White oaks (*Q. alba*) are typically between 50 and 75 cm with some individuals over 80 cm. The northernmost lobe of this forest has a small area of open grown, white oaks that are surprisingly old. There are several very old, heavily limbed white oak and very old red pine. One white oak had a 48.8 cm dbh and 276 rings. Another white oak had a 49.9 cm diameter and 253 rings. There are several larger white oaks with similar characteristics but typically with rot and were unable to be aged.

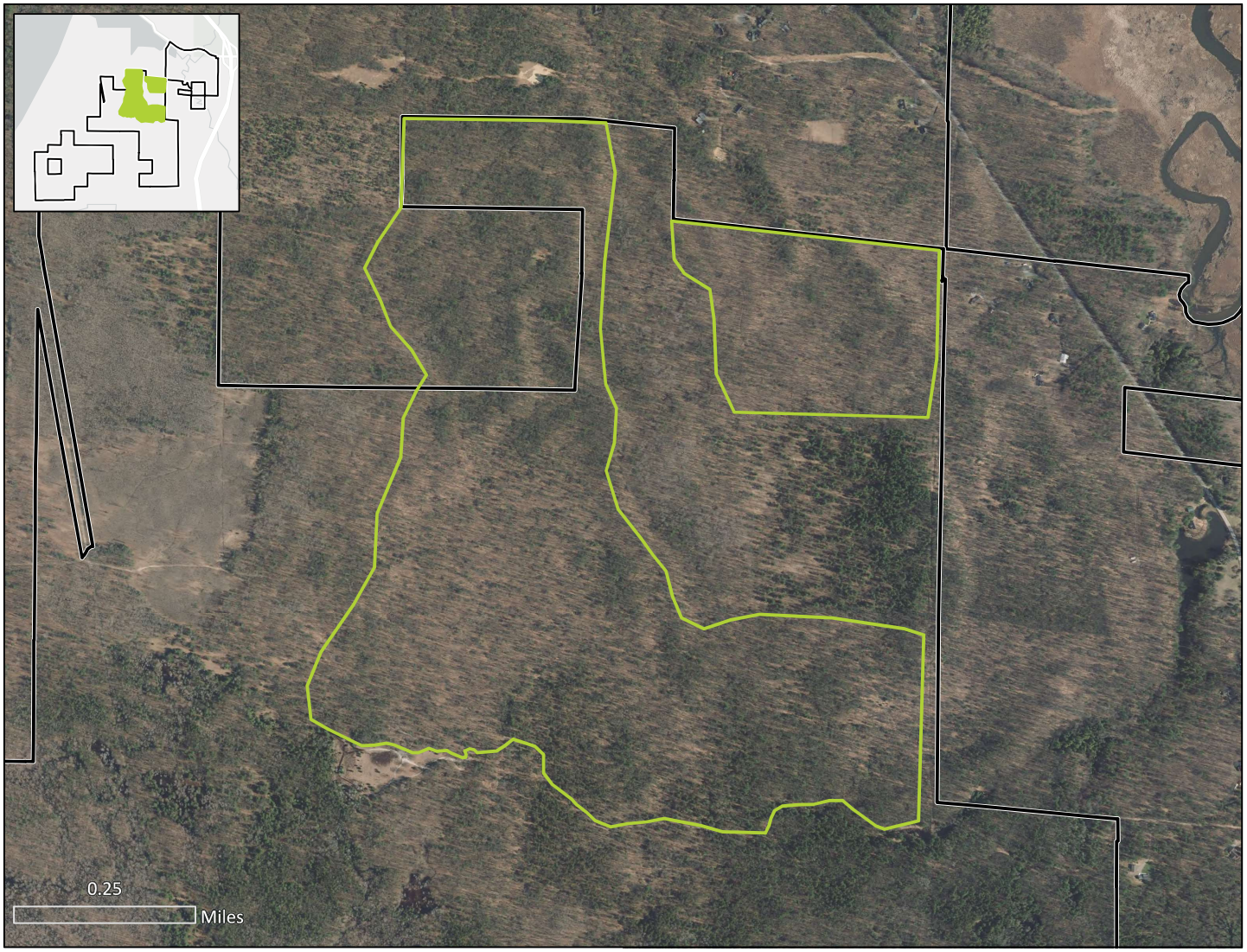


Figure 14. Location of Pentwater Woods dry-mesic northern forest (ESRI 2022).

The subcanopy features white pine, northern pin oak, red maple (*Acer rubrum*), sassafras (*Sassafras albidium*), infrequent red pine, white oak, beech (*Fagus grandifolia*), and infrequent jack pine (*P. banksiana*). The tall shrub layer features sassafras, witch-hazel (*Hamamelis virginiana*), juneberry (*Amelanchier arborea*), and many of the canopy species. The low shrub layer features extensive thickets of huckleberry (*Gaylussacia baccata*) and lowbush blueberry (*Vaccinium angustifolium*). The herbaceous layer is characterized by low diversity and is dense to locally sparse with Pennsylvania sedge (*Carex pensylvanica*), poverty grass (*Danthonia spicata*), and hair grass (*Avenella flexuosa*) as the primary graminoids. Forbs include wintergreen (*Gaultheria procumbens*), downy Solomon seal (*Polygonatum pubescens*), and star flower (*Trientalis borealis*). Bracken fern (*Pteridium aquilinum*) is common to locally dominant throughout the forest.

This forest occurs in an area colloquially known as Pentwater Plains. Imagery from 1938 (Figure 6, p. 7) indicates a sparse canopy across an extensive area that is now closed canopy forest. Additionally, several red pines in this forest have fire scars indicating as many as five fire over the past 140 years. Red pine is especially fire-adapted and develops scars that can reveal multiple historic fires. The high frequency of fire recorded in the scars on these living red pines is higher than would be expected from wildfires caused by lightning alone. The frequency of fires recorded in the scars on living trees potentially indicates historic cultural fires by Indigenous Peoples. It is possible that the area was seasonally occupied by a displaced band of Ottawa from the Grand Rapids area. There was historically an Indian encampment in the region that sold huckleberries to settlers in the late 1800s (Hartwick and Tuller 1890). Though the specific location of this tribe is unknown, it is possible that this part of the game area was burned for the purpose of maintaining berries as there is a concentration of fire-scarred red pines between 170 and 100-years-old with multiple fire scars, indicating a relatively recent and substantial influence from fire.

Pentwater Woods features an abundance of natural red pine atypical this far south. There are also extremely large white oaks, some of which were over 250 years old. The concentration of old trees were in the northernmost portion of the EO. Photo by J.M. Lincoln.

While such a high frequency of scars on red pine is consistent with Indigenous management of berry crops through cultural burning across the upper Great Lakes, the local historical office had no records of Indigenous Peoples burning the area in the early part of the 20th century. Alternatively, a nearby railroad (now Railroad Ave) may have caused the fires that led to the concentrations of fire-scarred red pine. Trains were often reported to cause fires at that time, though there was no indication of fires from the local historical office. We do not know with certainty the extent to which Indigenous management would have had on the landscape prior to European settlement, but the presence of fire-dependent prairie, extensive scarring on relatively young trees, and persistent stumps with scarring suggest that Indigenous cultural fire was a reoccurring and important disturbance factor over the past few hundred years.

Pentwater Woods was visited once in May of 2024. Thirty-three plant species were observed with one non-native species recorded. The total FQI was 28.1 and the Total Mean C was 4.9. Conservation metrics for Pentwater Woods and the comprehensive species list are available in Appendix 4.

Threats and Management Recommendations
Our primary recommendations are 1) to allow the forest to continue maturing and minimize timber harvests and fragmentation in adjacent stands; 2) continue to burn the forest in conjunction with the wet-mesic sand prairies; and 3) minimize the impacts of roads and trails in the forest.

This is an especially large example of mature forest that once covered a much greater extent of the surrounding landscape and for that reason our top management recommendation is to allow the forest to continue maturing without silvicultural intervention. This would also benefit the population of eastern whip-poor-will documented during rare bird surveys. The DNR is actively managing the area with fire, largely to maintain the prairie openings in the southern portion of the forest. Fires likely burned the lowlands and uplands in concert historically and would have happened at various times of the year

Pentwater Woods is characterized by relatively large-diameter oak and pine, an herbaceous component that is generally low diversity, and nearly no invasive species. Photo by A.P. Kortenhoven.

including late growing season to dormant season (late September through early March). The largest prairie opening has apparently been burned twice, once in 2018 and again in 2022. There are plans to include additional prairie openings and portions of the forest in future prescribed fires and we endorse these plans. The southern portion of this forest was burned in 2024. A fire line was previously dug around the edge of the prairie, and we suggest managers continue rerouting burn lines away from discrete openings to prevent degrading the highest quality remnants. We recommend managers continue applying prescribed burns and including the prairie openings and as much of the surrounding forest as possible while explicitly avoiding the use of equipment in the ecotone transition zone between the prairie and the forest.

We recommend applying prescribed fires at a frequency of approximately every 5 to 20 years to as large of an area possible, with an emphasis on including the highest quality portions of the forest and as many openings of the wet-mesic sand prairie as possible. We also suggest implementing low intensity/ low severity late-season burns at least initially as fire is reintroduced to the system. A higher frequency of fires would ideally be applied to prairies and surrounding forest with the lower frequency in forests away from the prairies.

To protect the prairie openings and minimize degrading the condition of the forest, we suggest managers redirect trails and roads away from openings and prevent logging equipment from crossing saturated soils. The largest opening of the prairie has been impacted by off-road vehicles and there is an expanding network of roads and trails in this area. Horses spread weedy species, and we recommend eliminating roads when possible and limiting expansion of the trail network. Ideally, trails would be configured in a way to serve as burn breaks while maximizing the size of the burn units.

Three fire-scarred red pine along the margins of the wet-mesic sand prairies. The concentration of trees is unusual and indicates a history of frequent fire and potentially alludes to Indigenous cultural fires. Photo by J.M. Lincoln.

3. Pentwater Great Lakes Marsh
Natural Community Type: Great Lakes marsh
Rank: G2 S3, imperiled globally and vulnerable within the state
Element Occurrence Rank: D
Size: 247.7 acres
Location: Compartment 1; Numerous Stands
Element Occurrence Identification Number: 6116

This wetland occurs in the eastern portion of Pentwater Lake at the confluence of the Pentwater River and the North Branch of the Pentwater River. The marsh complex is influenced by fluctuations in Great Lakes' levels and flooding from the rivers and there is complex and variable zonation. Soils are alkaline (pH 7.5), saturated mucks.

Shifting zones of open water occur along the two rivers and towards Pentwater Lake. These areas fluctuate with changes in Lake Michigan levels and meanders in the rivers. There are three primary zones including submergent marsh, emergent marsh, and a wet meadow zone with extensive muck flats throughout. The submergent marsh features water up to 1.5 meters deep with mucky bottoms and floating vegetation including yellow pond-lily (*Nuphar variegata*), pondweeds (*Potamogeton spp*.), waterweed (*Elodea canadensis*), and the invasive European frog's-bit (*Hydrocharis morsus-ranae*).

The emergent zone features hardstem bullrush (*Schoenoplectus acutus*), pickerel-weed (*Pontederia cordata*), duckweed (*Lemna minor*), lake sedge (*Carex lacustris*), softstem bulrush (*Schoenoplectus tabernaemontani*), and common arrowhead (*Sagittaria latifolia*) but is overwhelmingly dominated by invasive hybrid cat-tail (*Typha x glauca*) and narrow-leaved cat-tail (*T. angustifolia)*. Hybrid cat-tail and narrow-leaved cat-tail have also invaded much of the wet meadow zone, though areas that were above recent water level changes are still diverse and dominated

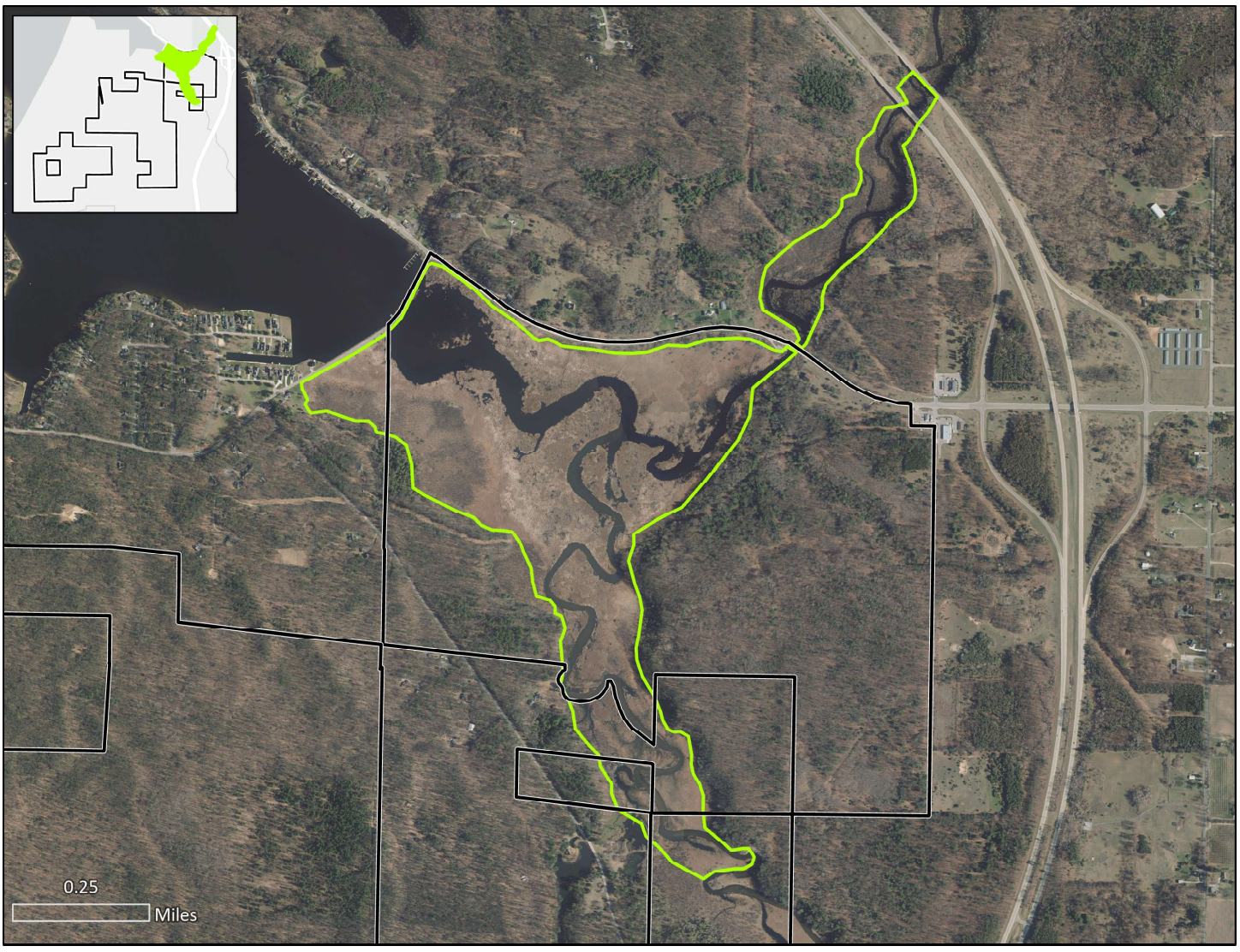


Figure 15. Pentwater Great Lakes Marsh (ESRI 2022).

by native vegetation. The most intact zones of the meadow feature sedges (*Carex stricta*, *Cx. aquatilis,* and *Cx. lacustris*), blue-joint (*Calamagrostis canadensis*), wild blue flag (*Iris versicolor*), the native broad-leaved cat-tail (*Typha latifolia*), marsh fern (*Thelyptris palustris*), monkey-flower (*Mimulus ringens*), water smartweed (*Persicaria amphibia*), and rough bedstraw (*Galium asprellum*). Zones of open mud flats feature cursed crowfoot (*Ranunculus sceleratus*), water hemlock (*Cicuta bulbifera*), and spotted touch-me-not (*Impatiens capensis*). Tag alder (*Alnus incana*) was locally dominant throughout the marsh prior to the rise in water levels but was killed due to prolonged inundation. It is now sprouting along the margins of the wetland, forming shrub thickets.

Invasive species are dominant throughout the wetland complex though there are small areas locally dominated by native species that may be slightly above high-water levels or buffered from wave action. Narrow-leaved cat-tail or the hybrid cat-tail is likely the most abundant species in the marsh. European frog's-bit has dominated many of the submergent zones, though much has been treated recently and the extent of the invasion is unclear. Invasive reed (*Phragmites australis var. australis*) is presently at a controllable level, though may occur on private property and will require landowner permission to treat. Where water levels increased dramatically along the interface with the surrounding uplands, there is abundant reed canary grass (*Phalaris caneriensis*) and Canada thistle (*Cirsium arvense*).

The Great Lakes marsh facing towards Pentwater Lake. Narrow-leaf cat-tail is the dominant species in the marsh but there are zones dominated by native vegetation (light green in the foreground).
Photo by J.M. Lincoln.

The site was first documented by MNFI Ecologists in 1989 and assigned a BC rank (Good to Fair). The overal rank was adjusted from BC to D (Fair to Poor) following the evaluation in 2022 due to a substantial increase of invasive species. There are likely many contributing factors to the ongoing degradation, but the dramatic lake level rise in the late 2010s flooded most of the site and facilitated the domination by narrow-leaved cat-tail and hybrid cat-tail in areas that were inundated. Areas above the high water level during this historic increase seem less impacted by invasive cat-tail.

Additional factors may have also led to the increase in invasive species. This area is impacted by abundant boat traffic along the two rivers which join within the marsh. It is possible that agricultural operations along the Pentwater River have also caused nutrient inputs that might increase the competitive advantage of aggressive invasive species. There is a causeway across Pentwater Lake that forms the western boundary of the Great Lakes marsh. The causeway was present in a 1914 map of the township and the extent of the marsh prior to the building of the causeway is unclear. But this causeway may have influenced the hydrology of the eastern basin of Pentwater Lake and likely continues to alter flow and deposition of sediments in the marsh.

Pentwater Great Lakes Marsh was visited June and August of 2022 and again in June of 2024. A total of forty-nine plant species were observed in the marsh with nine non-native species recorded. The total FQI was 25.9 and the Total Mean C was 3.8. Conservation metrics for the Pentwater Great Lakes Marsh and the comprehensive species list are available in Appendix 5.

The Great Lakes marsh features various zones and shifting composition. Photo by J.M. Lincoln.

Threats and Management Recommendations
Invasive species are likely he most significant threat to the native biodiversity of the marsh. The disturbance-prone nature of the system and the vulnerability of wetlands in general means that this will be an omnipresent threat and treatment will be complex and expensive. Control of invasive species will require sustained effort and introduce a substantial risk of collateral damage to native plants. While treating invasive species in the marsh is a worthwhile management objective, there will need to be constant reevaluation of priorities based on resources and feasibility of long-term control.

Invasive cat-tails are the most abundant species in the marsh. European frog's-bit has dominated many of the submergent zones, though much has been treated recently and the extent of the invasion is unclear. Invasive reed (*Phragmites*) is presently at a controllable level, though may occur on private property and will require landowner permission to treat. Eurasian milfoil is being treated in Pentwater Lake by the local lake association. There was a population of Himalayan blackberry (*Rubus bifrons*) documented along the road at the edge of the marsh. Game area staff were in the process of treating the blackberry as this report was being written. We recommend continuing to monitor for this species and working with nearby landowners on the north side of W Monroe Rd/US-31 to inform them of the large population of Himalayan blackberry on their property.

The long history of Indigenous occupations locally may have led to occasional fires in the marsh, particularly in conjunction with the adjacent uplands to the east which feature several fire-adapted species. However, because of the degraded nature of the marsh and the abundance of intact, fire-dependent systems elsewhere in the game area, we do not recommend this marsh as a priority for prescribed burns. Within the marsh there is excellent habitat for wild rice (*Zizania palustris*) and the species may have been in this system historically but eliminated as the marsh has been degraded. We recommend working with local Tribes to evaluate the site potential for introduction of wild rice.

The Great Lakes marsh occurs in the eastern portion of Pentwater Lake at the confluence of the North Branch of the Pentwater River and the Pentwater River. Despite the abundance of invasive species, the marsh remains important habitat for rare marsh birds, waterfowl, and various fish. It also contributes to the water quality of Pentwater Lake and the shoreline of Lake Michigan. Photo by J.M. Lincoln.

4. Golden Intermittent Wetland
Natural Community Type: Intermittent wetland
Rank: G2 S3, imperiled globally and vulnerable within the state
Element Occurrence Rank: B
Size: 7.7 acres
Location: Compartment 3; Stand 7.
Element Occurrence Identification Number: 26075

This is a small graminoid-dominated open wetland occupying a shallow depression within a matrix of oak-pine forest on a series of old dune ridges on an outwash plain. This opening is one of several small, isolated wetlands occurring between the dunes and these appear to be old interdunal wetlands that now support various wetland community types including bog, northern shrub thicket, intermittent wetland, northern wet meadow, and wet-mesic sand prairie.

These wetlands are maintained by a fluctuating water table that causes extended periods of inundation, limiting woody encroachment. Periods of inundation are typically in the spring but can occur throughout the year. Water levels are highly variable seasonally and annually and black oak at the margins likely died during recent high-water years. Fluctuating water levels and duration of inundation influence the pattern of vegetation. The variability of the water table leads to variable zonation and dramatic shifts temporally – season to season and year to year. The soils are characterized by acidic shallow mucks overlying acidic wet sands. Soils are highly variable due to irregular shape of wetland and subtle variations in topography.

Distinct zones of vegetation correspond to degree of inundation. The driest zone at the margins features sedges (*Carex vesicaria* and *Carex oligosperma*) and muhly grass (*Muhlenbergia uniflora*). There is a transition towards a moist zone dominated by golden-seeded spike rush (*Eleocharis elliptica*), northern

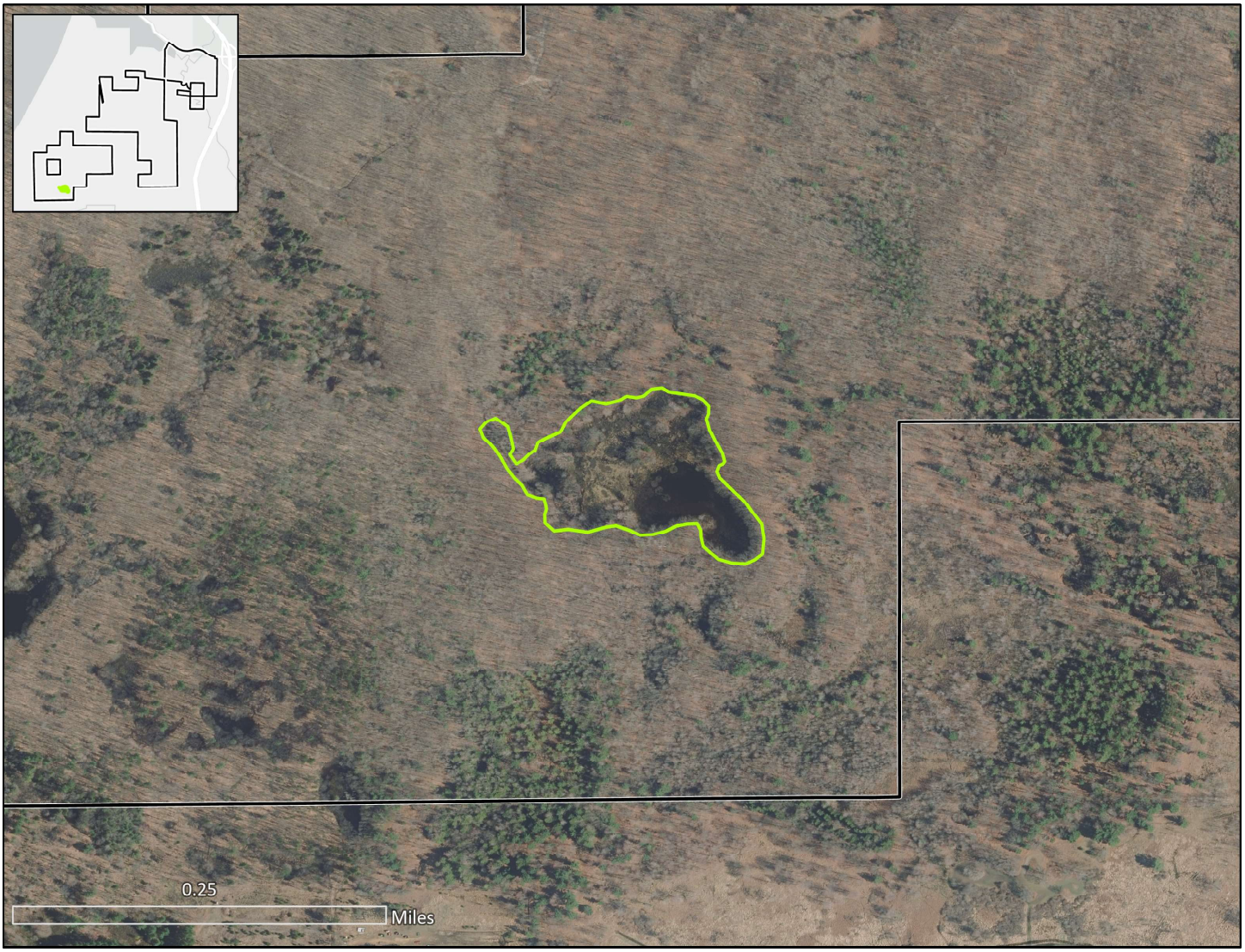
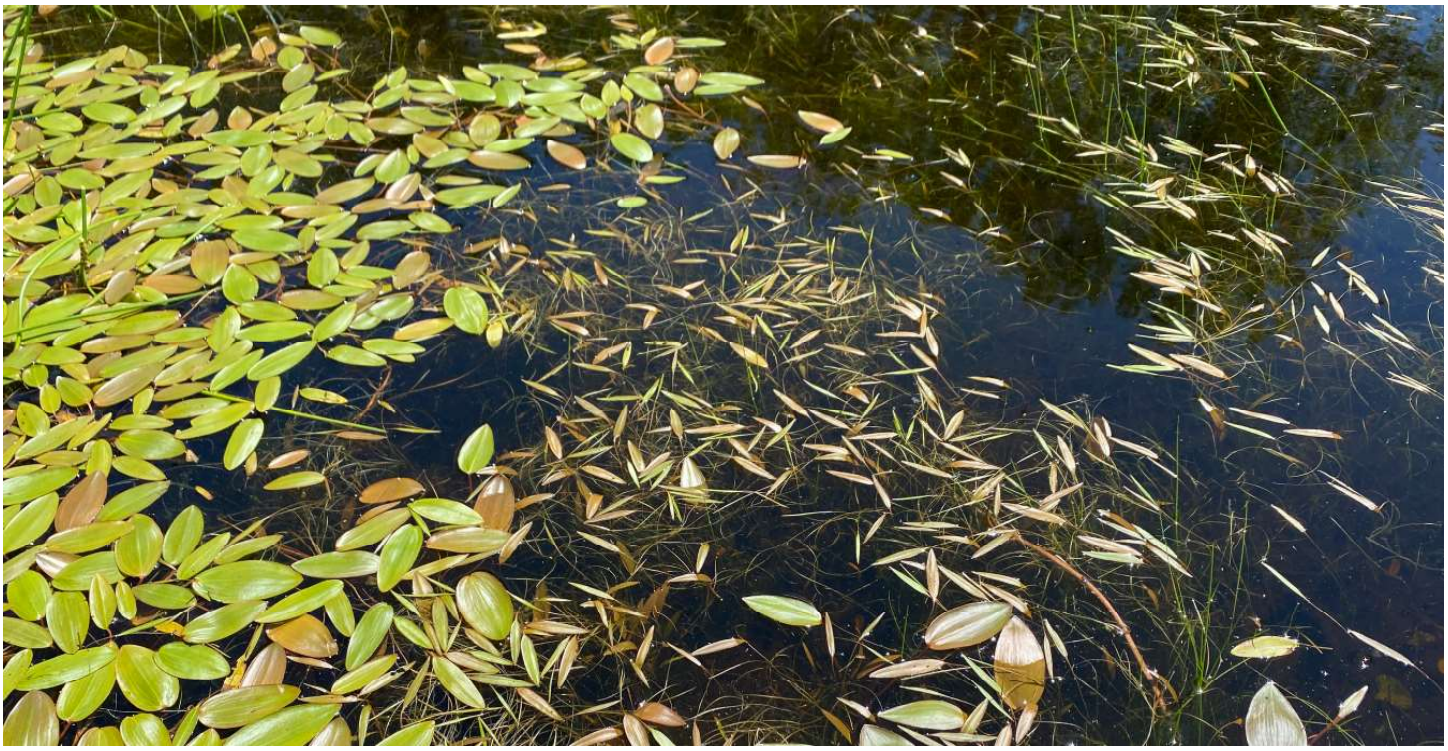
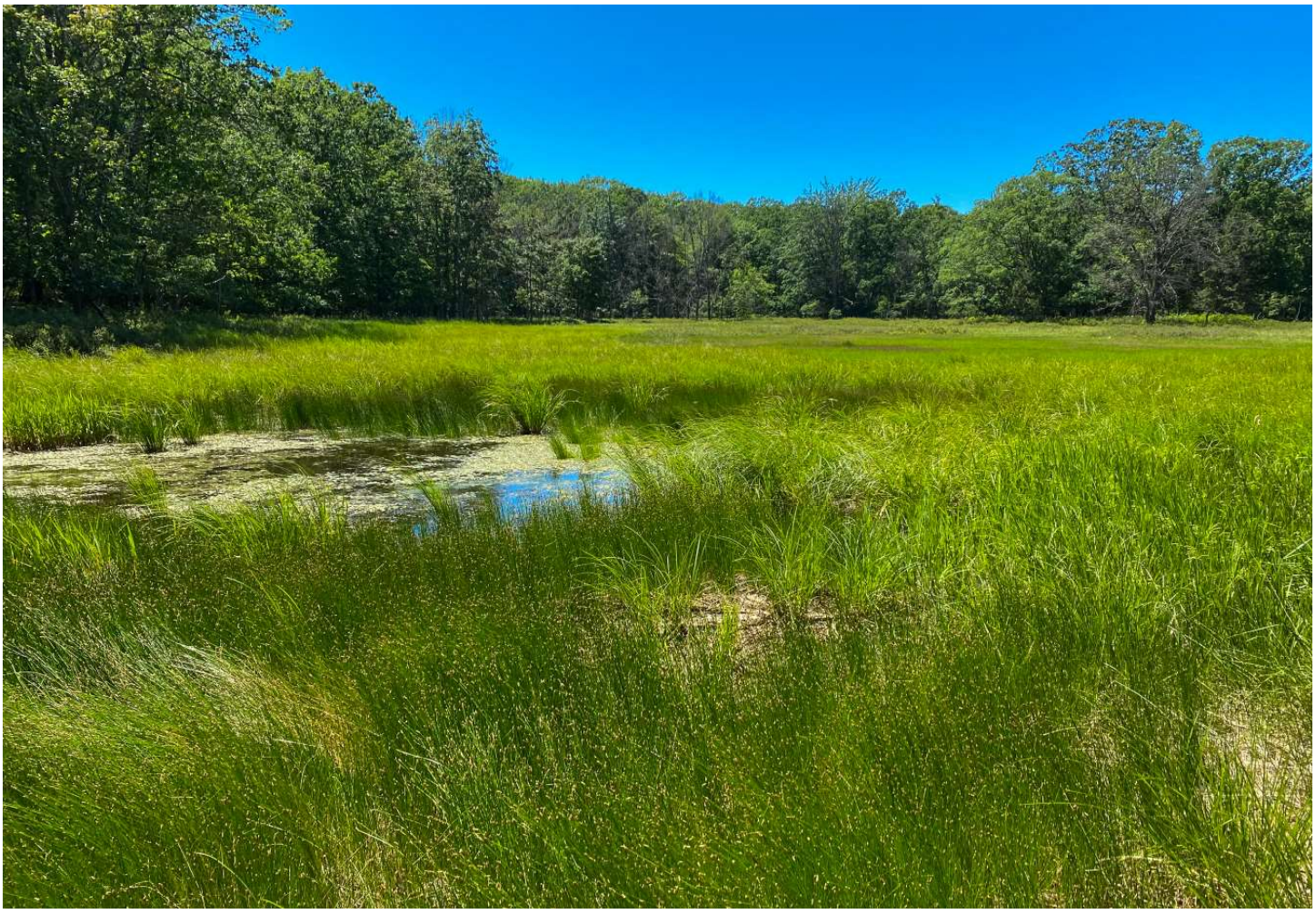


Figure 16. Location of Golden Intermittent Wetland (ESRI 2022).



The zone of open water in Golden Intermittent Wetland supports at least two species of pondweed, including waterthread pondweed (the narrower of the two leaves on the right) which is State Threatened and had not been documented in Oceana County prior to the MNFI survey of Pentwater SGA. Photo by J.M. Lincoln.



Golden Intermittent Wetland is characterized by vegetation zonation influenced by degree of inundation. Photo by J.M. Lincoln.

St. John's-wort (*Hypericum boreale*), lance-leaved violet (*Viola lanceolata*), and meadow-beauty (*Rhexia virginica*, State Special Concern). A zone of saturated muck was dominated by beak-rush (*Rhyncospera capitellata*), panic grass (*Dichanthelium lindheimeri*), and three-way sedge (*Dulichium arundinaceum*) and this surrounds the wettest zone with standing water and floating aquatic vegetation, particularly water-shield (*Brasenia schreberi*) and pondweed (*Potamogeton oakesianus*).

The State Threatened waterthread pondweed (*Potamogeton bicupulatus*) was observed here in 2022 and was locally abundant in the small zone of standing water. The southern edge of the opening featured a wet meadow zone with bluejoint (*Calamagrostis canadensis*), rattlesnake grass (*Glyceria canadensis*), floating manna grass (*Glycera septentrionalis*), soft-stemmed rush (*Juncus effusus*), and bulrush (*Scirpus atrovirens*). Michigan holly (*Ilex verticillata*) rings the wetland and there are irregular clumps of leatherleaf (*Chamaedaphne calyculata*) throughout.

Golden Intermittent Wetland was visited in August 2022. Thirty-three plant species were observed with 32 native species and one non-native species recorded. The total FQI was 34.5 and the Total Mean C was 6.0. Conservation metrics for Golden Intermittent Wetland and the comprehensive species list are in Appendix 6.

Threats and Management Recommendations
This is a small intermittent wetland, but it is in excellent condition with a concentration of conservative species and nearly no presence of invasive species. There is a small and easily treated patch of reed canary grass (*Phalaris arundinacea*) in the southeastern portion of the wetland. The site is surrounded by natural cover and is in a relatively isolated part of the game area. Surrounding uplands are fire-adapted and the site would ideally be included with prescribed burns. There are no nearby trails but widespread use of off-road vehicles is increasing, and trails are continually being developed throughout the game area. Ideally these would be prevented from impacting this wetland complex.

The uplands at the margins of Golden Intermittent Wetland feature large, old white oak and dense huckleberry, indicating a context of a fire-dependent landscape. Photo by J.M. Lincoln.

5. Pentwater Pond
Natural Community Type: Intermittent wetland
Rank: G2 S3, imperiled globally and vulnerable within the state
Element Occurrence Rank: B
Size: 9.5 acres
Location: Compartment 3; Stand 8.
Element Occurrence Identification Number: 26074

This is another small graminoid-dominated open wetland occupying a shallow depression within a matrix of oak-pine forest. Pentwater Pond is maintained by a fluctuating water table that causes extended periods of inundation, limiting woody encroachment. Periods of inundation are typically in the spring but can occur throughout the year. Fluctuating water levels and duration of inundation influence the pattern of vegetation and soils are variable due to irregular shape of wetland and variations in topography. The soils are characterized by acidic shallow mucks overlying acidic wet sands.

The intermittent wetland is characterized by distinct zones of vegetation that correspond to degree of inundation. Michigan holly (*Ilex verticillata*) and buttonbush (*Cephalanthus occidentalis*) form thickets that extend into the open wetland. There is a wet meadow zone with rattlesnake grass (*Glyceria canadensis*), blue-joint (*Calamagrostis canadensis*), sedges (*Carex crinita* and *Cx. hystericina*), and Virginia chain-fern (*Woodwardia virginica*) along the edge of the shrub thicket.

Towards the center of the wetland are large recently exposed zones of muck flats featuring three-way sedge (*Dulichium arundinaceum*), spike rushes (*Eleocharis elliptica*, *E. palustris*, and *E. intermedia*), northern St. John's-wort (*Hypericum boreale*), panic grass (*Dichanthelium lindheimeri*), spatulate-leaved sundew (*Drosera intermedia*), meadow-beauty (*Rhexia virginica*, State Special Concern) and lance-

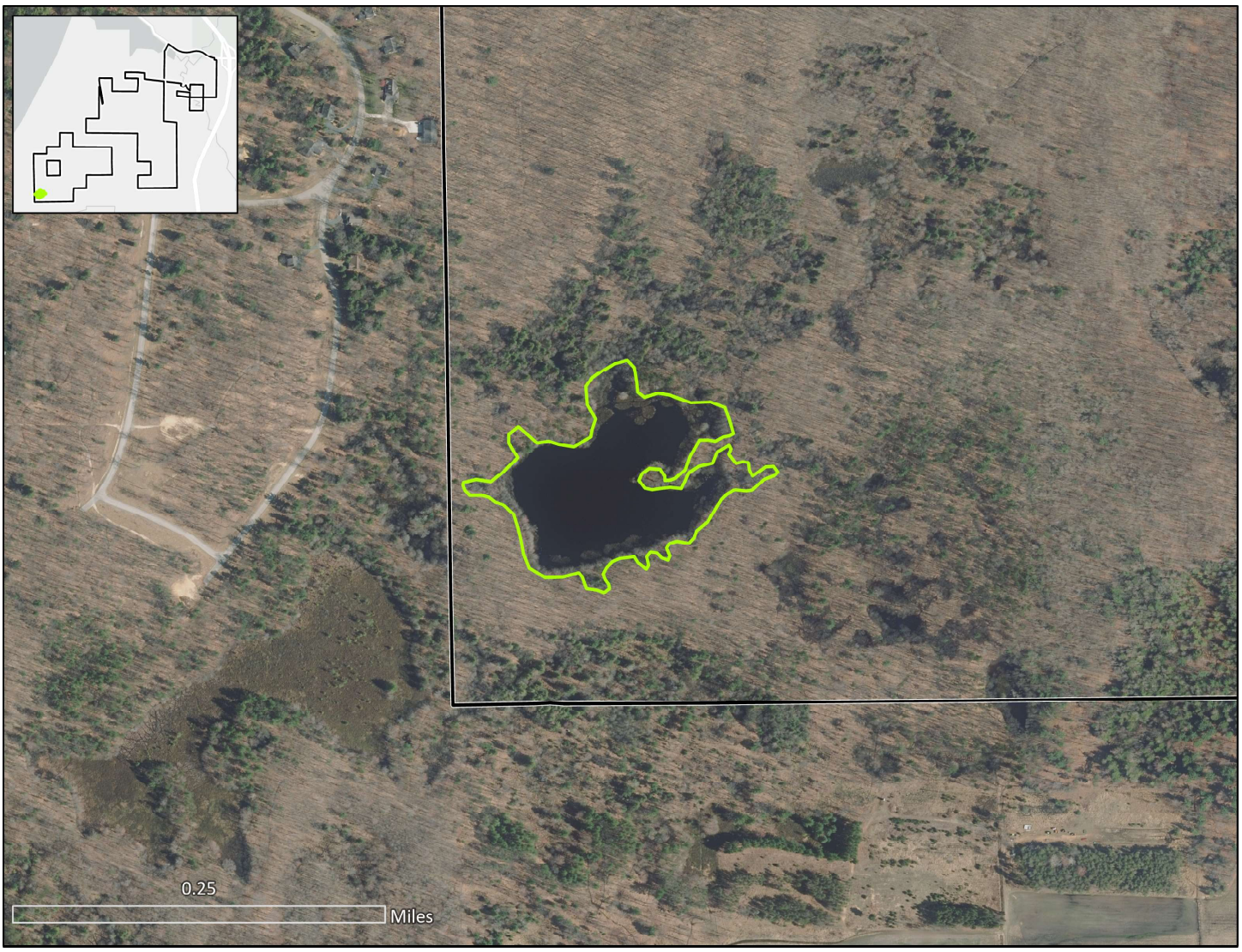


Figure 17. Location of Pentwater Pond intermittent wetland (ESRI 2022).

The water levels of Pentwater Pond intermittent wetland are highly variable from season to season and year to year. The top photo was taken in June of 2022 and the bottom photo was taken in March of 2022. This leads to distinct zones of vegetation and variability from year to year. Top photo by J.M. Lincoln, bottom photo by A.P. Kortenhoven.

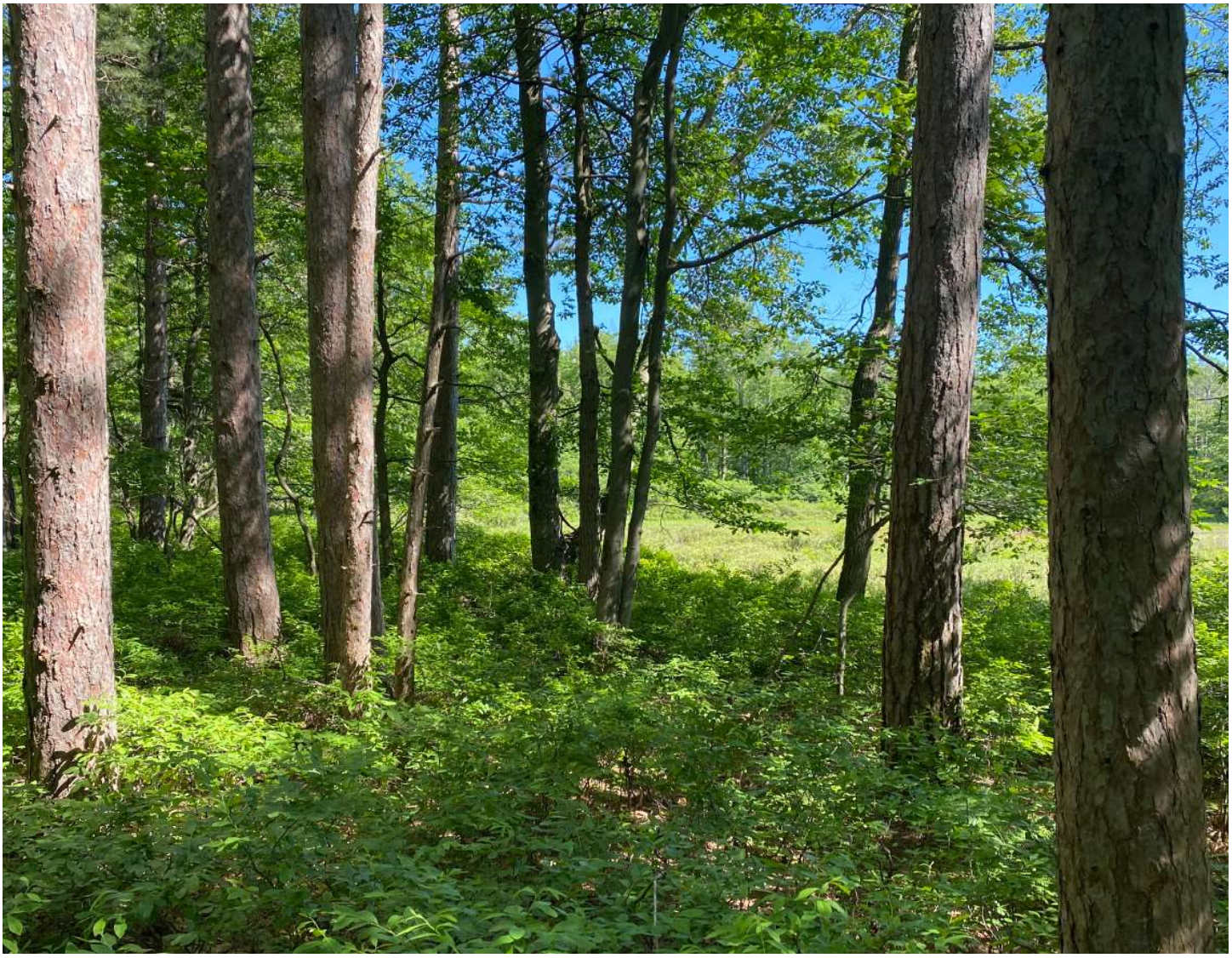
leaved violet (*Viola lanceolata*). The areas of deepest water feature a submergent zone with pondweed (*Potamogeton natans*) and water-shield (*Brasenia schreberi*).

Locally, black-gum (*Nyssa sylvatica*) is the dominant tree at the edges of the intermittent wetland with Michigan holly underneath. The adjacent upland forest is characterized as dry-mesic northern forest with red pine over huckleberry, suggesting a history of periodic fire. Wetter zones of surrounding forest support hemlock (*Tsuga canadensis*), leatherleaf (*Chamaedaphne calyculata*), and Virginia chain-fern (*Woodwardia virginica*).

Pentwater Pond was visited once in June of 2022. Thirty-three plant species, including 30 native and 3 non-native species were recorded. The total FQI was 31.6 and the Total Mean C was 5.5. Conservation metrics for Pentwater Pond and the comprehensive species list are in Appendix 7.

Threats and Management Recommendations
The primary threat to this system is invasive species, particularly reed canary grass (*Phalaris arundinacea*). A small patch of reed canary grass occurs in the southwest portion of the wetland at the margin of the surrounding upland. This could be treated relatively easily but may require follow-up surveys and treatments. There are no nearby trails but off-road vehicles and horses would potentially introduce invasive species and degrade the condition of this wetland.

While adjacent uplands feature natural red pine that suggest a history of fire, the degree of private property nearby, prevalence of nearby wetlands, and the remote nature of this wetland may make implementation of prescribed fire of the wetland and adjacent uplands operationally challenging.



The uplands at the margins of Pentwater Pond feature natural red pine and dense huckleberry, indicating the context as a fire-dependent landscape. Photo by J.M. Lincoln.

6. Watson Creek Woods
Natural Community Type: Mesic northern forest
Rank: G4 S3, apparently secure globally and vulnerable within the state
Element Occurrence Rank: D
Size: 21.4 acres
Location: Compartment 1; Stands 20, 23, 48, 51
Element Occurrence Identification Number: 27078

This second-growth forest occurs on the steep sandy slopes of a narrow valley along Watson Creek. The top of slope is up to 20 m above the stream and seeps occur at the base of the slopes and along the stream. The surrounding landscape is typically second- and third-growth forest with elements that indicate a history of fire (red pine and white oak), though the protective setting of the steep ravine means that fire likely did not consistently influence Watson Creek Woods. There is windthrow throughout, creating an accumulation of coarse woody debris.

There is little herbaceous vegetation throughout much of the forest due to droughty sands, acidic conditions, dense shade from hemlock (*Tsuga canadensis*), and intense deer herbivory. Soils are characterized by shallow acidic organics (pH 4.5-5.) overlying medium-textured sands (pH 5.0-5.5).

The closed-canopy forest (~75 - 90%) is dominated by hemlock and maple (*Acer saccharum* and *A. rubrum*) with red oak (*Quercus rubra*), beech (*Fagus grandifolia*), white oak (*Q. alba*), super canopy white pine (*Pinus strobus*), big-tooth aspen (*Populus grandidentata*), and northern white-cedar (*Thuja occidentalis*). Canopy trees are typically between 40 to 80 cm dbh. White oaks are typically near the top of slopes and cedar are infrequent along the seeps at the base of the slope and along the creek. The oldest tree cored was a 43.7 cm hemlock that had 168 rings. A 55.1 cm sugar maple had 139 rings, and most trees appear to be part of this cohort. Numerous

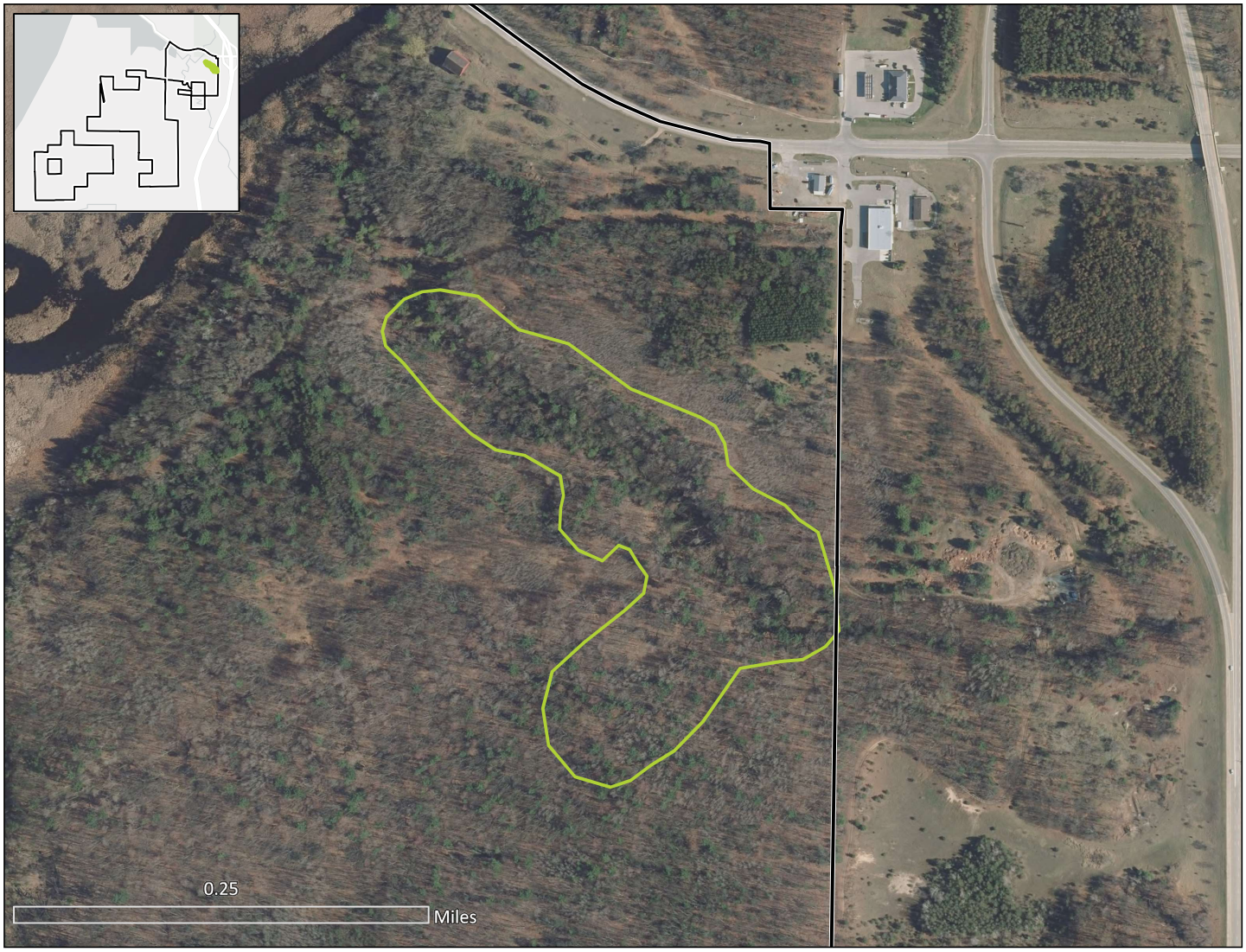
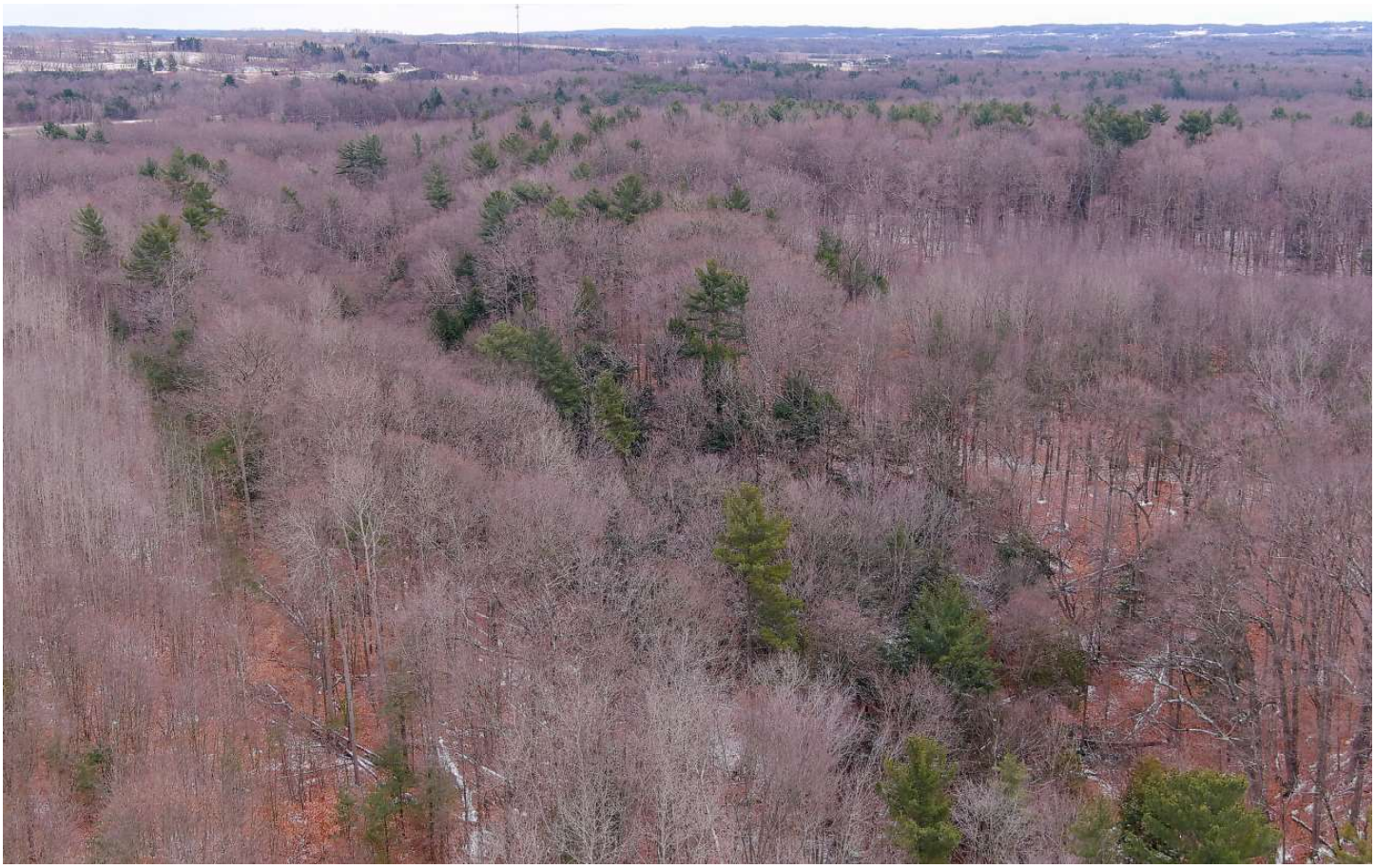


Figure 18. Location of Watson Creek Woods mesic northern forest (ESRI 2022).



The trees in Watson Creek Woods are some of the oldest and largest on the landscape. There are several large white pine (top photo) but the oldest trees are relegated to steep slopes along the creek in areas that were not recently logged. Photos by J.M. Lincoln.

diseases have altered the canopy of this forest. Tree diseases have dramatically reduced the abundances of beech, ash, and elm, and hemlock is likely soon to follow without continuing intervention. Beech bark disease is common throughout but there seems to be a concentration of resistant trees in this forest.

The subcanopy is dominated by beech, hemlock, red oak, red maple, yellow birch (*Betula alleghaniensis*), American elm (*Ulmus americana*), and ironwood (*Ostrya virgninana*). There is a very sparse understory (< 2 %) with few tall shrubs including witch-hazel (*Hamamelis virginiana*), juneberry (*Amelanchier arborea*), and spicebush (*Lindera benzoin*). The low shrub layer is also very sparse (< 2%) with maple-leaved viburnum (*Viburnum acerifolium*), spicebush, common blackberry (*Rubus allegheniensis*), and young juneberry. Invasive shrubs are occasionally prevalent, including autumn olive (*Elaeagnus umbellata*), common privet (*Ligustrum vulgare*), and multiflora rose (*Rosa multiflora*). Many seedlings of the canopy species, including beech, sugar maple, and green ash (*Fraxinus pennsylvanica*) occur in the ground cover.

The herbaceous layer is typically sparse and low diversity except along seeps along the creek and the steepest parts of the slopes and where windthrow has limited the deer herbivory. Typical species include star-flower (*Trientalis borealis*), Canada mayflower (*Maianthemum canadense*), sedges (*Carex intumescens*, *Cx. gracillima*, *Cx. pensylvanica*, and *Cx. cephaloidea*), partridge-berry (*Mitchella repens*), and pokeweed (*Phytolacca americana*). Ferns are locally abundant including lady fern (*Athyrium filix-femina*), New York fern (*Thelypteris noveboracensis*), and bracken fern (*Pteridium aquilinum*). Seeps are prevalent along the base of steep slopes and these locally feed Watson Creek with small rivulets surrounded by mucky soil. These tend to be the most diverse areas of the forest and feature zones dominated by sedges and grasses, especially *Carex scabrata*, *Cx. stipata*, *Cx. tenera*, and *Cx. crinata*. Grasses include fowl meadow grass (*Poa palustris*), fowl manna grass (*Glyceria striata*), and wood reedgrass (*Cinna latifolia*). This is also potential habitat for Hine's emerald dragonfly. The stream bank is dominated by native watercress (*Nasturtium officinale*) and spotted touch-me-not (*Impatiens capensis*) is common.

Watson Creek Woods was visited once in June of 2022. Seventy-eight plant species were observed in the mesic northern forest with 64 native species and 7 non-native species observed. The Total FQI was 30.3 and the Total Mean C was 3.6. Conservation metrics for Watson Creek Woods and the comprehensive species list are in Appendix 8.

Threats and Management Recommendations
Management recommendations include preventing fragmentation in adjacent areas by limiting logging of adjacent forests. This would also benefit the populations of rare land snails documented in this forest, as they are sensitive to sudden changes. We also suggest treating invasive shrubs such as multiflora rose, common privet, and autumn olive. Deer herbivory was obvious throughout and reducing deer densities would be beneficial for several species.

The proximity of Watson Creek Woods to Lake Michigan means severe storms are relatively frequent and leads to the accumulation of large coarse woody debris. Photo by J.M. Lincoln.

7. Pentwater Prairies
Natural Community Type: Wet-mesic sand prairie
Rank: G2G3 S2, imperiled to vulnerable globally and imperiled within the state
Element Occurrence Rank: BC
Size: 26.2 acres
Location: Compartment 2; Stands 4, 7, 8, 22, 23, 40.
Element Occurrence Identification Number: 26075

This prairie complex occurs as seven graminoid-dominated openings of various sizes. These occupy shallow depressions within a matrix of oak-pine forest. The prairie openings are one of several wetland types within a dune field, including bog, northern shrub thicket, and intermittent wetland. These wetland openings are characterized by sandy soils, though pH and moisture are variable between pockets of prairie. These wetlands are maintained by a fluctuating water table that causes inundation and limits woody encroachment. The variability of the water table leads to highly variable zonation spatially between openings. Water levels fluctuate both seasonally and annually. Drought also likely prevents woody encroachment and fire was historically an important disturbance.

Prevalent species include blue-joint (*Calamagrostis canadensis*), switch grass (*Panicum virgatum*), big bluestem (*Andropogon gerardii*), sedges (*Carex pellita* and *Cx. buxbaumii*), panic grasses (*Dichanthelium lindheimerii, D. boreale*, *D. implicatum* and *D. meridionale*), rushes (*Juncus greenii* and *J. canadensis*), and golden-seeded spike rush (*Eleocharis elliptica*). Forbs are less prevalent and include southern blue flag (*Iris virginica*), bushy aster (*Symphyotrichum dumosum*), violets (*Viola lanceolata* and *V. sagittata*), hyssop hedge nettle (*Stachys hyssopifolia*), and wild mint (*Mentha canadensis*). The non-native Kentucky bluegrass (*Poa pratensis*) is locally abundant.

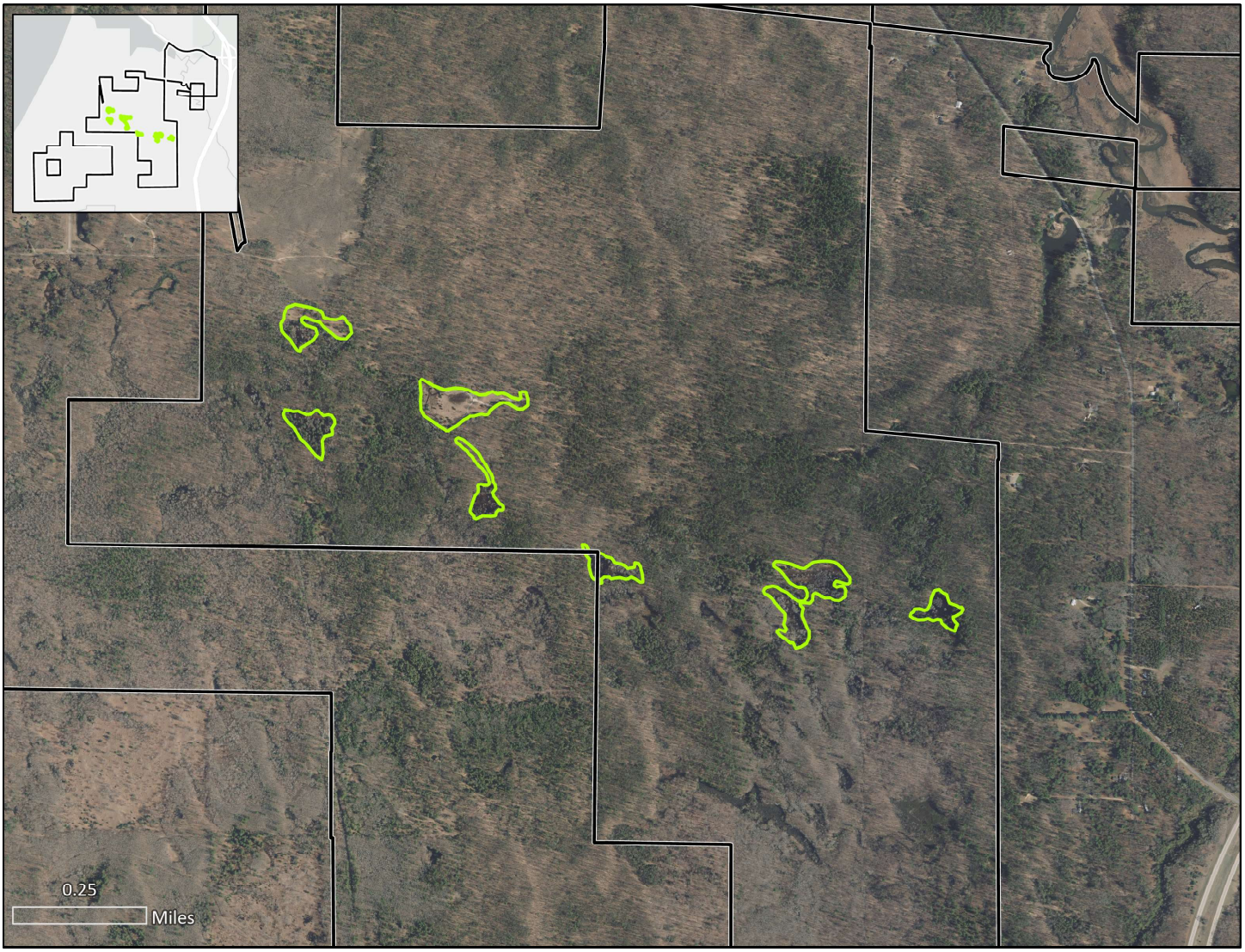
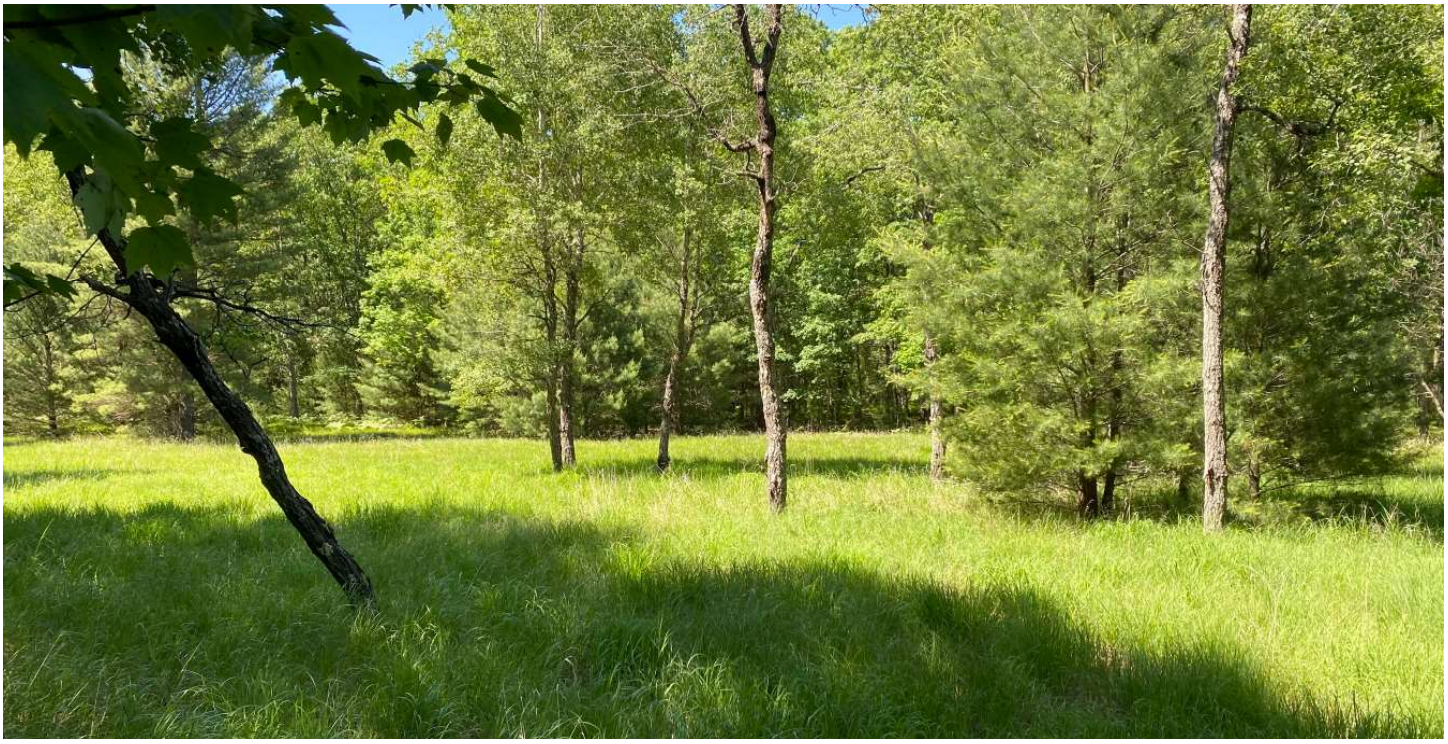


Figure 19. Location of Pentwater Prairies wet-mesic sand prairie (ESRI 2022).

In the wetter zones, prevalent species include swamp milkweed (*Asclepias incarnata*), sedges (*Cx. crinata* and *Cx. stricta*), and northern bugle weed (*Lycopus uniflorus*). Drier zones along the transition to oak forest feature black oatgrass (*Piptochaetium avenaceum*), huckleberry (*Gaylucaccia baccata*), hairy pinweed (*Lechea mucronata*), dwarf dandelion (*Krigia virginica*), hairy hawkweed (*Hieracium gronovii*), long-leaved bluets (*Houstonia longifolia*), broom-sedge (*Andropogon virginiana*), hairy bedstraw (*Galium pilosum*), and poverty grass (*Danthonia spicata*).

Shrubs are generally infrequent but include Michigan holly (*Ilex verticillata*), meadowsweet (*Spiraea alba*), willows (*Salix petiolaris* and *S. discolor*), leatherleaf (*Chamaedaphne calyculata*, and tag alder (*Alnus incarnata*).

Trees are nearly absent from the system, except for a few groves of quaking aspen (*Populus tremuloides*), sparse white pine (*Pinus strobus*), and infrequent oaks (*Quercus ellipsoidalis* and *Q. alba*). A 37.6 cm (14.8 in) dbh white oak had 60 growth rings.



The prairie openings are characterized by a diverse suite of grasses and few trees. The return of fire to the landscape will ideally expand these openings to include more of the surrounding uplands and improve habitat connectivity for the population of Great Lakes spittlebug that was documented during rare insect surveys. Photos by J.M. Lincoln.

The prairie openings are part of a fire-adapted landscape and occur within an extensive oak-pine forest with barrens indicator species occurring locally at the margins. Much of the area was sparsely canopied in the 1930s (Figure 6, pg 7) and many of the red pine in the surrounding forests are fire scarred, indicating the importance of fire as a disturbance maintaining this area. The fire-scarred red pines indicate multiple fires which is consistent with the occurrence of Indigenous cultural fires. The greatest concentration of fire-scarred trees occurs near the prairie openings potentially indicating an important connection between cultural fires and the prairie openings.

The Pentwater Prairies were visited in June and August of 2022. Eighty-six plant species were observed in the wet-mesic sand prairie with 78 native species and 8 non-native species. The Total FQI was 40.8 and the Total Mean C was 4.4. Conservation metrics for Pentwater Prairies and the comprehensive species list are in Appendix 9.

Threats and Management Recommendations

Our primary recommendations are 1) to prevent damage to the wetlands from off-road vehicles, trails, and equipment; 2) monitor the wetlands for invasive species; and 3) continue applying prescribed burns to the prairies and surrounding forest.

To protect the prairie openings and minimize degrading the condition of the forest, we suggest managers redirect trails and roads away from openings. The largest opening of the prairie has been impacted by off-road vehicles and there is an expanding network of roads and trails in this area. Horses often spread weedy species, and we recommend eliminating roads and trails when possible and limiting expansion of the trail network. Ideally, trails would be configured in a way to be as far from the openings as possible and to serve as burn breaks while maximizing the size of the burn units.

One of the openings was dominated by prairie cord grass in 2015. The surrounding uplands feature red and white pine and indicate a fire-adapted landscape. Photo by J.M. Lincoln.

Invasive species are presently at fairly low levels; however, invasives can spread rapidly and severely degrade the openings, particularly with such intense pressure from off-road-vehicles (ORVs). We recommend continual monitoring for invasive species and treating reed canary grass (*Phalaris arundinacea*) when encountered in the openings. Narrow-leaved cat-tail (*Typha angustifolia*), glossy buckthorn (*Frangula alnus*), and invasive reed (*Phragmites australis* var. *australis*) also pose serious risks and have been found in the surrounding landscape. We urge managers to monitor for these species as well.

The DNR is actively managing some of the prairie openings with prescribed fire. Apparently, the largest prairie opening has been burned twice, once in 2018 and again in 2022. There are plans to include additional prairie openings and portions of the forest in future prescribed fires and we endorse these plans. Fires likely burned the lowlands and adjacent uplands in concert historically and would have happened at various times of the year including late growing season to dormant season (late September through early March). A fire line was previously dug around the edge of the prairie, and we suggest managers continue rerouting burn lines away from discrete openings to prevent degrading the highest quality remnants.

We recommend managers continue applying prescribed burns and including the prairie openings and as much of the surrounding forest as possible while explicitly avoiding the use of equipment in the ecotone transition zone between the prairie and the forest. Great Plains spittlebug was documented in one of the openings and this approach to fire would likely be beneficial for habitat expansion of this rare insect. We recommend applying prescribed fires at a frequency of approximately every 5 to 10 years to as large of an area possible, with an emphasis on including the highest quality portions of the forest and as many openings of the wet-mesic sand prairie as possible. We also suggest implementing low intensity/ low severity late-season burns at least initially as fire is reintroduced to the system. A higher frequency of fires would ideally be applied to prairies and surrounding forest with the lower frequency in forests away from the prairies.

Initial prescribed fires resulted in a burn line being cut in at the edge of the prairie. The proximity of this opening to a nearby road has also facilitated extensive ORV damage. Area managers have already moved the burn lines outside of prairie openings and we suggest investigating the closure of the nearby road to prevent further degradation to this rare community type. Photo by J.M. Lincoln.

Two rare plants were documented during the natural community surveys in 2022. Populations of meadow-beauty (*Rhexia virginica*; State Special Concern) (left) occur in both intermittent wetlands. Waterthread pondweed (*Potamogeton bicupulatus*; State Threatened) (right) was observed in Golden Intermittent Wetland and is the first occurrence of this species in Oceana County. Photos by J.M. Lincoln.

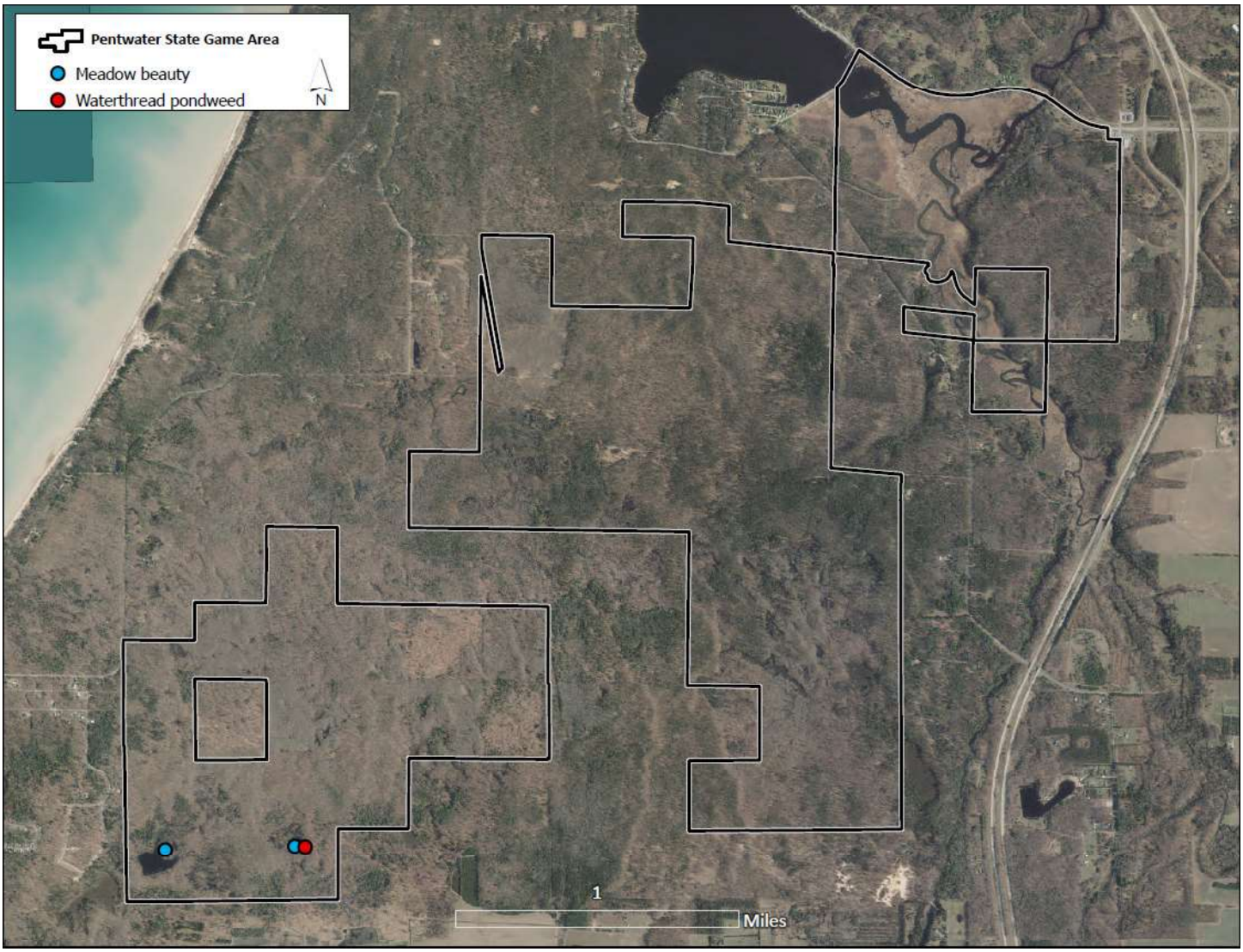


Figure 20. Location of rare plants in Pentwater State Game Area (ESRI 2022).

Rare Birds

Three eastern whip-poor-will (*Antrostomus vociferus*; State Threatened) were recorded during nocturnal bird surveys (Figure 21). No common nighthawks were recorded. Red-shouldered hawks were detected at four points, though we did not find any nesting hawks within the vicinity of these detections. Northern goshawks were not detected in the state game area. We conducted forest songbird surveys at 29 points but did not detect any rare forest songbirds. We documented 35 bird species during point counts at the Pentwater SGA (Appendix 10). Six species were detected at 30% or more survey points: red-eyed vireo (*Vireo olivaceus*; 73%), wood thrush (*Hylocichla mustelina*; 43%), ovenbird (*Seiurus aurocapilla*; 39%), eastern wood-pewee (*Contopus virens;* 33%), scarlet tanager (*Piranga olivacea*, 36%), and blue jay (*Cyanocitta cristata*, 30%).

Several bird species detected have special conservation status. Three species are MDNR featured species for habitat management. These featured species are pileated woodpecker, wood thrush, and wild turkey (*Meleagris gallopavo*). Wood thrush is also a species of greatest conservation need (SGCN; Derosier et al. 2015) and a focal species for conservation efforts under the Landbird Habitat Conservation Strategy (Potter et al. 2007) of the Upper Mississippi River and Great Lakes Region Joint Venture.

During secretive marsh bird surveys we recorded two least bitterns (*Ixobrychus exilis*, State Threatened) and two marsh wrens (*Cistothorus palustris*, State Special Concern) (Figure 21). Both bitterns were observed flying low over the marsh, one was flushed and a few seconds later a second bird flew out of the same cat-tail pocket.

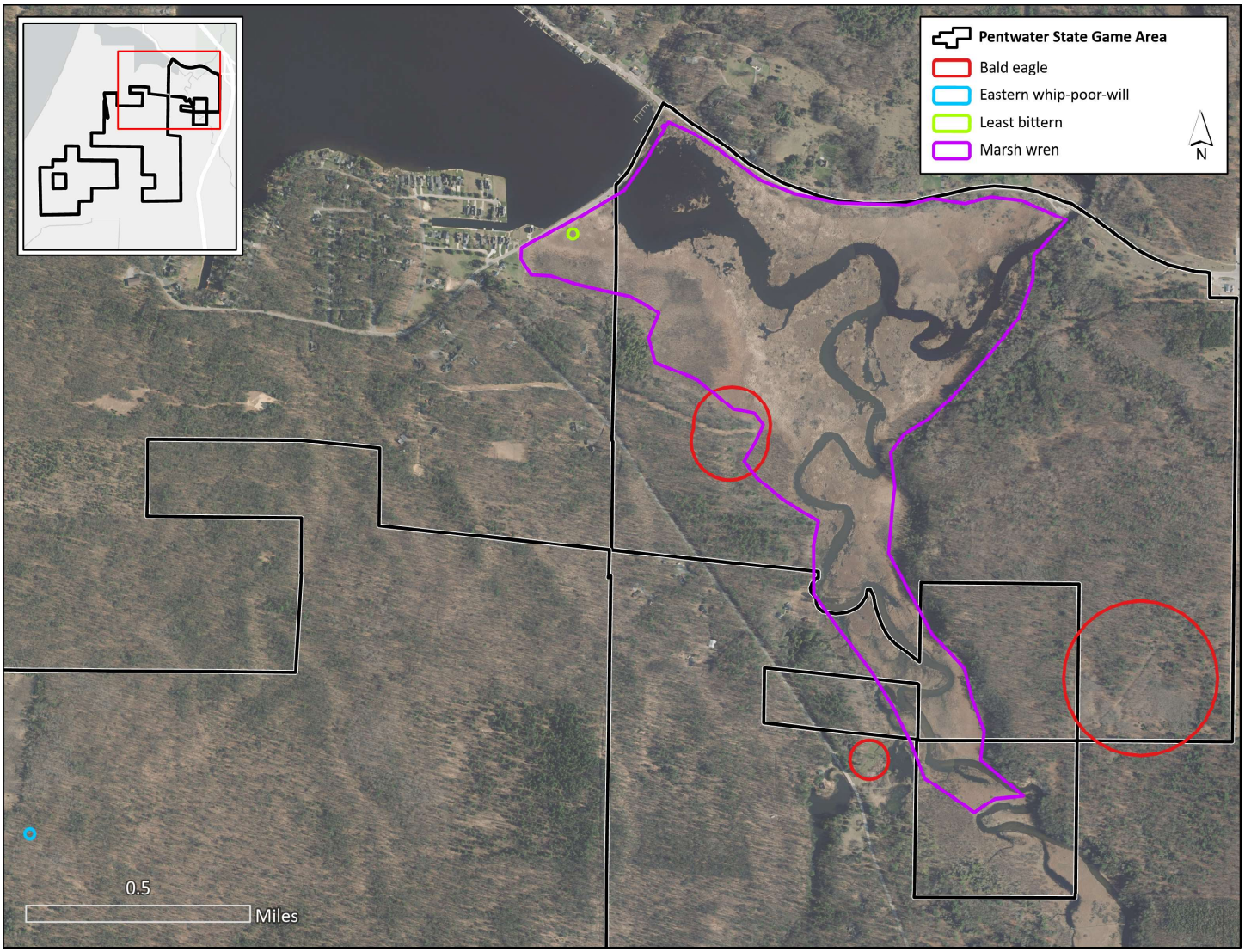


Figure 21. Location of rare birds in Pentwater State Game Area (ESRI 2022).

Marsh wrens (top photo) were documented in the Great Lakes marsh. Red-shouldered hawks (bottom photo) were observed within Pentwater Woods, though we were unable to locate a nest and the birds were likely nesting in forests on adjacent private property. Photos by A.P. Kortenhoven.

Rare Herptiles

We documented one new EO of Blanding's turtle (State Special Concern; EO ID 27097) consisting of multiple observations within the state game area. (Figure 22). One adult female Blanding's turtle was captured in the game area on June 26 during the aquatic funnel trapping surveys. Two adult Blanding's turtles were observed on June 17 and 18 during MNFI's natural community surveys. [redacted]

Additional observations of Blanding's turtles around the Pentwater SGA were compiled from the Michigan Herp Atlas. All these observations comprise a single EO (EO ID 27097) that is estimated to have fair viability (TMNFI 2024). This designation means that based on available information regarding this population's current condition, size, and landscape context, the EO has fair probability of persisting if current conditions are maintained.

We did not observe other rare herptile species during the surveys in 2022. We conducted an additional survey for wood turtles along the stretch of the Pentwater River within the game area in 2023 and did not observe wood turtles during that survey. Potential for wood turtles to occur within the game area is likely low given limited available habitat along the stretch of the Pentwater River within the game area.

Common reptile species detected during herptile surveys in 2022 included the northern water snake (*Nerodia sipedon sipedon*), northern map turtle (*Graptemys geographica*), snapping turtle (*Chelydra serpentina*), and painted turtle (*Chrysemys picta*) (Appendix H1). A total of 10 individual painted turtles and 6 snapping turtles (4 juveniles, 2 adults) were captured during the aquatic funnel trapping surveys.

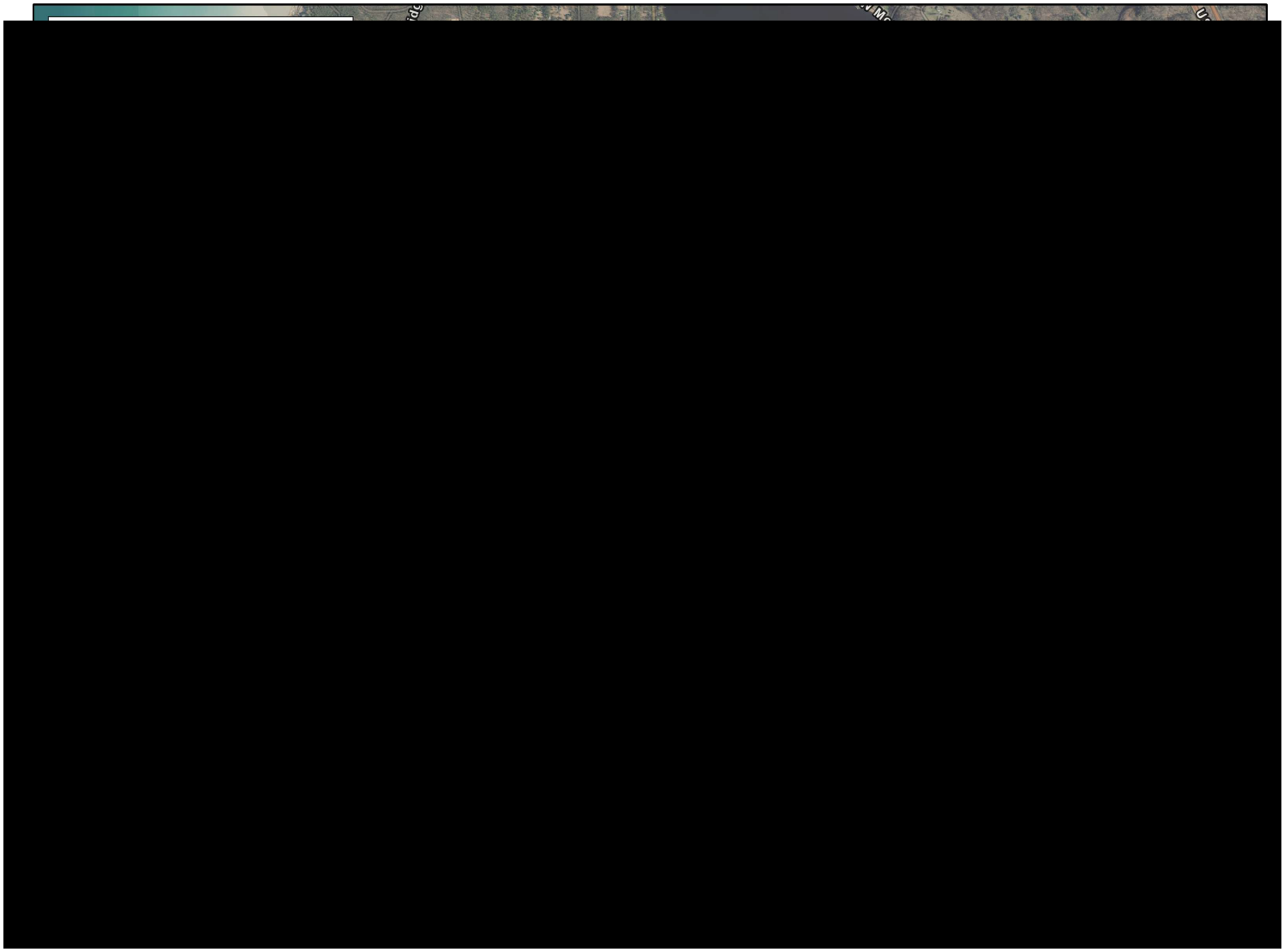


Figure 22. Location of rare herptiles in Pentwater State Game Area (ESRI 2022).

Blanding's turtles (top photo) are the only rare reptile documented in Pentwater SGA but were observed at several locations in the [redacted] portion of the game area. Several species of snake were observed in the game area, including this northern watersnake. Photos by J.M. Lincoln.

Rare Insects

No occurrences of Hine's emerald dragonfly were documented despite presence of suitable larval habitat. We documented suitable larval habitat along the northern edge of Watson Creek, including numerous crayfish burrows embedded in multiple small pockets of sedge meadow along a hillside seep. Each of these sedge meadow openings were small and somewhat isolated (approximately ¼ acre in size) but are relatively contiguous along Watson Creek. The stream continues to the Great Lakes marsh complex, which may provide additional larval habitat and adult foraging opportunities.

The three most common dragonfly species encountered during these surveys were the white-faced meadowhawk (*Sympetrum obtrusum*), twelve-spotted skipper (*Libellula pulchella*) and the common green darner (*Anax junius*).

We documented a single occurrence of Great Plains spittlebug in the Pentwater Prairies (Figure 23). The specimen was collected during a sweep of big bluestem, which was dispersed throughout the survey location. This occurrence (EO 27136) represents the first record of Great Plains spittlebug within Pentwater SGA and occurs in the wet-mesic sand prairie natural community EO. Across the survey locations, the most common insect families documented included leafhoppers (Cicadellidae, n = 52), short-horned grasshoppers (Acrididae, n = 27), fireflies (Lampyridae, n = 25), and stink bugs (Pentatomidae, n = 24) (Table 4, p. 55).

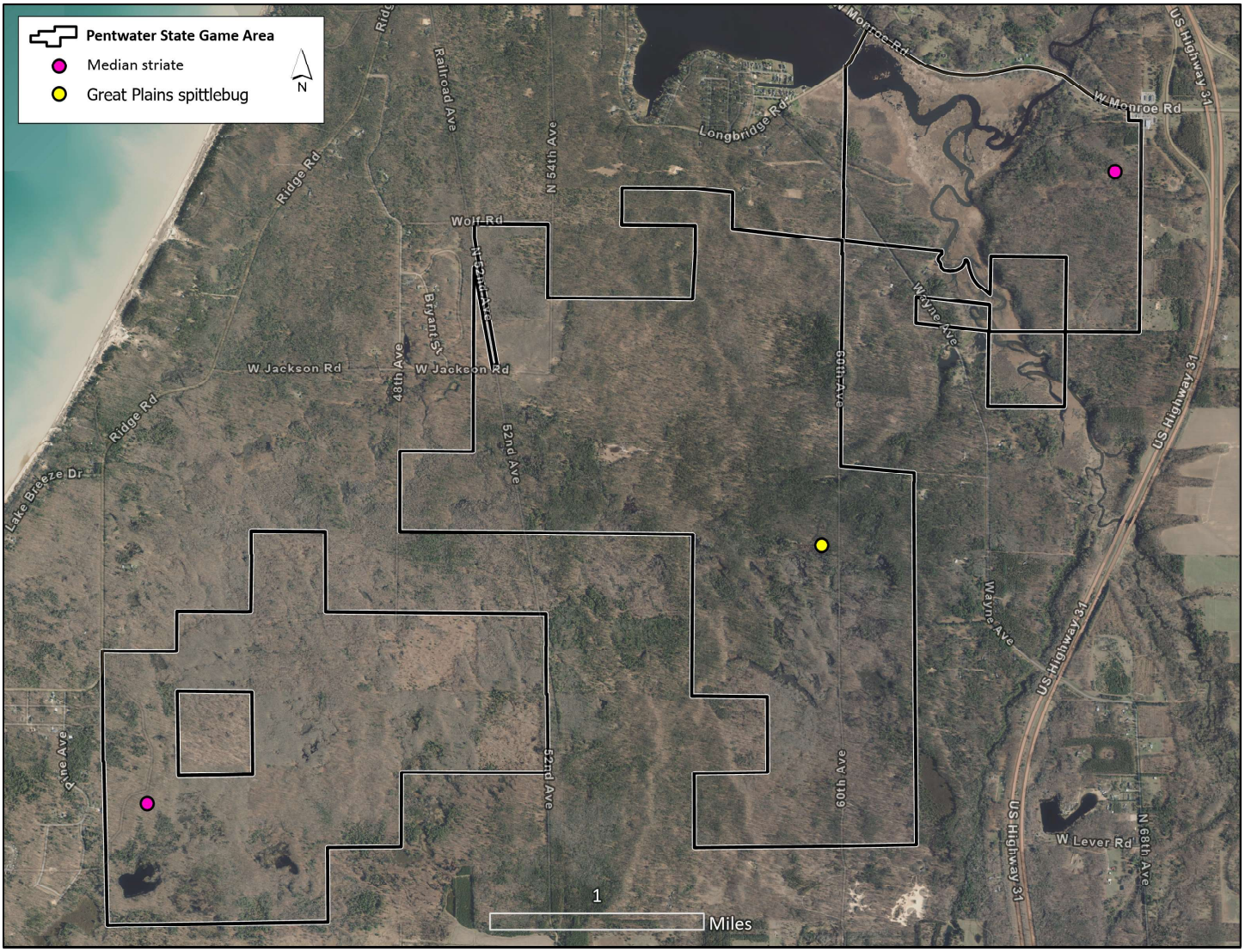


Figure 23. Location of insects and rare land snails in Pentwater State Game Area (ESRI 2022).

One of the three most frequently encountered dragonfly species was the common green darner.
Photo by J.M. Lincoln.

A Great Plains spittlebug was documented from Pentwater Prairie during sweep-net surveys.
Photo by L.M. Rowe.

Table 4. Incidental insects collected during sweep net surveys at Pentwater State Game Area.

Common Name	Order	Scientific Name	Number of Specimen Collected
Orb-weaver Spiders	Araneae	Araneidae	1
Jumping spiders		Salticidae	6
Crab spiders		Philodromidae	1
Labidognatha		Araneomorpha	8
Scarab beetles	Coleoptera	Scarabaeidae	19
Longhorn beetles		Cerambycidae	1
Leaf beetles		Chrysomelidae	2
Fireflies		Lampyridae	25
True weevils		Curculionidae	19
Net-winged beetles		Lycidae	2
Ladybugs		Coccinellidae	6
Tiger beetles		Cicindelidae	2
Sap beetles		Nitidulidae	1
Checkered beetles		Cleridae	6
Ground beetles		Carabidae	2
Beetles		Polyphaga	3
Click beetles		Elateridae	1
Robber flies	Diptera	Asilidae	1
Crane flies		Tipulidae	1
Fruit flies		Tephritoidea	8
True Flies		Empidoidea	2
Flies		*unknown*	5
Dance flies		Hybotidae	4
Long-legged flies		Dolichopodidae	20
Syrphid flies		Syrphidae	4
Land snails	Gastropoda	*unknown*	1
Leafhoppers	Hemiptera	Cicadellidae	52
Stink bugs		Pentatomidae	24
Assassin bugs		Reduviidae	1
Damsel bugs		Nabidae	1
Plant bugs		Miridae	21
Planthoppers		Dictyopharidae	1
Twig-wilters		Coreinae	1
Scentless plant bugs		Rhopalidae	3
Broad-headed bugs		Alydidae	7
True bugs		Heteroptera	5
Froghoppers		Cercopidae	1
Lygaeoid bugs		Heterogastridae	3
Ants	Hymenoptera	Formicidae	100+
Sweat bees		Halictidae	3
Sawflies		Symphyta	1
Ichneumon wasps		Ichneumonidae	1
Parasitic wasps		Diapriidae	1
Owlet moths	Lepidoptera	Noctuidae	3
Green lacewings	Neuroptera	Chrysopidae	10
Harvestmen	Opiliones	Opiliones	1
Short-horned grasshoppers	Orthoptera	Acrididae	27
Bush cricket		Tettigoniidae	14

Rare Land Snails

We collected 88 snails, including unidentifiable shell fragments (21) and immature shells (16), from nine species among all sites. We documented the median striate (*Striatura meridionalis*, State Special Concern) in litter surveys at two plots, comprising two new element occurrences (Figure 23, p. 53). Median striate was found in moist leaf litter in Watson Creek Forest where we documented 40 snails from seven species. The Birch Avenue Forest (Stand 25, Compartment 3) contained 48 snails from eight species (Table 4). We found two snails species (*Strobilops aeneu*s and *Zonitoides arboreus*) at Watson Creek forest during visual surveys (Table 4). At the Birch Avenue Forest, we documented 14 snails (including three unidentifiable shell fragments and three immature shells) during visual surveys, from two species (*Discus catskillensis* and *Zonitoides arboreus;* Table 5). We found 10 individuals of the carved glyph (*Glyphyalinia indentata*, vulnerable (S3) in Ontario), 11 individuals of the small spot (*Punctum minutissimum*, imperiled (S2) Indiana), three black striate (*Striatura ferrea*, vulnerable (S3) in Minnesota and Ontario and imperiled (S2) in Wisconsin).

Table 5. Land snails documented at Pentwater State Game Area.

		Watson Creek Woods - Site A		Watson Creek Woods - Site B		Compartment 3, Stand 25 - Site A		Compartment 3, Stand 25 - Site B		
Common Name	**Scientific Name**	**Visual**	**Leaf Litter**	**Visual**	**Leaf Litter**	**Visual**	**Leaf Litter**	**Visual**	**Leaf Litter**	**Total**
Unidentifiable	Shell fragment		5		2	3	9		2	21
Unidentifiable	Immature shell		5		6	3	1		1	16
Angular disc	*Discus catskillensis*					2				2
Comb snaggletooth	*Gastrocopta pentodon*				1		1			2
Carved glyph	*Glyphyalinia indentata*				5				5	10
Small spot	*Punctum minutissimum*		1		4		6			11
Median striate*	*Striatura meridionalis**				1		2			3
Black striate	*Striatura ferrea*		2		1					3
Bronze pinecone	*Strobilops aeneus*			1	1		2			4
Variable vertigo	*Vertigo gouldii*		1							1
Quick gloss	*Zonitoides arboreus*		3	1		6	8			18
	Total snails	**0**	**17**	**2**	**21**	**14**	**29**	**0**	**8**	**91**

*State Special Concern

Median striate (Left) and variable vertigo (Right) were documented in leaf litter collected during land snail surveys in Pentwater State Game Area. Photos by A. A. Cole-Wick.

Rare Mussels

Unionid mussels were documented in the Pentwater River during our surveys, though no listed or Special Concern mussel species were found. Aquatic surveys were performed at four sites in the Pentwater River within Pentwater SGA and three non-listed mussel species were found; fatmucket (*Lampsilis siliquoidea*), white heelsplitter (*Lasmigona complanata*), and giant floater (*Pyganodon grandis*) (Table 6). Live individuals of white heelsplitter and fatmucket were present, while giant floater was represented by shell only. A live white heelsplitter of four or less years of age, judging by the number of external growth rings, was found indicating reproduction has occurred in recent years. Live zebra mussels were found attached to a live fatmucket and zebra mussel byssal threads were attached to live white heelsplitters. Empty fatmucket and white heelsplitter shells also had live zebra mussels attached. Zebra mussels appeared to be present throughout the Pentwater River within the game area, though live individuals were noted at only one of the four sites surveyed and only shells were found at the other three.

Table 6. Unionid mussel species found at each aquatic survey site. Numbers of live unionid mussels are given. (S= only shells found; L= live found).

		1	2	3	4
Common name	Species	#	#	#	#
Fatmucket	*Lampsilis siliquoidea*		2	S	1*
White heelsplitter	*Lasmigona complanata*		1	2	2**
Giant floater	*Pyganodon grandis*		S		S
	Area searched (m^2)	45	60	150	150
Asian clams	*Corbicula fluminea*	S			
Zebra mussels	*Dreissena polymorpha*	S	S	S	L*

* One live fatmucket with 21 zebra mussels attached. Zebra mussel byssal threads were attached to several empty shells.

** Evidence of zebra mussel attachment (byssal threads) were seen on both live white heelsplitters.

Table 7. Incidental finds at aquatic survey sites in the Pentwater River.

Common Name	Species/Taxa	1	2	3	4
Snails	Gastropoda				
Pointed campeloma	*Campeloma decisum*		X		X
Chinese/Japanese mystery snail	*Cipangopaludina chinensis/japonica*	X	X		X
Limpet	*Ferrissia sp.*		X		
Two-ridge Rams-horn	*Helisoma anceps*	X	X	X	
Physa	*Physa sp.*		X	X	X
Marsh pondsnail	*Stagnicola elodes*	X			
Marsh rams-horn	*Planorbella trivolvis*	X	X	X	X
Threeridge valvata	*Valvata tricarinata*		X	X	
Fingernail clams	Sphaeriidae				
Crayfish	Decapoda				
Fish	Osteichthyes				
Largemouth bass	*Micropterus salmoides*		X		
Round goby*	*Neogobius melanostomus*	X		X	
Yellow perch	*Perca flavescens*		X		
Logperch	*Percina caprodes*		X		
European frog's-bit	*Hydrocharis morsus-ranae*	X			

* Non-native invasive

Seven species of native aquatic gastropods were noted as incidental finds (Table 7). Numerous young Chinese or Japanese mystery snails (*Cipangopaludina* sp.) were noted at Sites 2 and 4. This invasive snail species was found with an estimated maximum density on the order of 100 individuals per m^2. Another invasive aquatic species, European frog's-bit (*Hydrocharis morsus-ranae*), was observed at Site 1. Four fish species were observed including largemouth bass (*Micropterus salmoides*) and yellow perch (*Perca flavescens*), which are known to be host fish for the glochidia (larvae) of fatmucket, white heelsplitter, and giant floater; and round goby (*Neogobius melanostomus*), an invasive non-native fish known to be a host fish for fatmucket and giant floater. Logperch (*Percina caprodes*) and round goby are known to be hosts for the Federally Endangered snuffbox mussel (*Epioblasma triquetra*). Empty snuffbox shells were documented just south of the Pentwater River watershed in the Muskegon River in 2018 and 2002 (Lincoln et al. 2019) but not found during the Pentwater surveys of 2022.

Conditions for performing aquatic surveys were favorable with good water clarity. Although parts of the Pentwater River were too deep to wade, surveys targeted habitats shallow enough to wade or snorkel. Total alkalinity and water hardness were measured at aquatic survey Site 1 on September 8, 2022, and were 168 ppm and 162 ppm respectively. These measures are within a range that is generally suitable for aquatic animal life. The substrate at aquatic survey sites was dominated by fine particle sizes with high levels of organic particles, with the exception of Site One, which was approximately 60% boulder sized rip rap that is part of the causeways construction.

Live white heelsplitter (*Lasmigona complanata*) at aquatic survey site 3 in the Pentwater River. Photo by P.J. Badra.

DISCUSSION

Pentwater State Game Area (SGA) was established between 1958 and 1963 to protect wildlife habitat for hunting. In addition, it offers a large variety of recreational opportunities including fishing, birdwatching, foraging, hiking, skiing, and horseback riding. This report provides a strategic framework to coordinate the conservation of wildlife and habitats in Michigan, in support of the state's Wildlife Action Plan.

The game area has several important natural communities, large blocks of old forest, remnants of rare prairie, intermittent wetlands in very good condition, and populations of rare species. Prioritizing stewardship of representative natural communities is critical to biodiversity conservation because native organisms are best adapted to environmental and biotic forces with which they have survived and evolved over millennia. Biodiversity is most easily and effectively protected by preventing high-quality sites from degrading, and invasive plants are much easier to eradicate when their populations are small and not yet well-established. Generally, we recommend that management efforts to maintain ecological integrity and native biodiversity be focused within highest quality examples of the rarest natural communities as well as the least degraded areas of natural cover as these areas provide the best habitat for rare plant and animal species. To that end, we provide the following management recommendations for consideration.

We believe the main management needs in order of importance are to: 1) establish Priority Conservation Areas (PCAs) that include documented natural communities, the oldest forests, and sensitive habitats around which fragmentation is avoided and wetlands are protected; 2) develop and prioritize stewardship actions within those PCAs with the aim of improving or maintaining the condition of natural communities primarily by controlling invasive species and applying prescribed fire; and 3) conduct long-term monitoring on the condition of natural communities, populations of rare taxa, invasive species infestation, and the effectiveness of stewardship actions.

Pentwater State Game Area features areas of mature forest accruing coarse woody debris. The oldest forests tend to have the fewest invasive species and tend to support rare species. Photo by J.M. Lincoln.

Our fundamental recommendations are to minimize degradation of natural areas by limiting fragmentation within PCAs; preventing habitat loss by addressing priority infestations of invasive species; continuing to apply prescribed fire within the highest quality fire-dependent systems; and continually evaluating the effectiveness of stewardship actions.

The following discussion section has been organized around these management recommendations. In addition, based on our experience researching and surveying this game area, we provide recommendations for future survey and monitoring needs.

Establishing Priority Conservation Areas

Reducing Fragmentation

To direct stewardship actions, we have identified Priority Conservation Areas within which we suggest focusing invasive species treatment, the application of prescribed fire and limiting habitat fragmentation (Figure 24). In addition to sites that meet MNFI's standards for designation as a high-quality natural community, we have included important areas for maintaining ecosystem services or habitat for rare species. It is in these areas we recommend managers avoid intensive forestry operations and disturbance of soil to preserve the natural character of the most intact places. We included four categories in our

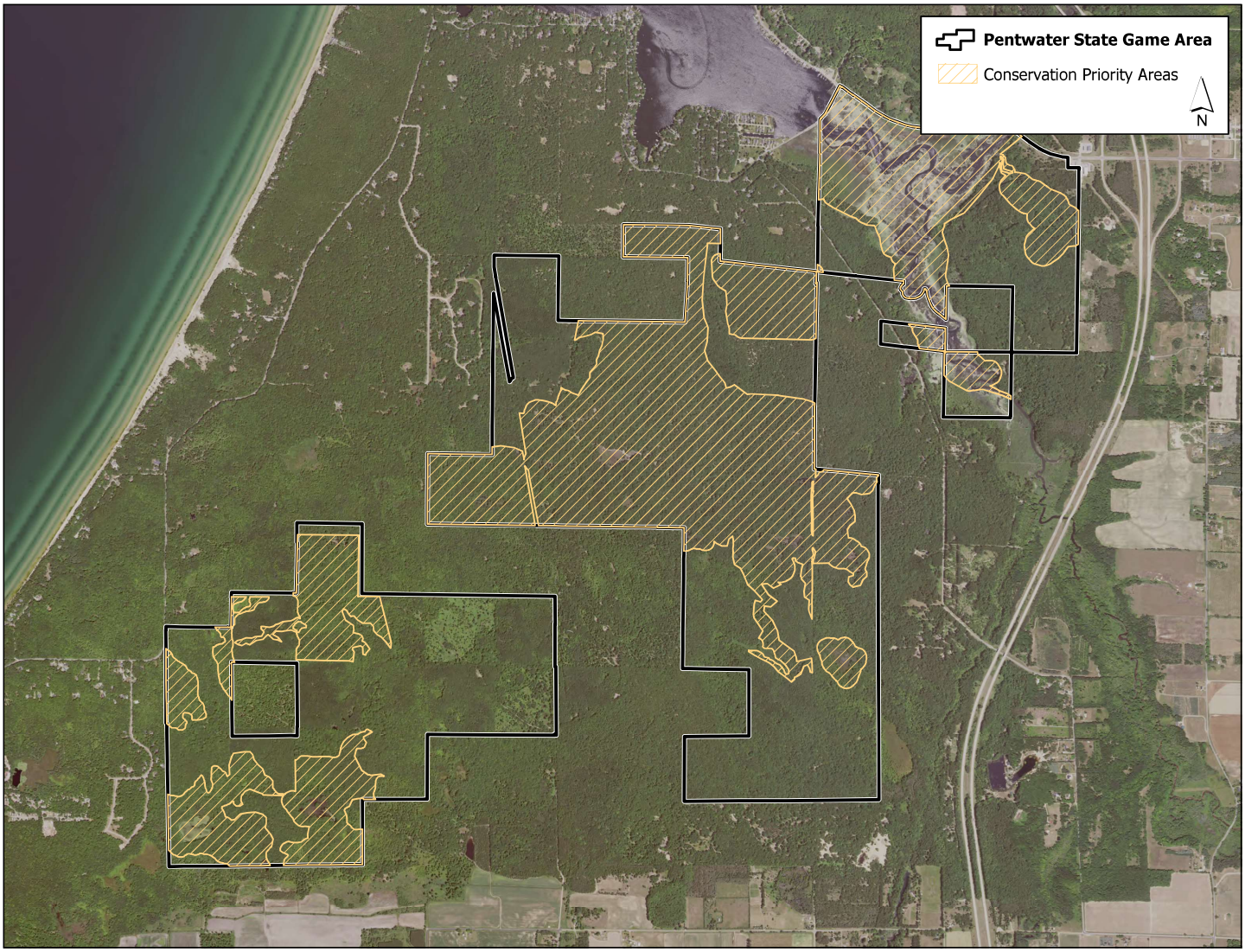


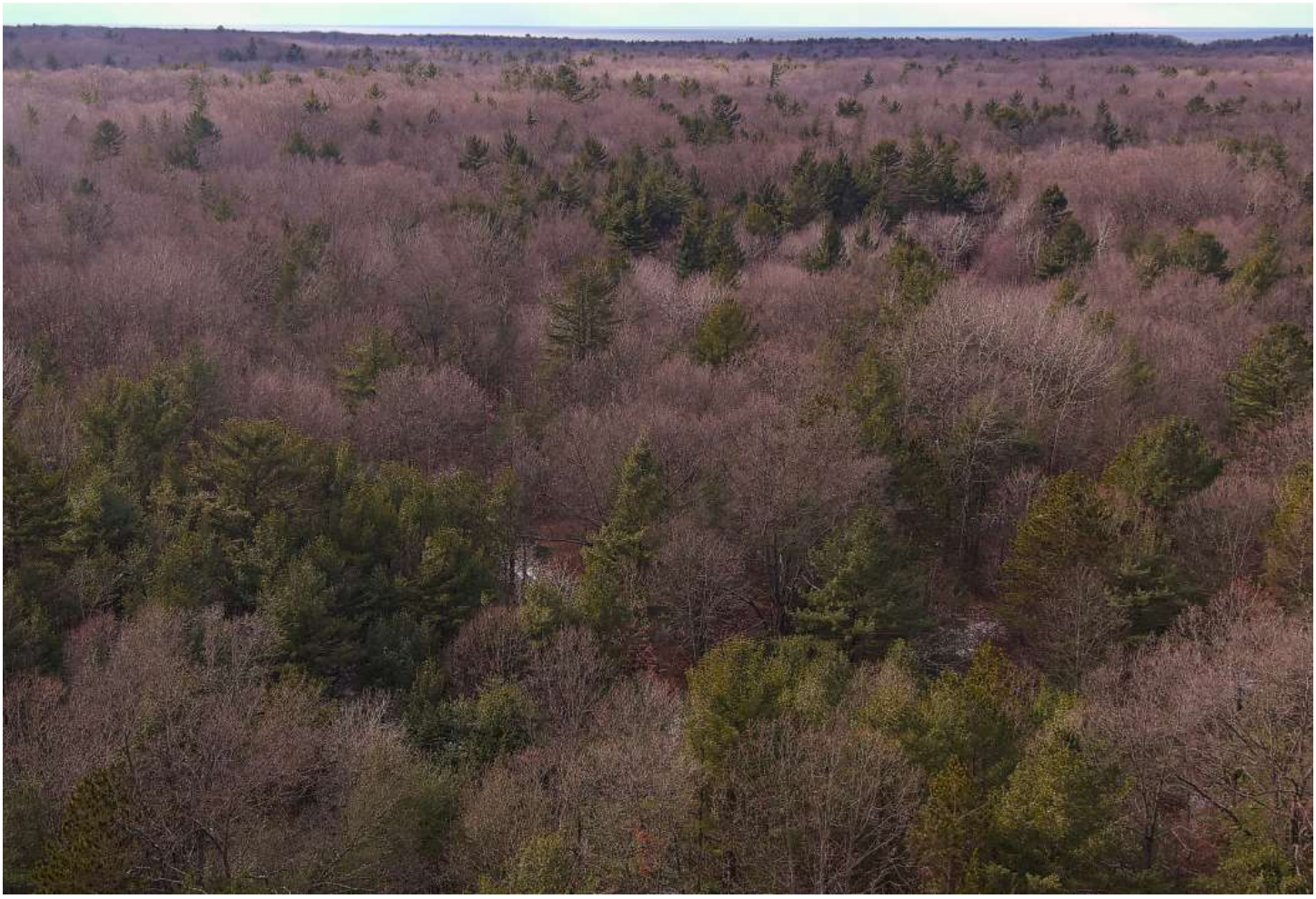
Figure 24. Proposed Priority Conservation Areas for Pentwater State Game Area. To prevent habitat fragmentation, protect ecological integrity of the highest quality forests, limit impacts to wetlands, and protect populations of rare species, we suggest that land managers establish management goals based on improving ecological integrity within the Priority Conservation Areas through the treatment of invasive species, application of prescribed fire, and implementing forestry actions that avoid negatively impacting soils and maintain long-lived canopy species.

proposed PCAs: 1) documented high-quality natural communities with an added 50 m buffer to minimize fragmentation; 2) areas that provide critical habitat for rare species; 3) wetlands that provide important ecosystem services, and 4) the oldest and largest examples of forest that do not meet MNFI standards for inclusion as natural communities but provide important habitat or ecosystem services such as protecting wetland health, carbon sequestration, and flood mitigation.

During the Integrated Inventory process, we documented two high-quality forested communities. Pentwater Woods is an especially large example of dry-mesic northern forest for this part of the state. It has local pockets of old-growth trees, it is adjacent to some of the wet-mesic prairie openings, and it supports the population of eastern whip-poor-will (*Antrostomus vociferus*, State Threatened). Watson Creek Woods is a mesic northern forest, though much smaller and relatively degraded, it provides habitat for land snails and protects water quality of Watson Creek. Both forests are much richer floristically than surrounding areas that have been recently logged and consequently have more invasive species. Protecting these forests and surrounding stands from logging is a top recommendation.

As shown in our land-use index (Figure 7, p. 8), Pentwater SGA is relatively unfragmented compared to the surrounding landscape. Landscape fragmentation is the process by which natural habitats are divided into smaller, isolated fragments due to agriculture, urbanization, and infrastructure development. Fragmentation reduces the size and quality of suitable habitat, which can lead to the loss of rare species that require specific habitat conditions. The process isolates populations of rare species by eliminating connectivity between areas of suitable habitats, which can impede the movement of animals and plants and disrupt important ecological processes such as pollination and seed dispersal thereby limiting gene flow.

Local population extinctions within fragments are accelerated by reduced habitat and population size. Within fragmented landscapes, herptile population viability and diversity are reduced by the prevalence of mesopredators (e.g., raccoons, skunks, and opossums). Numerous neotropical migrant songbirds are dependent on interior forest habitat and are highly susceptible to nest parasitism and predation (Robinson et al. 1995, Heilman et al. 2002). Native plant diversity within forested fragments is threatened by low seedling survivorship, infrequent seed



Pentwater State Game Area features extensive areas of mature, unfragmented forest, similar to historic conditions. Preventing fragmentation around these forests is a top conservation priority Photo by J.M. Lincoln.

dispersal, high levels of herbivory, and growing prevalence of invasive species and native weeds, which thrive along the increasing edges and disperse throughout fragmented landscapes along roads and trails (Brosofske et al. 2001, Heilman et al. 2002, Hewitt and Kellman 2004).

Remaining unfragmented natural spaces are becoming increasingly important to populations of rare species because of the scarcity of large blocks of unfragmented habitat and the continually increasing pressures from development. Providing suitable habitat and maintaining connectivity among and between wetland and upland habitats could make populations of herptiles more resilient to local habitat disruptions and improve their long-term viability. Natural spaces such as Pentwater SGA serve as important refuges for species that are struggling to survive in the fragmented landscape. Protecting and restoring natural habitats and promoting connectivity between them are essential for maintaining healthy ecosystems, conserving local native biodiversity, and building resilience in the face of accelerating development and a changing climate.

As part of a holistic approach to improving conditions of ecosystems and rare species habitat, we suggest avoiding clearcutting forests within the PCAs. Additionally, avoiding timber harvests on steep slopes will protect water quality and limit erosion. Management objectives for priority upland forests within the PCA should avoid implementing intensive timber harvest in and around wetlands to protect aquatic systems and limit forest fragmentation around the highest quality forests to most effectively protect native biodiversity

The dry-mesic northern forest in Pentwater SGA provides valuable habitat for many species. The importance of these forests for migratory birds is amplified by the proximity to Lake Michigan. Many migrating birds follow the lakeshore and seek areas of extensive, unfragmented forest to rest and forage. In addition, preventing fragmentation of mature forest blocks within the game area would encourage forest-interior species to nest. Nest parasites such as cowbirds thrive in fragmented landscapes and reduce the reproductive success of forest-breeding songbirds through nest parasitism (Robinson et al. 1995). Efforts to reduce forest fragmentation (i.e. edge habitat) can lessen brown-headed cowbird nest parasitism. While we did not document red-shouldered hawk nests, four birds responded to our playbacks during surveys within the game area in 2022. Two of the birds that responded to playback did so from private land adjacent to large, forested areas on the game area and they were likely responding from a nest. Red-shouldered hawks require large blocks of forest with adjacent wetlands and their habitat requirements are abundant throughout the identified PCAs.

Clearcuts result in a simplified forest structure with reduced composition. While this early successional habitat is beneficial for several game species, our management recommendations center around protecting the oldest forests of the game area from this type of fragmentation. Photo by J.M. Lincoln.

Land snails play an important role in the decomposition process by consuming decaying plant matter, recycling nutrients back into the soil. They also serve as a food source for birds, amphibians, and small mammals, making them a component part of the food chain. They are also indicators of environmental health due to their sensitivity to habitat changes. As low-vagility organisms that cannot escape rapid alterations to their environment, the "survive where you are" life strategy is necessary for the survival of land snails (Coppolino 2010). Although land snails are equipped with multiple adaptations for survival, habitat alterations such as logging are a serious threat to these slowly moving and microclimate sensitive species (Hyman 1967). To protect these ecologically important invertebrates, intensive forestry operations should be minimized in areas where rare snails were documented and where high snail species richness were observed.

Protecting Wetlands

There are numerous high-quality wetlands in Pentwater. These wetlands function as valuable for various wildlife, including Blanding's turtles. In addition, these wetlands provide numerous ecosystem services including water filtration, pollinator habitat, recreation, coastal shoreline buffering, flood protection, and nutrient cycling. Maintaining the quality of wetlands is critical for meeting the needs of all the life history stages of Blanding's turtles and providing habitat for a diversity of amphibian and reptile species occurring within the Pentwater SGA. Relative to uplands, these features also contribute disproportionately to ecosystem services such as protecting water quality and nutrient cycling. Because of the value of wetlands, we recommend managers focus on protecting and stabilizing wetland systems by limiting logging and heavy equipment within PCAs, especially avoiding forested areas along the slopes

The Great Lakes marsh is a prevalent feature of Pentwater State Game Area. We suggest minimizing fragmentation and preventing future disruptions by avoiding logging on the slopes along the Great Lakes marsh. Photo by J.M. Lincoln.

adjacent to Pentwater Lake and Pentwater River; protecting areas around the prairie and intermittent wetland openings; and avoiding damage to vernal pools throughout the game area.

The structure and processes of riparian ecosystems are determined by their interface with adjacent ecosystems (Tepley et al. 2004). The biodiversity refugia potential of riparian corridors within fragmented landscapes can be predicted based on width and contiguity of the natural cover (Goforth et al. 2002). Wider, more contiguous riparian corridors will provide the greatest benefits to long-term biodiversity conservation in fragmented landscapes (Goforth et al. 2002). We therefore stress the importance of minimizing fragmentation along the slopes of Pentwater Lake and Pentwater River.

Adjacent land use can negatively impact stream habitat and native mussel species. Increases in sedimentation or sediment load from timber harvest can lead to changes in abundance of invertebrates (Noel et al. 1986, Brown et al. 1997) and fish, including fish species that rare mussels rely on as hosts (Broadmeadow and Nisbet 2004, Nislow and Lowe 2006). Native mussels are intolerant of high levels of siltation. Changes in the amount of instream coarse woody debris caused by timber harvest can impact stream habitat (Smokorowski and Pratt 2007) and aquatic animal communities (Bilby and Ward 1991). Maintaining vegetated riparian buffers along streams is a common and important practice to mitigate impacts to aquatic species and ecosystems (Olson et al. 2007). Allowing for naturally vegetated buffers of 100 m or more from rivers, streams, headwaters, ponds, and lakes can help to minimize impacts of timber harvest on native mussels. Due to the downstream cumulative effect of river ecosystems, buffers protecting headwaters and smaller river habitats contribute to the maintenance of habitat quality in the entire waterway downstream of these areas. This is also outlined in the DNR's Master Plan for the game area: to provide sustainable populations of wood ducks by not implement forest management activities within 100 ft of the floodplains of North Branch of the Pentwater River, Pentwater River, and along Watson Creek (Goal II, Action 1).

The causeway was present in 1938, though it is unclear how it may have altered the Great Lakes marsh. Fluctuating lake levels, nutrient inputs from agricultural operations up stream, and invasive species have all influenced the condition of the marsh. Photo by J.M. Lincoln.

The game area supports additional wetland types that are both rare and in excellent condition. Wet-mesic sand prairies are imperiled within Michigan. The intermittent wetlands are especially diverse and in unusually good condition compared to examples of the community type in most of southern Michigan. The intermittent wetlands provide important habitat for sustainable populations of wood ducks and helps satisfy a goal of the DNR's Master Plan for Pentwater SGA to maintain quality emergent wetlands (Goal II, Objective B). We suggest avoiding anything that might damage these areas by altering their hydrology, particularly preventing off-road vehicles (ORVs) from degrading them, redirecting unofficial trails that may be developed near them, preventing logging in the stands surrounding the wetlands, and protecting areas of saturated soils in adjacent stands from heavy equipment. These actions may help prevent invasive species infestations but also prevent alterations to hydrology that can be extremely disruptive to such wetlands. Ideally, the portions of Jackson Rd and 60th Ave that bisect the game area near the prairie openings would be closed to limit risk from ORVs. We also suggest managers limit fragmentation around the southwest portion of the game area in the forests that surround the intermittent wetlands.

These forests support mature trees, extensive zones of saturated soils, with vernal pools, small isolated swamps, and populations of Blanding's turtles. Blanding's turtle is the only rare herptile species that has been documented in the Pentwater SGA and several individuals were found in the wetlands of the southwest part of the game area. Although the Blanding's turtle is regularly observed in Michigan, the species has declined throughout its range and is being evaluated by the U.S. Fish and Wildlife Service for federal listing. Blanding's turtles are primarily aquatic and spend most of their time in wetlands. They utilize a variety of clean, shallow wetlands with ample submerged vegetation and soft organic substrates. Blanding's turtles require core or resident wetlands; surrounding wetland, aquatic, and terrestrial habitats for foraging, thermoregulation, refugia, and nesting (up to 1.2 mi/2 km from core wetlands); and suitable habitat between these areas so that turtles can safely move among these areas (Congdon et al. 2011, King et al. 2013). Blanding's turtles also tend to exhibit high site fidelity, with individual turtles often utilizing the same wetlands, nesting areas, and overwintering years over many years (Ross and Anderson 1990, Congdon et al. 2011).

Vernal pools in the southwestern portion of the game area provide habitat for Blanding's turtles and numerous other species. Photo by J.M. Lincoln.

Protecting vernal pools will also help maintain important habitats for wood ducks, Blanding's turtles, and other amphibians and reptiles in the game area. Vernal pools are small, shallow, seasonally flooded wetlands that are typically wet in the spring and dry up or drawn down significantly by late summer/early fall (Colburn 2004, Calhoun and deMaynadier 2008). Since vernal pools dry up and are not connected to permanent waterbodies, they lack fish predators and provide critical breeding habitat for a number of invertebrate and amphibian species resulting in a unique and diverse assemblage of animal species (Colburn 2004, Calhoun and deMaynadier 2008). In addition to providing important habitat for wildlife, vernal pools provide ecosystem services in the form of energy and nutrient cycling, water storage and infiltration, and groundwater recharge. These ecosystem services provided by vernal pools help maintain healthy forests (Colburn 2004, Calhoun and deMaynadier 2008).

Continuing Stewardship

The DNR currently has many ongoing stewardship projects at Pentwater SGA, and these recommendations are intended to support these efforts by providing a prioritization framework based on conserving native biodiversity. Our top recommendation is to focus ecosystem stewardship efforts in the highest quality natural communities within the PCAs. Future stewardship actions will ideally include continuing to treat invasive species and tree diseases; directing trails to minimize impacts within the highest quality natural communities; continuing to apply prescribed fires; and developing partnerships to help with the prioritized goals.

Invasive Species Management

Monitoring wetlands and treating invasive plant species is a goal of the WLD's master plan for Pentwater SGA. We support this goal and encourage a multi-faceted approach to invasive species control. It is critical to maintain the integrity of the landscape

Treatment of invasive species within the Great Lakes marsh has the potential to impact native vegetation that persists. On the left is a sedge meadow dominated by native species. On the right, a wall of non-native cat-tail. It is unclear how best to manage the issue of invasive species within the marsh. Photo by J.M. Lincoln.

surrounding the high-quality natural areas. Initial treatment of invasive species should be focused within the highest quality wetlands. In order of priority, we recommend surveying for and treating reed canary grass in the prairies and intermittent wetlands, treating invasive shrubs in Watson Creek Woods, and evaluating potential approaches to treating invasive species in the Great Lakes marsh.

Small populations of newly establishing invasive species should be removed as rapidly as possible before they infest additional areas. The wet-mesic sand prairie openings are the rarest community type in Pentwater SGA and eliminating invasive species from these openings, particularly reed canary grass, is a top priority. Likewise, the intermittent wetlands are in excellent to good condition and have nascent populations of reed canary grass and are therefore priority areas for targeting invasive species control.

The Great Lakes Marsh has been substantially altered by invasive species since the marsh was first documented in 1989. There are likely many contributing factors to the ongoing degradation but the dramatic lake level rise in the late 2010s caused most of the marsh to flood and now non-native invasive species now nearly totally dominate the wetland. Their treatment will be complex, expensive, and introduce a substantial risk of collateral damage to native plants. While treating invasive species in the marsh is a worthy management objective, there will need to be constant reevaluation of priorities based on resources and feasibility of long-term control. There is excellent habitat for wild rice throughout the marsh and the species may have been present historically. We recommend working with local Tribes to evaluate the site potential for reintroduction as part of the process to restore the marsh.

In upland areas where timber harvest is going to be implemented, we recommend treating invasive species in forests before modifying the canopy structure especially where invasive shrubs are prevalent and threaten to outcompete native vegetation following canopy release. The increase of invasive species following logging operations can decrease native biodiversity, forest productivity, and water and soil quality (Pimentel et al. 2000). Similar to hydrologic disruptions facilitating invasion of wetlands, timber harvest in fragmented landscapes can significantly increase populations of invasive species, with autumn olive, multiflora rose, Japanese barberry, and common privet as already problematic in the game area. Forest management in the absence of addressing invasive species can detrimentally affect regenerating forest ecosystems.

In the past, autumn olive, multiflora rose, and other non-native species now understood to be highly invasive were historically planted on game areas because of a perceived benefit to wildlife. However, the negative impacts of these invasive shrubs have proven to be more detrimental than any potential benefits. To reduce the risk of introducing problematic

Reed canary grass along the southern edge of Pentwater Pond intermittent wetland. Photo by J.M. Lincoln.

species in the future, we recommend the DNR immediately instate a policy to plant only species known to be native to the region, particularly focusing on Michigan genotypes when available.

Treating invasive species is difficult and expensive, and severe infestations can take several years to control. Treatments should be implemented by someone trained on the identification of rare species and the location of the populations of rare species should be clearly communicated prior to control. Control measures should be enacted by someone familiar with applying herbicides in sensitive areas and wetlands. Partnerships with organizations such as local Cooperative Invasive Species Management Area (CISMA) will be important for reducing existing populations and addressing new populations within the game area and in nearby natural areas. It may be possible to develop a stewardship taskforce combining resources from multiple organizations from the DNR, local municipalities, West Michigan CISMA, and the Little River Band of Ottawa Indians to treat invasive species and address other stewardship concerns. Considering the historic occupation of this area by Indigenous peoples, the abundance of habitat for wild rice, and the importance of partnerships for long-term success, this seems like an ideal area to apply such a model.

Applying Prescribed Fire

The ecological benefits of returning fire to landscapes historically dominated by fire-dependent ecosystems are evident. Fire is a critical management tool for maintaining upland forests in the game area. There is archeological evidence that Indigenous Peoples have occupied this area for centuries (Quimby 1968). Though it is uncertain when, where, and how Indigenous Peoples utilized the area that is now Pentwater SGA, the propensity of pyrogenic species, the proximity to the lakeshore, and historical accounts, suggest a history of at least periodic Indigenous occupancy and application of cultural fire.

Red pine is especially dependent on the application of fire and has a unique relationship with Indigenous cultural fire. Red pine scars distinctively after fires, recording the time, season, and frequency of fires. Both living trees and old stumps can be used to establish a fire history for a particular site. We found one red pine stump in Pentwater Woods from a tree harvested in the late 1800s with a fire-scar that showed at least five fires. We also found several living trees with scars indicating five or more fires This evidence is consistent with the application of Indigenous cultural fire in other areas of the Great Lakes (Anderton 1999, Kipfmueller et al. 2017, and Kipfmueller et al. 2021). The presence of fire-

A recent prescribed burn in Pentwater Woods. Such low intensity, low severity fires cause almost no mortality of canopy trees but provide substantial benefits for the herbaceous composition of the natural communities where the burns are applied. Photo by A.P. Kortenhoven.

dependent prairies, extensive scarring on relatively young trees, and persistent stumps with scarring suggest that Indigenous cultural fire was a reoccurring and important disturbance factor in portions of the game area. The greatest concentration of fire-scarred trees occurs near the prairie openings indicating a potential connection between cultural fires and the prairie openings.

This area is colloquially referred to as the Pentwater Plains. It was sparsely canopied in the 1930s (Figure 6, p. 7) and many of the red pine in the surrounding forests are fire scarred, suggesting a high frequency of cultural fire 150 to 90 years ago. It is worth noting that Pentwater Plains is just east of a historic railroad, now 52nd Ave. Rail lines often were the cause of errant fires historically, and it is possible that at least some of the fires were due to this rail line. The Pentwater Historical Society had no evidence of either rail fires or Indigenous fires in this area, despite the clear evidence of scars on the tree. Further work is needed to elucidate the cause of the fires. Because of the extensive natural red pine and the concentration of wet-mesic sand prairies, this portion of the game area is our highest priority for burning regardless of the cause of historic fires. We recommend that managers continue applying prescribed fire in this area.

Fire is beneficial to many rare taxa. Pentwater Woods provides habitat for common nighthawks and eastern-whip-poor-will. Managing these forests with fire will maintain natural openings critical to the nesting needs of these species. Recent prescribed fires have created an excellent patchwork of burned and non-burned areas that provide nesting and foraging habitat. Likewise, the population of the Great Plains spittlebug that we documented in the wet-mesic sand prairie EO, has likely benefited from recent burns which maintain prairie habitat and gradually expand the openings. Because pockets of suitable habitat are separated by closed-canopy forest, the population of spittlebug at Pentwater SGA is presumed to be small and potentially isolated to a single prairie opening. Our primary recommendation for avoiding local extinction of the spittlebug population is to continue applying prescribed fire to a broad area that connects and expands multiple prairie openings. Local migration to adjacent prairie openings within Pentwater SGA is unlikely without connecting habitat, particularly the prairie grasses which this species relies upon (i.e. big bluestem/ little bluestem).

MNFI has developed a model for assessing prescribed fire needs on state lands (Cohen et al. 2021). This model identifies fire-dependent ecosystems within Pentwater SGA that have the highest ecological need for fire management (Figure

A fire scar on a red pine in the northern portion of Pentwater Woods with evidence of at least five burns. Red pines uniquely record a site's fire history due to their ability withstand fire and heal over damaged bark. Each arrow points to an area where the tree healed over a fire scar. These burns likely happened early in the 20th century based on the age of the trees. A photo without arrows is in Appendix 11. Photo by J.M. Lincoln.

26). Resources for burning are limited and should be prioritized for targeted project areas. The area of dry-mesic northern forest surrounding the wet-mesic sand prairies is a top priority area for implementing prescribed burns and has already been included in prescribed burns by the DNR. Another priority area is the forest that surrounds Golden Intermittent Wetland in the southwest portion of the game area. We recommend consistent application of prescribed fire in these areas with the goals of reducing dominance of mesophytes like red maple in the subcanopy, increasing herbaceous vegetation, expanding ecotones for herptiles, improving habitat connectivity between prairie openings, and promoting recruitment of white oak and red pine.

Applying fire is complex and requires many considerations and we provide some general recommendations for managers. While prioritizing areas to apply prescribed fire, we encourage developing as large of a project areas as possible for including variable habitats and maximizing refugia; establishing permanent project boundaries that avoid ecotones and utilizing existing features such as trails and streams to function as burn breaks; prioritizing the consistent application of fire at a rate of approximately five to twenty years within priority areas; incorporating invasive species treatment before and after burns; applying burns of varying intensity and seasonality; applying slow-moving back burns or timing burns to avoid impacting rare herptiles; and allowing seedbank expression by not supplementing restoration sites with additional plant species until reevaluating sites after several burns.

As part of the effort to reintroduce fire to the landscape, we suggest the development of permanent project boundaries using existing features such as roads, trails, and the river that can act as burn breaks to facilitate burning across ecotones and avoiding creating new burn breaks near sensitive areas. Developing large, permanent burn units that

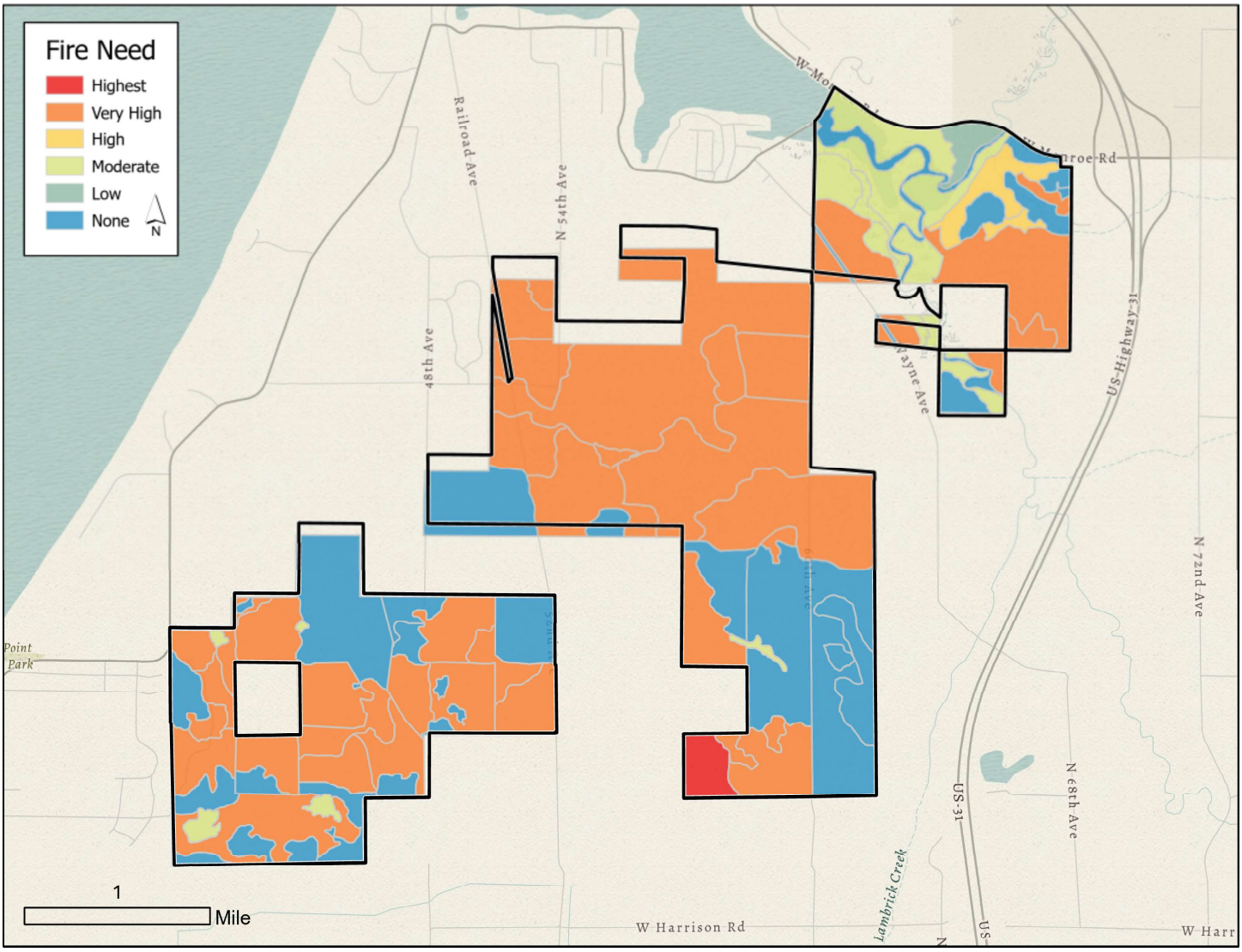


Figure 25. Prescribed fire needs assessment of Pentwater State Game Area. Most of the uplands within the game area have a “very high” or “high” need for prescribed fire. Some areas that have a fire need of “none” are forested wetlands with upland inclusions that could be included in prescribed burns.

include areas beyond the highest quality natural communities can also provide forests with various age classes, a goal outlined in Pentwater master plan and is often achieved through timber harvest alone. The consistent application of fire across large areas of forest will also help promote small forest openings 0.1 to 1 acre in size and is beneficial for brood rearing for grouse and turkey and provides forage for deer (Goal I, Objectives A and B). Managing age classes and openings with fire is an ideal approach to meeting objectives of the DNR's master plan for Pentwater because it minimizes risks of damaging high-quality natural areas with equipment, promotes habitat for focal species, and returns a critical natural disturbance to a large portion of the game area.

Blanding's turtles, and other turtle species nest in open uplands adjacent to occupied wetlands (Lee 2007, Lee and Monfils 2008, Harding and Mifsud 2017, Lincoln et al. 2019). This transition zone or ecotone between uplands and lowlands is often very diverse and commonly used by herptiles at different times of the year for thermoregulation and nesting. Thermal characteristics of nest sites are especially important as Blanding's turtles exhibit temperature-dependent sex determination, meaning clutch sex ratios are determined by temperatures (males: <82°F, females >86°F; Gutzke and Packard 1987). Burn units that include high-quality wetlands adjacent to the targeted upland areas can improve continuity between uplands and lowlands, or ecotones. Modern burn practices often exclude these ecotones from prescribed fires and even use the area for burn breaks. We urge managers to avoid this approach and prioritize the inclusion of ecotones in burns, particularly around the high-quality wet-mesic sand prairies and intermittent wetlands.

Maintaining continuity between suitable wetland and upland habitats that meet the needs of life history stages of herptiles is critical for conserving these species, particularly Blanding's turtle. Ditching

We recommend developing large burn units with variable habitats included in the burns. Forested areas surrounding the wet-mesic sand prairies supported seasonally wet zones with species found in the prairies. Including these forests in prescribed burns may express dormant pockets of prairie while providing refugia for fire-sensitive animals such as Blanding's turtles. Photo by J.M. Lincoln.

combined with the absence of fires in many wetlands causes ecotones to convert from diverse, open transition areas to dense shrub thickets that function as a boundary between wetland and upland. These areas become less useful for thermoregulation of herptiles. Because the gradient between upland and wetland was historically more open and critical for many species, we recommend continuing to focus on including these transition areas in prescribed burns by designing burn units that have breaks away from the margins of wetlands.

Although prescribed fire typically improves the overall quality of habitat for many animal species, its impact on rare animals should be considered when planning a burn. Refugia, or unburned areas, are critical if prescribed burning needs to occur during spring and early summer. We suggest burning relatively large areas and striving for patchy burns by burning either when fuels are somewhat patchy or when weather conditions will not support hot, unbroken fire lines. Spacing out burns is beneficial for protecting populations of fire-sensitive species including Blanding's turtles, spittlebugs, and rare land snails.

Monitoring

New threats to native biodiversity and ecological integrity are constantly emerging. For that reason, we suggest continual ecological monitoring of Pentwater SGA. Specifically, we prioritize monitoring condition of natural communities, particularly impacts from trails and ORVs, populations of invasive species, and impacts from deer. We also suggest continual evaluation of populations of rare species, and assessment of the effectiveness of stewardship actions, especially following prescribed fire and the treatment of invasive species.

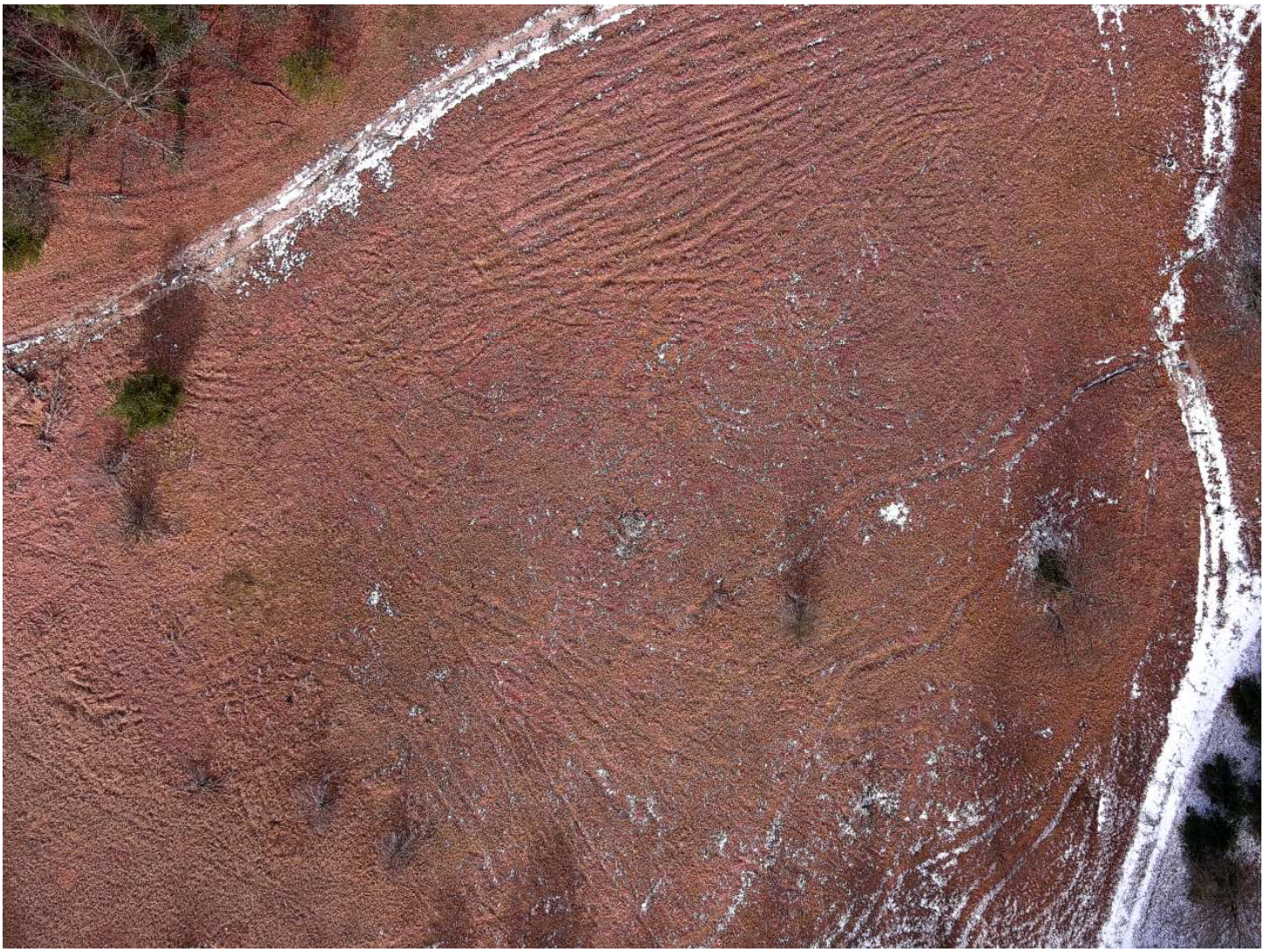
Because biodiversity is most easily and effectively protected by preventing high-quality sites from degrading, we suggest the implementation of continual monitoring within the high-quality natural communities and throughout actively managed areas to gauge the success of restoration activities. Invasive plants are much easier to eradicate when their populations are small and not yet well-established, and periodic early-detection surveys should be implemented to allow for the identification of invasive species that have yet to establish a stronghold within Pentwater SGA.

The ecotone is the boundary between different natural community types and can often be extremely diverse. In this case the ecotone is between wet-mesic sand prairie and dry-mesic northern forest. With repeated application of fire, this boundary becomes less stark and more useful for reptiles which use this habitat for thermoregulation and nesting. One of our top recommendations is to avoid putting burn breaks in the ecotones of wetlands and develop large burn units that include multiple habitat types so that the ecotones can expand overtime. Photo by J.M. Lincoln.

There are several roads and trails throughout the game area. While many of these are low-impact, do not intersect sensitive wetlands, and pose little threat, some of the roads increase ORV access to important natural communities. Damage from ORVs appears to be increasing and has been observed in several of the prairie openings. The proximity to Silver Lake State Park introduces a substantial risk to use from ORVs and we urge managers to monitor changes in use of trails and attempt to limit new trails, redirect trails away from wetlands, and close existing roads through the most sensitive portions of the game area.

The overabundance of white-tailed deer in the game area and in the surrounding landscape is having deleterious impacts on the composition of natural communities and habitat for rare species. The overabundance of deer has a direct negative impact on many plant species due to over browsing and indirect effects such as the facilitation of invasive plant species (Augustine and Decalesta 2003, Knight et al. 2009, Frerker et al. 2014). Natural communities are at risk of becoming functionally extinct as major components fail to recruit. The deer densities in this part of the state are extremely high and many forests do not have regenerate following timber harvests. The simplification of ecosystems and landscapes will continue to have lasting consequences. Therefore, we recommend investigating ways of lowering abundance of white-tail deer densities.

Many of the rare species are cryptic and difficult to detect and document in a single field season. Continuing targeted surveys will help determine if additional rare herptile species and SGCN occur in the game area, particularly gray ratsnakes, smooth greensnakes, northern ribbonsnakes, northern ring-necked snakes, eastern box turtles, and blue racers. Monitoring is especially valuable for clarifying the status, distribution, extent, and estimated viability of the Blanding's turtle populations within Pentwater SGA to inform an adaptive management approach of this species. Pentwater SGA contains suitable habitat for the rare insect species that were surveyed for, and these targets should be surveyed for periodically. Additionally, rare species documented



One of the openings of the wet-mesic sand prairie has been severely impacted by off-road vehicles. This poses extreme risk of introducing non-native invasive species. One of our top recommendations is to close nearby roads to limit the access to ORVs. Photo by J.M. Lincoln.

within the game area are facing serious decline across their range and may increase in abundance following active stewardship of priority natural areas. Limiting habitat fragmentation, reducing populations of invasive species, and applying prescribed fires can increase populations of rare insect species and changes following stewardship actions would be good to document to inform best management practices within the region.

Additional surveys and long-term monitoring of the Blanding's turtle population within and around the game area are needed to assess the status, distribution, viability, and management needs of this population. Road mortality poses a substantial threat to amphibian and reptile populations (Rudolph et al. 1999, Steen et al. 2006, Shepard et al. 2008). Road mortality can be mediated by installing appropriate signage and installing barrier fencing along high-use areas (Ontario Ministry of Natural Resources and Forestry 2016). Turtle nest predation rates in highly fragmented landscapes and anthropogenically disturbed habitats can be very high (Lee 2007, Lee and Monfils 2008, Lincoln et al. 2019). Suitable nesting habitats, especially those that are safe from nest predators, may be limited in the Pentwater SGA given the level of habitat fragmentation and disturbance within and adjacent to the game area. Control of mesopredators (e.g., raccoons) around nesting areas, particularly during the turtle nesting season, would help reduce predation of turtle nests and enhance reproductive success and population recruitment but would need to be conducted over the long term to be effective. Other methods for reducing turtle nest predation also can be investigated (e.g., nest cages, electric fences/enclosures). Monitoring prior to and after implementation of management actions is critical for ensuring their effectiveness.

While we did not locate the federally endangered Hine's emerald dragonfly during the Watson Creek survey, we documented suitable larval habitat within the zones of wet meadow along the stream. Numerous crayfish burrows were present in each

Deer-chewed stump sprouts on a red maple stump in a recent timber harvest. Deer herbivory following timber harvests is extreme within the game area. This overabundance of deer is dramatically altering the successional trajectory of forests and poses a serious concern for biodiversity. Photo by J.M. Lincoln.

of the openings, which were characterized by a graminoid dominated groundcover. Hine's emerald dragonfly may be utilizing these burrows as larval refuge and a follow-up study using a bilge pump to clear a subset of the burrows is recommended. Considering recent discoveries of Hine's emerald dragonfly within 2 miles of this site, it's possible the species persists at Pentwater SGA.

Continual monitoring and consideration of land snails in management activities will allow Pentwater SGA to maintain its diverse land snail community. Land snail populations are poorly studied and the addition of these two populations of median striate in Pentwater SGA helps clarify the distribution of this species throughout the Midwest where the conservation status of the species is largely unknown. During land snail surveys, we documented carved glyph (*Glyphyalinia indentata*, vulnerable (S3) in Ontario), small spot (*Punctum minutissimum*, imperiled (S2) Indiana), and black striate (*Striatura ferrea*, vulnerable (S3) in Minnesota and Ontario and imperiled (S2) in Wisconsin). The conservation status of these species have not been assessed in Michigan and the populations at Pentwater SGA are important for determining their conservation status. Introduced snail species can become a threat to local land snail populations by competing for microhabitat space and food resources (Robinson 1999). To prevent the introduction of non-native snails, care should be taken to properly clean boots, vehicles, and equipment that enter natural areas, including removing mud and vegetation that may contain snail propagules.

We also recommend investigating removing barriers along the Pentwater river to improve connectivity of

MNFI Entomologist David Cuthrell during insect surveys at Pentwater SGA. We suggest continuing periodic surveys for Hine's emerald dragonfly, particularly along Watson Creek. Photo by L.M. Rowe.

populations of mussels and fish. Alteration of stream flow with dams or other in-stream structures can lead to scouring of substrates used by mussels and should be avoided. Poor stream crossings, such as culverts that are too small or that are perched above stream water level, can also interfere with fish passage. Native mussels rely on transport by fish hosts while in the larval stage. These fish hosts allow for mussel migration to new habitats and transportation of between mussel populations. Barriers to fish passage between mussel populations can cause negative impacts to mussels from inbreeding and genetic isolation of populations (Watters 1996, Haag 2012).

The effects of fire will need to be carefully monitored, and plans should be adjusted based on the response of vegetation. Because fire affects the plant species that are growing at the time of application, varying the timing of the fires will need to be carefully considered. The exact seasonality, frequency, and conditions under which burns take place should be continually evaluated by local experts familiar with the site and the rare species that occupy it. Periodic surveys would also provide an opportunity to monitor the effects of management actions on these and other species of management interest.

Pentwater SGA Wildlife Biologist Pete Kailing examining a large eastern hemlock following a prescribed burn. Photo by J.M. Lincoln.

CONCLUSIONS

Game areas are important for supporting biodiversity, promoting ecological resilience, maintaining ecological integrity, and providing ecosystem services. In this report, scientists from Michigan Natural Features Inventory provided detailed information about several important high-quality natural communities and populations of rare species documented during surveys in Pentwater SGA. To maintain the game area's contribution to biodiversity protection, resilience, ecological integrity, and ecosystem services, we recommend that managers prioritize actions around sustaining the unique natural communities and populations of rare species by minimizing fragmentation around the highest quality forests and wetlands; continuing to control invasive species within the highest quality wetlands; applying prescribed fire to priority areas of dry-mesic northern forest and wet-mesic sand prairie; and monitoring populations of rare taxa, invasive species, and the impacts of stewardship actions.

Pentwater Game Area may be relatively small and lack the abundance of rare species compared to other game areas, but it plays an important role in preserving West Michigan's biodiversity. The Great Lakes marsh remains a vital habitat for rare birds, migratory waterfowl, spawning habitat for several fish species, and contributes to water quality of Pentwater Lake, despite being degraded by invasive species. The intermittent wetlands documented in the game area support populations of Blanding's turtle, waterthread pondweed, and Virginia meadow beauty. Wet-mesic sand prairie is recognized as an imperiled community type in Michigan and the site in Pentwater SGA is the first of its kind to be documented in Oceana County and supports a population of Great plains spittlebug – well outside of its core range in Texas and Oklahoma.

Pentwater SGA also supports the largest dry-mesic northern forest documented within Oceana County or any of the surrounding counties, providing critical habitat for eastern whip-poor-wills and birds migrating along the lakeshore. Portions of this forest support old-growth trees and it has been included in recent prescribed burns. Thanks to the successful reintroduction of fire, there is natural red pine regeneration, despite regionwide challenges to reproduction of this species. This reinforces the importance of fire as a management tool in maintaining healthy ecosystems and the importance of continuing to apply fire for maintenance of habitat.

This report emphasizes the compatibility between the Wildlife Division's charge to support game species and managing for ecosystem integrity and rare species. Pentwater SGA stands out as a place where Michigan's citizens can enjoy hunting, nature-based recreation, and the experience of intact, high-quality natural communities. Partnering with other conservation organizations will be essential to protect this natural heritage for future generations. By following the recommendations outlined in this report, the ecological and recreational values of this unique landscape can be safeguarded.

Extensive, unfragmented forests are relatively prevalent in Pentwater SGA but increasingly rare across southern Michigan. Photo by J.M. Lincoln

The Great Lakes marsh of Pentwater State Game Area provides habitat for numerous rare species and offer important ecosystem services such as improving water quality, habitat for fish and waterfowl, and carbon sequestration. Despite the prevalence of invasive species, the marsh harbors important native biodiversity and provides Michigan residents important access to fishing and recreation and improves the water quality of Pentwater Lake and the local shoreline along Lake Michigan. Photos by J.M. Lincoln.

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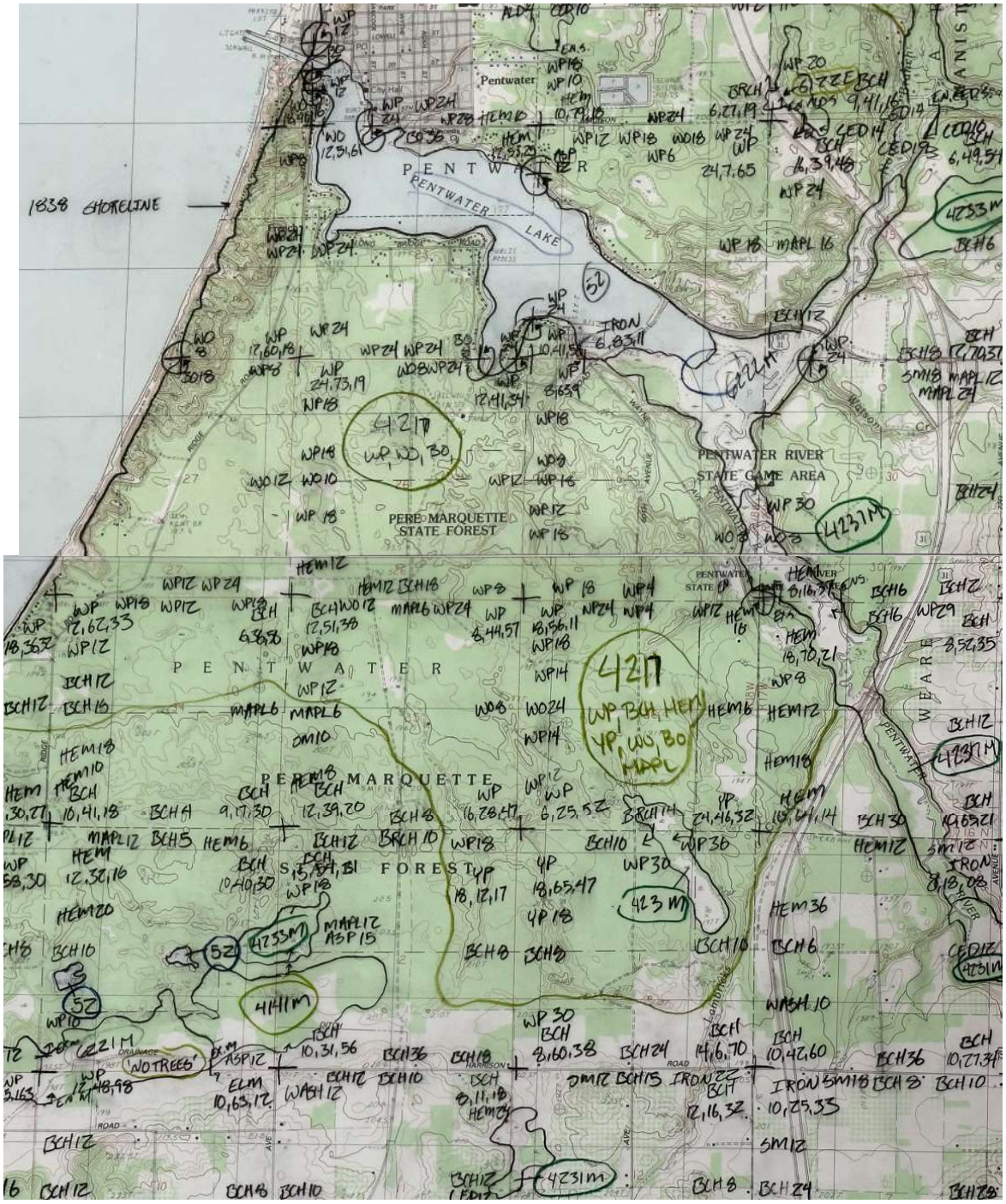
APPENDICES

Appendix 1. Notes from the General Land Office Surveyor John Mullett, transcribed on to mylar topographic maps. These notes from the 1838 surveys and maps serve as the basis for the circa-1800 vegetation maps.



Appendix 2. 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.

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

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

G? = incomplete data.

STATE RANKS

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

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

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

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

S5 = common and widespread in the state.

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

S? = incomplete data.

Appendix 3. Floristic Quality Assessment for Pentwater Bog (EO ID 25389, pg 25).

Conservatism-Based Metrics:

Total Mean C:	5.8
Native Mean C:	5.8
Total FQI:	22.5
Native FQI:	22.5
Adjusted FQI:	58
% C value 0:	0
% C value 1-3:	20
% C value 4-6:	46.7
% C value 7-10:	33.3
Native Tree Mean C:	5
Native Shrub Mean C:	6.3
Native Herbaceous Mean C:	6

Physiognomy Metrics:

Tree:	4	26.70%
Shrub:	4	26.70%
Vine:	0	0%
Forb:	2	13.30%
Grass:	1	6.70%
Sedge:	3	20%
Rush:	0	0%
Fern:	1	6.70%
Bryophyte:	0	0%

Species Richness:

Total Species:	15	
Native Species:	15	100%
Non-native Species:	0	0%

Duration Metrics:

Annual:	0	0%
Perennial:	15	100%
Biennial:	0	0%
Native Annual:	0	0%
Native Perennial:	15	100%
Native Biennial:	0	0%

Species Wetness:

Mean Wetness:	-2.3
Native Mean Wetness:	-2.3

Appendix 3 (Continued). Floristic Quality Assessment for Pentwater Bog (EO ID 25389, pg 25).

Scientific Name	Common Name	Acronym	Native?	C	W	Physiognomy
Aronia prunifolia	chokeberry	AROPRU	native	5	-3	shrub
Betula papyrifera	paper birch	BETPAP	native	2	3	tree
Calamagrostis canadensis	blue-joint	CALCAN	native	3	-5	grass
Chamaedaphne calyculata	leatherleaf	CHACAL	native	8	-5	shrub
Eleocharis palustris	spike-rush	ELEPAL	native	5	-5	sedge
Gaylussacia baccata	huckleberry	GAYBAC	native	7	3	shrub
Ilex verticillata	michigan holly	ILEVER	native	5	-3	shrub
Nyssa sylvatica	black-gum	NYSSYL	native	9	-3	tree
Pinus strobus	white pine	PINSTR	native	3	3	tree
Quercus velutina	black oak	QUEVEL	native	6	5	tree
Schoenoplectus acutus	hardstem bulrush	SCHACU	native	5	-5	sedge
Scirpus cyperinus	wool-grass	SCICYP	native	5	-5	sedge
Triadenum fraseri	marsh st. johns-wort	TRIFRA	native	6	-5	forb
Utricularia gibba	humped bladderwort	UTRGIB	native	8	-5	forb
Woodwardia virginica	virginia chain-fern	WOOVIR	native	10	-5	fern

Appendix 4. Floristic Quality Assessment for Pentwater Woods (EO ID 27471, pg 27).

Conservatism-Based Metrics:

Total Mean C:	4.9
Native Mean C:	5
Total FQI:	28.1
Native FQI:	28.3
Adjusted FQI:	49.2
% C value 0:	6.1
% C value 1-3:	6.1
% C value 4-6:	75.8
% C value 7-10:	12.1
Native Tree Mean C:	4.5
Native Shrub Mean C:	5.7
Native Herbaceous Mean C:	5.2

Species Richness:

Total Species:	33	
Native Species:	32	97%
Non-native Species:	1	3%

Species Wetness:

Mean Wetness:	3.2
Native Mean Wetness:	3.2

Physiognomy Metrics:

Tree:	12	36.40%
Shrub:	6	18.20%
Vine:	0	0%
Forb:	7	21.20%
Grass:	6	18.20%
Sedge:	1	3%
Rush:	0	0%
Fern:	1	3%
Bryophyte:	0	0%

Duration Metrics:

Annual:	1	3%
Perennial:	32	97%
Biennial:	0	0%
Native Annual:	1	3%
Native Perennial:	31	93.90%
Native Biennial:	0	0%

Appendix 4 (Continued). Floristic Quality Assessment for Pentwater Woods (EO ID 27471, pg 27).

Scientific Name	Common Name	Native?	C	W	Physiognomy
Acer rubrum	red maple	native	1	0	tree
Amelanchier arborea	juneberry	native	4	3	tree
Avenella flexuosa	hair grass	native	6	5	grass
Carex pensylvanica	sedge	native	4	5	sedge
Comptonia peregrina	sweetfern	native	6	5	shrub
Cypripedium acaule	pink lady-slipper; moccasin flower	native	5	-3	forb
Danthonia spicata	poverty grass; oatgrass	native	4	5	grass
Epigaea repens	trailing-arbutus	native	7	3	shrub
Fagus grandifolia	american beech	native	6	3	tree
Gaultheria procumbens	wintergreen	native	5	3	shrub
Gaylussacia baccata	huckleberry	native	7	3	shrub
Hamamelis virginiana	witch-hazel	native	5	3	shrub
Maianthemum canadense	canada mayflower	native	4	3	forb
Melampyrum lineare	cow-wheat	native	6	3	forb
Monotropa uniflora	indian-pipe	native	5	3	forb
Oryzopsis asperifolia	rough-leaved rice-grass	native	6	5	grass
Pinus banksiana	jack pine	native	5	3	tree
Pinus resinosa	red pine	native	6	3	tree
Pinus strobus	white pine	native	3	3	tree
Piptatherum pungens	rice-grass	native	9	5	grass
Piptochaetium avenaceum	black oatgrass	native	10	3	grass
Poa pratensis	**kentucky bluegrass**	**non-native**	**0**	**3**	**grass**
Polygonatum pubescens	downy solomon seal	native	5	5	forb
Populus grandidentata	big-tooth aspen	native	4	3	tree
Pteridium aquilinum	bracken fern	native	0	3	fern
Quercus alba	white oak	native	5	3	tree
Quercus ellipsoidalis	hills oak	native	4	5	tree
Quercus rubra	red oak	native	5	3	tree
Quercus velutina	black oak	native	6	5	tree
Sassafras albidum	sassafras	native	5	3	tree
Trientalis borealis	star-flower	native	5	0	forb
Vaccinium angustifolium	low sweet blueberry	native	4	3	shrub
Viola adunca	sand violet	native	4	3	forb

Appendix 5. Floristic Quality Assessment for Pentwater Great Lakes Marsh (EO ID 6116, pg 31).

Conservatism-Based Metrics:

Total Mean C:	3.7
Native Mean C:	4.5
Total FQI:	25.9
Native FQI:	28.5
Adjusted FQI:	40.7
% C value 0:	18.4
% C value 1-3:	22.4
% C value 4-6:	49
% C value 7-10:	10.2
Native Tree Mean C:	n/a
Native Shrub Mean C:	5
Native Herbaceous Mean C:	4.5

Species Richness:

Total Species:	49	
Native Species:	40	81.60%
Non-native Species:	9	18.40%

Species Wetness:

Mean Wetness:	-4
Native Mean Wetness:	-4.5

Physiognomy Metrics:

Tree:	0	0%
Shrub:	1	2%
Vine:	2	4.10%
Forb:	32	65.30%
Grass:	5	10.20%
Sedge:	8	16.30%
Rush:	0	0%
Fern:	1	2%
Bryophyte:	0	0%

Duration Metrics:

Annual:	5	10.20%
Perennial:	43	87.80%
Biennial:	1	2%
Native Annual:	4	8.20%
Native Perennial:	36	73.50%
Native Biennial:	0	0%

Appendix 5 (Continued). Floristic Quality Assessment for Pentwater Great Lakes Marsh (EO ID 6116, pg 31).

Scientific Name	Common Name	Native?	C	W	Physiognomy
Alnus incana	speckled alder	native	5	-3	shrub
Bidens cernua	nodding beggar-ticks	native	3	-5	forb
Calamagrostis canadensis	blue-joint	native	3	-5	grass
Caltha palustris	marsh-marigold	native	6	-5	forb
Carex aquatilis	sedge	native	7	-5	sedge
Carex lacustris	sedge	native	6	-5	sedge
Carex prairea	sedge	native	10	-3	sedge
Carex stipata	sedge	native	1	-5	sedge
Carex stricta	sedge	native	4	-5	sedge
Carex utriculata	sedge	native	5	-5	sedge
Ceratophyllum demersum	coontail	native	1	-5	forb
Cicuta bulbifera	water hemlock	native	5	-5	forb
Cirsium arvense	**canada thistle**	**non-native**	**0**	**3**	**forb**
Cirsium vulgare	**bull thistle**	**non-native**	**0**	**3**	**forb**
Elodea canadensis	common waterweed	native	1	-5	forb
Eupatorium perfoliatum	boneset	native	4	-3	forb
Galium asprellum	rough bedstraw	native	5	-5	vine
Glyceria striata	fowl manna grass	native	4	-5	grass
Heteranthera dubia	water star-grass	native	6	-5	forb
Hydrocharis morsus-ranae	**european frogs-bit**	**non-native**	**0**	**-5**	**forb**
Impatiens capensis	spotted touch-me-not	native	2	-3	forb
Iris versicolor	wild blue flag	native	5	-5	forb
Lemna minor	common duckweed	native	5	-5	forb
Lythrum salicaria	**purple loosestrife**	**non-native**	**0**	**-5**	**forb**
Mimulus ringens	monkey-flower	native	5	-5	forb
Myriophyllum sibiricum	spiked water-milfoil	native	10	-5	forb
Nuphar variegata	yellow pond-lily	native	7	-5	forb
Nymphaea odorata	sweet-scented waterlily	native	6	-5	forb
Persicaria amphibia	water smartweed	native	6	-5	forb
Phalaris canariensis	**canary grass**	**non-native**	**0**	**3**	**grass**
Phragmites australis var. australis	**reed**	**non-native**	**0**	**-3**	**grass**
Pilea fontana	bog clearweed	native	5	-3	forb
Poa palustris	fowl meadow grass	native	3	-3	grass
Pontederia cordata	pickerel-weed	native	8	-5	forb
Potamogeton berchtoldii	pondweed	native	4	-5	forb
Potamogeton zosteriformis	flat-stemmed pondweed	native	5	-5	forb
Ranunculus sceleratus	cursed crowfoot	native	1	-5	forb
Sagittaria latifolia	common arrowhead	native	4	-5	forb
Schoenoplectus acutus	hardstem bulrush	native	5	-5	sedge
Schoenoplectus tabernaemontani	softstem bulrush	native	4	-5	sedge
Solanum dulcamara	**bittersweet nightshade**	**non-native**	**0**	**0**	**vine**
Solidago uliginosa	bog goldenrod	native	4	-5	forb
Sparganium eurycarpum	common bur-reed	native	5	-5	forb
Spirodela polyrhiza	greater duckweed	native	6	-5	forb
Thelypteris palustris	marsh fern	native	2	-3	fern
Typha Ã—glauca	**hybrid cat-tail**	**non-native**	**0**	**-5**	**forb**
Typha angustifolia	**narrow-leaved cat-tail**	**non-native**	**0**	**-5**	**forb**
Typha latifolia	broad-leaved cat-tail	native	1	-5	forb
Urtica dioica	stinging nettle	native	1	0	forb

Appendix 6. Floristic Quality Assessment for Golden Intermittent Wetland (EO ID 26075, pg 35).

Conservatism-Based Metrics:

Total Mean C:	6
Native Mean C:	6.2
Total FQI:	34.5
Native FQI:	35.1
Adjusted FQI:	61.1
% C value 0:	3
% C value 1-3:	21.2
% C value 4-6:	27.3
% C value 7-10:	48.5
Native Tree Mean C:	1
Native Shrub Mean C:	6.7
Native Herbaceous Mean C:	6.4

Species Richness:

Total Species:	33	
Native Species:	32	97%
Non-native Species:	1	3%

Species Wetness:

Mean Wetness:	-3.9
Native Mean Wetness:	-4.1

Physiognomy Metrics:

Tree:	1	3%
Shrub:	3	9.10%
Vine:	0	0%
Forb:	10	30.30%
Grass:	7	21.20%
Sedge:	8	24.20%
Rush:	4	12.10%
Fern:	0	0%
Bryophyte:	0	0%

Duration Metrics:

Annual:	1	3%
Perennial:	32	97%
Biennial:	0	0%
Native Annual:	0	0%
Native Perennial:	32	97%
Native Biennial:	0	0%

Scientific Name	Common Name	Native?	C	W	Physiognomy
Acer rubrum	red maple	native	1	0	tree
Brasenia schreberi	water-shield	native	6	-5	forb
Calamagrostis canadensis	blue-joint	native	3	-5	grass
Carex intumescens	sedge	native	3	-3	sedge
Carex oligosperma	sedge	native	10	-5	sedge
Carex vesicaria	sedge	native	7	-5	sedge
Chamaedaphne calyculata	leatherleaf	native	8	-5	shrub
Dichanthelium implicatum	panic grass	native	3	0	grass
Dichanthelium lindheimeri	panic grass	native	8	-5	grass
Dulichium arundinaceum	three-way sedge	native	8	-5	sedge
Eleocharis elliptica	golden-seeded spike rush	native	6	-5	sedge
Eleocharis palustris	spike-rush	native	5	-5	sedge
Euthamia caroliniana	lakes flat-topped goldenrod	native	10	-3	forb
Glyceria canadensis	rattlesnake grass	native	8	-5	grass
Glyceria septentrionalis	floating manna grass	native	7	-5	grass
Hypericum boreale	northern st. johns-wort	native	5	-5	forb
Ilex mucronata	mountain holly	native	7	-5	shrub
Ilex verticillata	michigan holly	native	5	-3	shrub
Iris versicolor	wild blue flag	native	5	-5	forb
Juncus canadensis	canadian rush	native	6	-5	rush
Juncus dudleyi	dudleys rush	native	1	-3	rush
Juncus effusus	soft-stemmed rush	native	3	-5	rush
Juncus greenei	greenes rush	native	7	0	rush
Muhlenbergia uniflora	muhly grass	native	8	-5	grass
Phalaris canariensis	canary grass	non-native	0	3	grass
Potamogeton bicupulatus	waterthread pondweed	native	10	-5	forb
Potamogeton oakesianus	pondweed	native	10	-5	forb
Rhexia virginica	meadow-beauty	native	9	-5	forb
Rhynchospora capitellata	beak-rush	native	6	-5	sedge
Scirpus atrovirens	bulrush	native	3	-5	sedge
Symphyotrichum dumosum	bushy aster	native	7	0	forb
Triadenum fraseri	marsh st. johns-wort	native	6	-5	forb
Viola lanceolata	lance-leaved violet	native	8	-5	forb

Appendix 7. Floristic Quality Assessment for Pentwater Pond intermittent wetland (EO ID 26074, pg 38).

Conservatism-Based Metrics:

Total Mean C:	5.5
Native Mean C:	6
Total FQI:	31.6
Native FQI:	32.9
Adjusted FQI:	57.2
% C value 0:	9.1
% C value 1-3:	15.2
% C value 4-6:	30.3
% C value 7-10:	45.5
Native Tree Mean C:	n/a
Native Shrub Mean C:	6.8
Native Herbaceous Mean C:	5.9

Physiognomy Metrics:

Tree:	0	0%
Shrub:	4	12.10%
Vine:	0	0%
Forb:	11	33.30%
Grass:	6	18.20%
Sedge:	10	30.30%
Rush:	1	3%
Fern:	1	3%
Bryophyte:	0	0%

Species Richness:

Total Species:	33	
Native Species:	30	90.90%
Non-native Species:	3	9.10%

Duration Metrics:

Annual:	2	6.10%
Perennial:	31	93.90%
Biennial:	0	0%
Native Annual:	1	3%
Native Perennial:	29	87.90%
Native Biennial:	0	0%

Species Wetness:

Mean Wetness:	-4.1
Native Mean Wetness:	-4.6

Scientific Name	Common Name	Native?	C	W	Physiognomy
Agrostis stolonifera	**creeping bent**	**non-native**	**0**	**-3**	**grass**
Apocynum cannabinum	indian-hemp	native	3	0	forb
Brasenia schreberi	water-shield	native	6	-5	forb
Calamagrostis canadensis	blue-joint	native	3	-5	grass
Carex crinita	sedge	native	4	-5	sedge
Carex hystericina	sedge	native	2	-5	sedge
Carex vesicaria	sedge	native	7	-5	sedge
Cephalanthus occidentalis	buttonbush	native	7	-5	shrub
Chamaedaphne calyculata	leatherleaf	native	8	-5	shrub
Dichanthelium lindheimeri	panic grass	native	8	-5	grass
Drosera intermedia	spatulate-leaved sundew	native	8	-5	forb
Dulichium arundinaceum	three-way sedge	native	8	-5	sedge
Eleocharis acicularis	spike-rush	native	7	-5	sedge
Eleocharis elliptica	golden-seeded spike rush	native	6	-5	sedge
Eleocharis intermedia	spike-rush	native	7	-5	sedge
Eleocharis palustris	spike-rush	native	5	-5	sedge
Eupatorium perfoliatum	boneset	native	4	-3	forb
Glyceria canadensis	rattlesnake grass	native	8	-5	grass
Glyceria septentrionalis	floating manna grass	native	7	-5	grass
Hypericum boreale	northern st. johns-wort	native	5	-5	forb
Hypochaeris radicata	**cats-ear**	**non-native**	**0**	**3**	**forb**
Ilex mucronata	mountain holly	native	7	-5	shrub
Ilex verticillata	michigan holly	native	5	-3	shrub
Juncus dudleyi	dudleys rush	native	1	-3	rush
Nuphar variegata	yellow pond-lily	native	7	-5	forb
Phalaris canariensis	**canary grass**	**non-native**	**0**	**3**	**grass**
Potamogeton natans	pondweed	native	5	-5	forb
Rhexia virginica	meadow-beauty	native	9	-5	forb
Rhynchospora capitellata	beak-rush	native	6	-5	sedge
Scirpus atrovirens	bulrush	native	3	-5	sedge
Triadenum fraseri	marsh st. johns-wort	native	6	-5	forb
Viola lanceolata	lance-leaved violet	native	8	-5	forb
Woodwardia virginica	virginia chain-fern	native	10	-5	fern

Appendix 8. Floristic Quality Assessment for Watson Creek Woods (EO ID 27078, pg 41).

Conservatism-Based Metrics:

Total Mean C:	3.6
Native Mean C:	4
Total FQI:	30.3
Native FQI:	32
Adjusted FQI:	38
% C value 0:	12.7
% C value 1-3:	26.8
% C value 4-6:	53.5
% C value 7-10:	7
Native Tree Mean C:	4.1
Native Shrub Mean C:	4
Native Herbaceous Mean C:	4

Species Richness:

Total Species:	71	
Native Species:	64	90.10%
Non-native Species:	7	9.90%

Species Wetness:

Mean Wetness:	0.6
Native Mean Wetness:	0.5

Physiognomy Metrics:

Tree:	16	22.50%
Shrub:	11	15.50%
Vine:	2	2.80%
Forb:	19	26.80%
Grass:	4	5.60%
Sedge:	11	15.50%
Rush:	0	0%
Fern:	8	11.30%
Bryophyte:	0	0%

Duration Metrics:

Annual:	4	5.60%
Perennial:	67	94.40%
Biennial:	0	0%
Native Annual:	3	4.20%
Native Perennial:	61	85.90%
Native Biennial:	0	0%

Scientific Name	Common Name	Native?	C	W	Physiognomy
Acer rubrum	red maple	native	1	0	tree
Acer saccharum	sugar maple	native	5	3	tree
Alnus incana	speckled alder	native	5	-3	shrub
Amelanchier arborea	juneberry	native	4	3	tree
Arisaema triphyllum	jack-in-the-pulpit	native	5	0	forb
Athyrium filix-femina	lady fern	native	4	0	fern
Betula alleghaniensis	yellow birch	native	7	0	tree
Betula papyrifera	paper birch	native	2	3	tree
Carex arctata	sedge	native	3	5	sedge
Carex blanda	sedge	native	1	0	sedge
Carex cephaloidea	sedge	native	5	3	sedge
Carex crinita	sedge	native	4	-5	sedge
Carex gracillima	sedge	native	4	3	sedge
Carex intumescens	sedge	native	3	-3	sedge
Carex laxiflora	sedge	native	8	0	sedge
Carex pensylvanica	sedge	native	4	5	sedge
Carex scabrata	sedge	native	4	-5	sedge
Carex stipata	sedge	native	1	-5	sedge
Carex tenera	sedge	native	4	0	sedge
Chelone glabra	turtlehead	native	7	-5	forb
Circaea alpina	small enchanters-nightshade	native	4	-3	forb
Dryopteris intermedia	evergreen woodfern	native	5	0	fern
Elaeagnus umbellata	**autumn-olive**	**non-native**	**0**	**3**	**shrub**
Epifagus virginiana	beech-drops	native	10	5	forb

Appendix 8 (Continued). Floristic Quality Assessment for Watson Creek Woods (EO ID 27078, pg 41).

Scientific Name	Common Name	Native?	C	W	Physiognomy
Epipactis helleborine	**helleborine**	**non-native**	**0**	**0**	**forb**
Equisetum arvense	common horsetail	native	0	0	fern
Fagus grandifolia	american beech	native	6	3	tree
Fraxinus pennsylvanica	red ash	native	2	-3	tree
Geranium robertianum	herb robert	native	3	3	forb
Geum canadense	white avens	native	1	0	forb
Glyceria striata	fowl manna grass	native	4	-5	grass
Gymnocarpium dryopteris	oak fern	native	5	3	fern
Hamamelis virginiana	witch-hazel	native	5	3	shrub
Impatiens capensis	spotted touch-me-not	native	2	-3	forb
Ligustrum vulgare	**common privet**	**non-native**	**0**	**3**	**shrub**
Lindera benzoin	spicebush	native	7	-3	shrub
Maianthemum canadense	canada mayflower	native	4	3	forb
Mitchella repens	partridge-berry	native	5	3	forb
Nasturtium officinale	watercress	native	4	-5	forb
Onoclea sensibilis	sensitive fern	native	2	-3	fern
Oryzopsis asperifolia	rough-leaved rice-grass	native	6	5	grass
Osmunda cinnamomea	cinnamon fern	native	5	-3	fern
Ostrya virginiana	ironwood; hop-hornbeam	native	5	3	tree
Parthenocissus quinquefolia	virginia creeper	native	5	3	vine
Phalaris canariensis	**canary grass**	**non-native**	**0**	**3**	**grass**
Phytolacca americana	pokeweed	native	2	3	forb
Pinus resinosa	red pine	native	6	3	tree
Pinus strobus	white pine	native	3	3	tree
Poa palustris	fowl meadow grass	native	3	-3	grass
Polygonatum pubescens	downy solomon seal	native	5	5	forb
Populus grandidentata	big-tooth aspen	native	4	3	tree
Prunus virginiana	choke cherry	native	2	3	shrub
Pteridium aquilinum	bracken fern	native	0	3	fern
Quercus alba	white oak	native	5	3	tree
Quercus rubra	red oak	native	5	3	tree
Ranunculus hispidus	swamp buttercup	native	5	0	forb
Rosa multiflora	**multiflora rose**	**non-native**	**0**	**3**	**shrub**
Rubus allegheniensis	common blackberry	native	1	3	shrub
Rubus pubescens	dwarf raspberry	native	4	-3	shrub
Rubus strigosus	wild red raspberry	native	2	0	shrub
Rumex crispus	**curly dock**	**non-native**	**0**	**0**	**forb**
Solanum dulcamara	**bittersweet nightshade**	**non-native**	**0**	**0**	**vine**
Solidago caesia	bluestem goldenrod	native	6	3	forb
Solidago patula	swamp goldenrod	native	6	-5	forb
Symphyotrichum lateriflorum	calico aster	native	2	0	forb
Thelypteris noveboracensis	new york fern	native	5	0	fern
Thuja occidentalis	arbor vitae	native	4	-3	tree
Trientalis borealis	star-flower	native	5	0	forb
Tsuga canadensis	hemlock	native	5	3	tree
Ulmus americana	american elm	native	1	-3	tree
Viburnum acerifolium	maple-leaved viburnum	native	6	5	shrub

Appendix 9. Floristic Quality Assessment for Pentwater Prairies (EO ID 21677, pg 44).

Conservatism-Based Metrics:

Total Mean C:	4.4
Native Mean C:	4.9
Total FQI:	40.8
Native FQI:	43.3
Adjusted FQI:	46.7
% C value 0:	11.6
% C value 1-3:	19.8
% C value 4-6:	47.7
% C value 7-10:	20.9
Native Tree Mean C:	3.6
Native Shrub Mean C:	4.8
Native Herbaceous Mean C:	5.1

Species Richness:

Total Species:	86	
Native Species:	78	90.70%
Non-native Species:	8	9.30%

Species Wetness:

Mean Wetness:	0.3
Native Mean Wetness:	0

Physiognomy Metrics:

Tree:	7	8.10%
Shrub:	17	19.80%
Vine:	1	1.20%
Forb:	30	34.90%
Grass:	19	22.10%
Sedge:	8	9.30%
Rush:	2	2.30%
Fern:	2	2.30%
Bryophyte:	0	0%

Duration Metrics:

Annual:	5	5.80%
Perennial:	78	90.70%
Biennial:	3	3.50%
Native Annual:	3	3.50%
Native Perennial:	74	86%
Native Biennial:	1	1.20%

Scientific Name	Common Name	Native?	Physiognomy	C	W
Acer rubrum	red maple	native	tree	1	0
Agrostis scabra	ticklegrass	native	grass	4	0
Alnus incana	speckled alder	native	shrub	5	-3
Anaphalis margaritacea	pearly everlasting	native	forb	3	5
Andropogon gerardii	big bluestem	native	grass	5	0
Andropogon virginicus	broom-sedge	native	grass	4	3
Apocynum cannabinum	indian-hemp	native	forb	3	0
Arabidopsis lyrata	sand cress	native	forb	7	3
Arctostaphylos uva-ursi	bearberry	native	shrub	8	5
Asclepias incarnata	swamp milkweed	native	forb	6	-5
Asclepias syriaca	common milkweed	native	forb	1	5
Avenella flexuosa	hair grass	native	grass	6	5
Boehmeria cylindrica	false nettle	native	forb	5	-5
Calamagrostis canadensis	blue-joint	native	grass	3	-5
Carex buxbaumii	sedge	native	sedge	10	-5
Carex crinita	sedge	native	sedge	4	-5
Carex merritt-fernaldii	sedge	native	sedge	4	5
Carex pellita	sedge	native	sedge	2	-5
Carex stricta	sedge	native	sedge	4	-5
Carex tonsa	sedge	native	sedge	5	5
Centaurea stoebe	**spotted knapweed**	**non-native**	**forb**	**0**	**5**
Cephalanthus occidentalis	buttonbush	native	shrub	7	-5
Chamaedaphne calyculata	leatherleaf	native	shrub	8	-5
Clinopodium vulgare	wild-basil	native	forb	3	5
Comandra umbellata	bastard-toadflax	native	forb	5	3
Comptonia peregrina	sweetfern	native	shrub	6	5

Appendix 9 (Continued). Floristic Quality Assessment for Pentwater Prairies (EO ID 21677, pg 44).

Scientific Name	Common Name	Native?	Physiognomy	C	W
Cornus amomum	silky dogwood	native	shrub	2	-3
Danthonia spicata	poverty grass; oatgrass	native	grass	4	5
Dichanthelium boreale	northern panic grass	native	grass	7	0
Dichanthelium depauperatum	panic grass	native	grass	4	5
Dichanthelium lindheimeri	panic grass	native	grass	8	-5
Dichanthelium meridionale	mat panic grass	native	grass	7	5
Eleocharis elliptica	golden-seeded spike rush	native	sedge	6	-5
Festuca saximontana	fescue	native	grass	6	5
Frangula alnus	**glossy buckthorn**	**non-native**	**shrub**	**0**	**0**
Fraxinus pennsylvanica	red ash	native	tree	2	-3
Galium pilosum	hairy bedstraw	native	forb	6	5
Gaultheria procumbens	wintergreen	native	shrub	5	3
Gaylussacia baccata	huckleberry	native	shrub	7	3
Hieracium gronovii	hairy hawkweed	native	forb	5	5
Hieracium venosum	rattlesnake-weed	native	forb	6	5
Houstonia longifolia	long-leaved bluets	native	forb	6	5
Hypericum canadense	canadian st. johns-wort	native	forb	6	-3
Hypericum majus	larger canada st. johns-wort	native	forb	4	-3
Ilex verticillata	michigan holly	native	shrub	5	-3
Iris virginica	southern blue flag	native	forb	5	-5
Juncus canadensis	canadian rush	native	rush	6	-5
Juncus greenei	greenes rush	native	rush	7	0
Krigia virginica	dwarf dandelion	native	forb	4	5
Lechea mucronata	hairy pinweed	native	forb	5	5
Lycopus uniflorus	northern bugle weed	native	forb	2	-5
Mentha canadensis	wild mint	native	forb	3	-3
Nuttallanthus canadensis	blue toadflax	native	forb	8	5
Nyssa sylvatica	black-gum	native	tree	9	-3
Oenothera perennis	small sundrops	native	forb	5	0
Panicum flexile	panic grass	native	grass	8	-3
Panicum virgatum	switch grass	native	grass	4	0
Phalaris arundinacea	reed canary grass	native	grass	0	-3
Pinus strobus	white pine	native	tree	3	3
Piptochaetium avenaceum	black oatgrass	native	grass	10	3
Poa compressa	**canada bluegrass**	**non-native**	**grass**	**0**	**3**
Poa pratensis	**kentucky bluegrass**	**non-native**	**grass**	**0**	**3**
Populus tremuloides	quaking aspen	native	tree	1	0
Potentilla simplex	old-field cinquefoil	native	forb	2	3
Pteridium aquilinum	bracken fern	native	fern	0	3
Quercus alba	white oak	native	tree	5	3
Quercus ellipsoidalis	hills oak	native	tree	4	5
Rosa palustris	swamp rose	native	shrub	5	-5
Rubus hispidus	swamp dewberry	native	shrub	4	-3
Rubus pubescens	dwarf raspberry	native	shrub	4	-3
Rumex acetosella	**sheep sorrel**	**non-native**	**forb**	**0**	**3**
Salix discolor	pussy willow	native	shrub	1	-3
Salix petiolaris	slender willow	native	shrub	1	-3
Schizachyrium scoparium	little bluestem	native	grass	5	3
Scirpus cyperinus	wool-grass	native	sedge	5	-5
Spartina pectinata	cordgrass	native	grass	5	-3

Appendix 9 (Continued). Floristic Quality Assessment for Pentwater Prairies (EO ID 21677, pg 44).

Scientific Name	Common Name	Native?	Physiognomy	C	W
Spergula arvensis	**spurrey**	**non-native**	**forb**	**0**	**5**
Spiraea alba	meadowsweet	native	shrub	4	-3
Stachys hyssopifolia	hyssop hedge nettle	native	forb	10	-3
Symphyotrichum dumosum	bushy aster	native	forb	7	0
Thelypteris palustris	marsh fern	native	fern	2	-3
Tragopogon pratensis	**common goats beard**	**non-native**	**forb**	**0**	**5**
Vaccinium angustifolium	low sweet blueberry	native	shrub	4	3
Vicia villosa	**hairy vetch**	**non-native**	**vine**	**0**	**5**
Viola lanceolata	lance-leaved violet	native	forb	8	-5
Viola sagittata	arrow-leaved violet	native	forb	8	0

Appendix 10. All birds documented during rare bird surveys.

Common Name	Scientific Name	Number of points observed
Red-winged Blackbird	*Agelaius phoeniceus*	6
great-blue heron	*Ardea herodias*	3
Tufted Titmouse	*Baeolophus bicolor*	12
Northern Cardinal	*Cardinalis cardinalis*	18
Eastern Wood-Pewee	*Contopus virens*	33
American Crow	*Corvus brachyrhynchos*	9
Blue Jay	*Cyanocitta cristata*	30
Pileated Woodpecker	*Dryocopus pileatus*	3
Gray Catbird	*Dumetella carolinensis*	3
Acadian Flycatcher	*Empidonax virescens*	6
Common Yellowthroat	*Geothlypis trichas*	15
Wood Thrush	*Hylocichla mustelina*	42
Red-bellied Woodpecker	*Melanerpes carolinus*	18
Brown-headed Cowbird	*Molothrus ater*	12
Great-crested Flycatcher	*Myiarchus crinitus*	3
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	18
Downy Woodpecker	*Picoides pubescens*	9
Hairy Woodpecker	*Picoides villosus*	12
Scarlet Tanager	*Piranga olivacea*	36
Black-capped Chickadee	*Poecile atricapillus*	24
Ovenbird	*Seiurus aurocapilla*	39
American Redstart	*Setophaga ruticilla*	6
Black-throated Green Warbler	*Setophaga virens*	6
White-breasted Nuthatch	*Sitta carolinensis*	9
American Goldfinch	*Spinus tristis*	3
Chipping Sparrow	*Spizella passerina*	6
Winter Wren	*Troglodytes hiemalis*	3
American Robin	*Turdus migratorius*	21
Red-eyed Vireo	*Vireo olivaceus*	73

Appendix 11. A fire scar on a red pine in the northern portion of Pentwater Woods with evidence of at least five burns. Red pines uniquely record a site's fire history due to their ability withstand fire and heal over damaged bark. These burns likely happened early in the 20th century based on the age of the trees. Photo by J.M. Lincoln.

MNFI research assistant Wyatt O. Lincoln identifying fire-scarred red pine while conducting natural community surveys. Photo by J.M. Lincoln.