A Reassessment of High Quality Natural Communities on Camp Grayling

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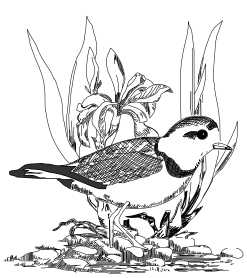

June 30, 2005

Report Number 2005-11

MICHIGAN STATE UNIVERSITY EXTENSION

Cover photograph: Best Bog on Camp Grayling (M. Kost).

EXECUTIVE SUMMARY

This report presents the results of a reevaluation of 14 natural communities first identified in the early 1990s and discussed in Higman et al. (1994). Several significant changes have occurred since the natural communities were originally documented. Most notably, invasive species present a threat to many of the communities, particularly the mesic sand prairie at the Portage Lake Complex. This site contains a population of the invasive plant, leafy spurge (*Euphorbia esula*), that threatens to degrade habitat for numerous rare species including Houghton's goldenrod (*Solidago houghtonii*), a federally threatened species. Several of the wetlands recently experienced fire, which appears to have bolstered species diversity and habitat heterogeneity in both the wetland and upland habitats. Water levels for many of the wetlands have dropped considerably since first surveyed in the 1990s. This phenomenon is likely the result of regional decreases in water levels tied throughout the Upper Great Lakes Region. Degradation by off road vehicles was observed in two wetlands but was not severe in either, indicating that education, enforcement, and deterrent efforts are having a positive affect. The report contains detailed site summaries and conservation and management recommendations for each natural community with the **Results** section entitled **Site Descriptions and Management Recommendation**. In addition, we present seven natural community abstracts in the **Appendices** (see **List of Appendices** for list of abstracts).

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INTRODUCTION

During the summer of 2004 Michigan Natural Features Inventory (MNFI) staff conducted surveys of fourteen high quality natural communities that had been previously identified as part of an inventory effort on Camp Grayling in the early 1990s (Higman et al. 1994). The surveys were initiated because it had been over ten years since the high quality communities were identified and potential threats to their ecological integrity such as fire suppression, invasive species, off road vehicles (ORVs), etc., can cause significant degradation within this time frame. This report summarizes the findings of MNFI's surveys, provides management recommendations aimed at protecting biodiversity, and presents natural community abstracts for seven of the community types that occur on Camp Grayling.

METHODS

Preparation for field surveys involved studying element occurrence records, aerial photographs, topographic maps, and previously recorded site information (Higman et al. 1994). In addition, relevant ecological literature was reviewed for each community type. A site packet was then assembled for each of the fourteen community occurrences, which contained relevant aerial photographs, topographic maps, element occurrence records, natural community forms, and pertinent literature.

Community surveys were conducted during the summer of 2004. Each natural community occurrence was visited one or more times over the summer to evaluate potential threats and collect additional information on soils, species composition, water levels, recent natural and anthropogenic disturbances, community boundaries, and landscape context.

Following completion of the field surveys, the data was analyzed and transcribed to update the element occurrence records in the statewide biodiversity conservation database managed by MNFI. The data from each element occurrence was also used to determine its Alliance according to the US National Vegetation Classification (Faber-Langendoen 2001). Lastly, information from the field surveys was used to produce site descriptions and conservation and management recommendations for each natural community occurrence, which appear within the **Results** section under **Site Descriptions and Management Recommendations**.

RESULTS

Fourteen community element occurrences were updated in the statewide biodiversity conservation database managed by MNFI. In addition, seven community abstracts were written and appear in the appendices. Site descriptions and management recommendations were produced and appear below.

Site Descriptions and Management Recommendation

The site descriptions that appear below are an updated version of the original site descriptions from Higman et al. (1994). **Invasive species** followed by an **asterisk (*)** are considered to be highly invasive and efforts to control their spread and remove them from high quality natural communities are considered a top management objective for maintaining biodiversity. The highly invasive species that were identified within the natural communities discussed below include the following: giant reed (*Phragmites australis*), reed canary grass (*Phalaris arundinacea*), spotted knapweed (*Centaurea maculosa*), common St. John's wort (*Hypericum perforatum*), and Canada bluegrass (*Poa compressa*).

1. Portage Creek-Howes Lake Complex

Natural Community Type: mesic sand prairie

Rank: G1 S1?, critically imperiled

Alliance: *Andropogon gerardii* - (*Calamagrostis canadensis*, *Panicum virgatum*) Herbaceous Alliance (V.A.5.N.a)

Location: T26N R04W, T27N R04W, T26N R05W

M. Kost

Photo 1. Prairie dropseed, a state threatened grass, dominates portions of the mesic sand prairie at the Portage Creek Complex.

Site Description:

This mesic sand prairie is located in a three-mile-long band extending from the west side of Howes Lake to the southwest, parallel to Portage Creek. The prairie is divided into eighteen fragments totaling approximately 77 acres. This is a shrub/grass-dominated wetland that experiences significant water table fluctuation during the year. When the southern portion of this site was first located in June, 1992, surface soils were saturated. By September, the water table had dropped to 75 cm (30 in) below the surface. It is quite likely that these fragments flood most years in the spring. Soil organic matter at this site reaches a depth of 15.5 cm (6 in). Subsoil pH was measured at 7.0 (7.5).

This site was first identified due to the presence of the federally threatened (FE) Houghton's goldenrod (*Solidago houghtonii*), which was previously known from around Howes Lake, and at the intersection of M-72 and Arrowhead Road. Through analysis of aerial photos, proglacial landforms, and ground searches, it was discovered that these small goldenrod populations were oriented in a linear fashion in what was a prairie-like habitat. It was discovered that these linear patches of prairie habitat were located in historical shoreline deposits from pro-glacial Lake Margrethe. By following these narrow depressions to the southwest, the full extent of this rare plant community was discovered.

Jack pine (*Pinus banksiana*), and in places, tamarack (*Larix laricina*) are common tree species intermixed with the prairie, forming a widely scattered canopy. Dominant shrubs include speckled alder (*Alnus rugosa*), leatherleaf (*Chamaedaphne calyculata*), shrubby cinquefoil (*Potentilla fruticosa*), chokeberry (*Aronia prunifolia*), and several willows (*Salix* spp.). Common ground cover species include several sedges (*Carex buxbaumii*, *C. leptalea*, *C. stricta*, *C. viridula*), blue-joint grass (*Calamagrostis canadensis*), hair-grass (*Deschampsia cespitosa*), big bluestem (*Andropogon gerardii*), and marsh wild-timothy (*Muhlenbergia glomerata*). Other rare plant species found here include prairie dropseed (*Sporobolus heterolepis*, state threatened), Clinton's bulrush (*Scirpus clintonii*, state threatened), Vasey's rush (*Juncus vaseyi*, state threatened), and Long-leaved aster (*Aster longifolius*, special concern). In some fragments, prairie dropseed is the dominant species in the ground cover. Surveys of the community documented 91 vascular plant species at this site, indicating the relatively high diversity of the site. The secretive locust (*Appalachia arcana*, special concern) was also found within this complex.

Surrounding the prairie fragments, spruce and tamarack-dominated swamp, second-growth jack pine forest and jack pine plantations are common. In the 1980s, jack pine was harvested and replanted along M-72 surrounding the prairie remnants. Several roads pass through the prairie in a number of locations.

Protection of this prairie habitat should include the establishment of upland buffer areas where intensive forest management and training activities will be excluded. Where possible, a 100-200 m buffer zone would likely be sufficient. Although existing roads probably pose little additional threat to the prairie fragments, thought should be given to the possibility of closing the dirt road east of the intersection at M-72 and Arrowhead Road. This is an often washed-out road that has Houghton's goldenrod growing along both its margins.

Invasive species control at this site, especially for leafy spurge (*Euphorbia esula*) is a top priority. General Land Office survey notes indicate that wildfires once burned through the community as does its position within a large, level, outwash plain dominated by jack pine (Comer et al. 1995). Thus, maintenance of biodiversity at this site should include prescription burning on an occasional basis. Further research into the nature of the soils, parent material, and water table fluctuations of this site are needed. Monitoring of Houghton’s goldenrod should be reinitiated. For additional information on conservation and management of mesic sand prairies, see the natural community abstract in Appendix 1.

Soil: Information was gathered from thirteen soil cores taken within the dispersed patches of mesic sand prairie that were mapped in 1992. Below is a general description of soils compiled from the thirteen samples.

0 to 10 (20) cm: light-colored-loamy sand (pH 6.5 (7.0)) mixed with black organic matter (may also be described as black loamy sand)
10 to 50 (70) cm: iron-colored sand or occasionally light-colored sand (pH 7.0 (7.5)) with organic streaking and occasionally strong iron mottling
50 (70) cm to 130 cm: iron-colored sand or occasionally light-colored sand (pH 7.0 (7.5)) with strong iron mottling

Water table: No standing water was observed at the surface nor within the visible portions of holes made by the soil auger; however, saturated sands were encountered in many soil cores at depths ranging from 40 cm to 60 cm. Even at depths of 130 cm, saturated sands were not observed in some cores. Conversely, in one swale that was dominated by wetland plants but which also contained Houghton’s goldenrod, saturated, iron-colored sands were encountered at 20 cm.

Invasive species

Scientific Name	Common Name	Estimated Abundance
Agrostis gigantea	redtop	uncommon
*Centaurea maculosa**	spotted knapweed*	uncommon
*Euphorbia esula**	leafy spurge*	locally abundant
Hieracium aurantiacum	orange hawkweed	locally common
*Hypericum perforatum**	common St. John's wort*	occasional
*Poa compressa**	Canada bluegrass*	locally common
Prunella vulgaris	lawn prunella	uncommon
Tragopogon dubius	goat's beard	occasional

Conservation and Management:

- Monitor for and remove invasive species, especially leafy spurge
- Conduct prescribed burns on an occasional basis
- Monitor population of Houghton's goldenrod

2. Frog Lake Complex Frog Lake Complex

Natural Community Type: intermittent wetland

Rank: G3, S2; very rare globally, imperiled in state

Alliance: *Chamaedaphne calyculata* - (*Kalmia angustifolia*) Seasonally Flooded Dwarf-Shrubland Alliance (IV.A.1.N.f)

Location: T27N R02W

M. Kost

Photo 2. The Frog Lake Complex contains a diverse grouping of nine depressional wetlands that experience fluctuating water levels as evidenced by the concentric rings of differing vegetation in the photo above.

Site Description:

The Frog Lake Complex is a series of small lakes and wet depressions located seven miles north of M-72 just west of Stephans Bridge Road. It was formed by melting ice blocks on sandy glacial deposits. The intermittent wetlands are formed in the smallest depressions and along several lake margins that experience water level fluctuations. The nine different depressions total approximately 10 acres. The complete complex of immediately adjacent uplands includes approximately 200 acres and occurs within the Pine Barrens Management Opportunity Area identified in Higman et al (1994) and the focus of Kost et al. (2000). Prairie cord grass (*Spartina pectinata*) typically dominates the edge of these wetlands, with running bog sedge (*Carex oligosperma*) and leatherleaf (*Chamaedaphne calyculata*) dominating zones with deeper water. Other common plant species include tall goldenrod (*Solidago altissima*), blue-joint grass (*Calamagrostis canadensis*), and wood sage (*Teucrium canadense*). Sixty eight plant species were documented in these wetlands. Although no listed species of plants or animals were located within the complex, two uncommon leafhoppers (*Notus* spp. and *Cicadula smithi*) were found here. Adjacent uplands include pine barrens and second growth forest of jack pine (*Pinus banksiana*). Hill's thistle (special concern) occurs within the adjacent pine barrens. Two track roads cross the area.

Protection of this complex should involve limiting vehicle use to currently existing roads. Easy access to the south end of Frog Lake resulted in damage from off road vehicles during 1993. There may be no way to avoid this type of damage without closing immediately adjacent access roads. A vegetated upland buffer of at least 100 meters should be maintained around each wetland depression. The ecological integrity of these intermittent wetland communities may be directly related to the maintenance of open pine barren habitat in the immediately adjacent upland. Thus, management of this site should include the use of prescribed burning in the uplands and allowing fire to carry into the wetlands. Invasive species monitoring and control should be implemented within the wetlands and adjacent uplands. For additional information on conservation and management of intermittent wetlands, see the natural community abstract in Appendix 2.

Soil: Soil cores were examined in each of the nine depressional, intermittent wetlands that comprise the Frog Lake Complex. The information presented below is a general description compiled from these soil cores, which were generally very similar in composition and pH.

0 to 150 cm: fibric, sedge peat (pH 5.5)

Note: the sands around Frog Lake were alkaline (pH 8.0) and one very small depression at the south end of Frog Lake contained marl (pH 8.0).

Water table: No standing water was observed in any of the wetlands except for two depressions that contain lakes. No water could be observed within the holes produced by the soil auger; however, the fibric peat extracted from the soil cores was moist in all samples.

Invasive species:

Scientific Name	Common Name	Estimated Abundance
*Centaurea maculosa**	spotted knapweed*	uncommon
*Phalaris arundinacea**	reed canary grass*	occasional
*Phragmites australis**	giant reed*	uncommon
*Poa compressa**	Canada bluegrass*	locally common

Conservation and Management:

- Monitor for and remove invasive species
- Limit vehicle use in area to currently existing roads
- Maintain vegetated upland buffer of at least 100 meters around each depression
- Conduct prescribed fire in adjacent uplands on an occasional basis and allow it to carry into the wetlands

3. Lake Margrethe North
Community Type: intermittent wetland
Rank: G3 S2, very rare globally, imperiled in state
Alliance: *Chamaedaphne calyculata* - (*Kalmia angustifolia*) Seasonally Flooded Dwarf-Shrubland Alliance (IV.A.1.N.f)
Location: T26N R04W

M. Kost

Photo 3. The Lake Margrethe North intermittent wetland contains open *Carex oligosperma*-dominated sedge flats on organic soil interspersed with raised leatherleaf- and jack pine-dominated islands on acidic sands.

M. Kost

Photo 4. The sedge, *Carex oligosperma*, commonly dominates the sedge flats within acidic wetlands such as intermittent wetland and bog.

Site Description:

This 237 acre wetland is located one mile north of Lake Margrethe on a poorly drained glacial lake bed. Although surface soils here are medium sands, there is likely a layer of heavy soils several feet below the surface that is responsible for the fluctuation in water levels. According to the original land surveys of 1850, this wetland was mostly open, dominated by shrubs, sedges and grasses. Today, much of the area has closed in with jack pine, and occasionally, white pine and red pine forming a partial overstory canopy. Species such as leatherleaf (*Chamaedaphne calyculata*), speckled alder (*Alnus rugosa*), and sheep laurel (*Kalmia angustifolia*) dominate the shrub layer. Running bog sedge (*Carex oligosperma*) and sedge (*Carex livida*) dominate the ground layer, with the latter sedge dominating large, open portions of the complex. Just 22 plant species were noted in this wetland complex. An active bald eagle nest (*Haliaeetus leucocephalus*, federally threatened (FT)) is located at the north end of the wetland. The secretive locust (*Appalachia arcana*, special concern) was also found within this wetland.

Over the years, this wetland has been impacted by road construction, timber harvest, and pine plantation establishment. Road construction may have caused slight alterations in the hydrology of this system. It is also possible that the area was historically maintained more open by periodic fires spreading from the adjacent, fire prone, jack pine plains. The suppression of wildfires during the past sixty years may also account for the development of an overstory canopy. Most of the tree plantations established at the east end of the complex failed shortly after establishment.

Protection of this complex should include maintaining an adequate vegetated upland buffer. Consider limiting access to the community during the bald eagles nesting season. Where the road crosses the wetland, culverts should be installed under the road to allow for water flow. Tire tracks were observed within the wetland during the 2004 surveys. To prevent further degradation of the natural community, vehicles (e.g., ORVs) should be prevented from entering the wetland. Consider conducting prescribed fire in wetland and surrounding upland on an occasional basis. Invasive species monitoring and control should be implemented within the wetland and adjacent uplands. For additional information on conservation and management of intermittent wetlands, see the natural community abstract in Appendix 2.

Soils:
Within Carex oligosperma- and Carex aquatilis-dominated sedge flats:
0 to 25 cm: fibric, sedge peat (pH 4.5)
25+cm: coarse-textured loamy sand
Water table: 10 cm below soil surface

Within slightly raised areas dominated by leatherleaf and widely scattered jack pine with sheep laurel (*Kalmia angustifolia*), blueberry (*Vaccinium angustifolia*), and wintergreen (*Gaultheria procumbens*):
0 to 5 cm: mull hummus (pH 4.5)
5 to 20m cm: grey-brown sand (pH 5.0).
20 to 50 cm: iron colored sand with large iron mottles
50 to 100 cm: saturated, light brown sand with few iron mottles
Water table: 50 cm below soil surface

Invasive species: None observed

Conservation and Management:
- Prevent use of ORV's in wetland
- Remove trash from adjacent parking areas
- Conduct prescribed burn on an occasional basis
- Limit access during bald eagle nesting season
- Maintain vegetated upland buffer
- Install culverts under roads that cross wetland
- Monitor for and remove invasive species

4. The Doughnut

Natural Community Type: intermittent wetland

Rank: G3 S2, very rare globally, imperiled in state
Alliance: *Chamaedaphne calyculata* - (*Kalmia angustifolia*) Seasonally Flooded Dwarf-Shrubland Alliance (IV.A.1.N.f)

Location: T27N R04W

M. Kost

Photo 5. The Doughnut is an intermittent wetland that contains a ring of *Carex oligosperma*, which surrounds a leatherleaf- and tree-dominated center. Degradation by off road vehicles (ORVs) is evident within this wetland.

M. Kost

Photo 6. The frame of an abandoned snowmobile occurs on the edge of the Doughnut intermittent wetland near the parking area and should be removed. Also visible are tracks from ORV use in the wetland.

Site Description:

This nine acre wetland is located just northwest of Howes Lake. It lies in a shallow depression on the wide outwash channel which includes the riverbed of the Manistee River. This site takes its name from its vegetative structure, which includes an outer ring dominated by running bog sedge (*Carex oligosperma*) and leatherleaf (*Chamaedaphne calyculata*), surrounding a tree-dominated center, with jack pine (*Pinus banksiana*) and black spruce (*Picea mariana*). Other common plant species include blue joint (*Calamagrostis canadensis*), thin grass (*Agrostis perennans*), laurel (*Kalmia polifolia*), and large cranberry (*Vaccinium macrocarpon*). Only 23 vascular plant species were noted in this wetland. The secretive locust (*Appalachia arcana*, special concern) was found in and around this wetland.

Historically, in the immediately adjacent uplands, jack pine barrens and closed-canopy, jack pine forest was characteristic. Today much of this area remains as second growth jack pine forest and burned openings. A narrow two track road passes along the west side of the wetland, and there has been garbage dumped along the wetland margins.

Protection of this wetland should include maintaining an upland vegetated buffer for at least 100 meters. Fires occurring in the adjacent uplands should be allowed to carry into the wetland. Tire tracks were observed within the wetland during the 2004 surveys. To prevent further degradation of the natural community, vehicles (e.g., ORVs) should be prevented from entering the wetland. Consider managing the adjacent uplands with prescribed fire on a periodic basis and allowing fire to carry into the wetland. Invasive species monitoring and control should be implemented within the wetland and adjacent uplands. For additional information on conservation and management of intermittent wetlands, see the natural community abstract in Appendix 2.

Soils:
0 to 110 cm: muck (pH 4.5 (4.0))
110+ cm: coarse-textured, gleyed sand

Water table: 10 to 20 cm of standing water in *Carex oligosperma*-dominated outer ring

Invasive species: None observed

Conservation and Management Recommendations:

- Prevent use of ORV's in wetland.
- Consider installing a barrier at parking area to prevent ORV use of wetland
- Conduct prescribed fire in adjacent uplands and allow fire to carry into wetland
- Maintain vegetated upland buffer for at least 100 meters
- Remove abandoned snowmobile from edge of wetland
- Monitor for and remove invasive species

5. Barker Creek Fen

Natural Community Type: northern fen

Rank: G3 S3, very rare and local throughout range
Alliance: *Carex lasiocarpa* Saturated Herbaceous Alliance (V.A.5.N.m)

Location: T27N R02W

M. Kost

Photo 7. The Barker Creek northern fen is a level peatland dominated by slender woolly sedge with scattered, raised, peat mounds harboring sphagnum moss and shrubs (leatherleaf, sweet bay, shrubby cinquefoil and sage willow).

M. Kost

Photo 8. A thick layer of dried, sedge leaf litter blankets the organic soil at Barker Creek Fen and inhibits seed bank expression and species diversity. Prescribed fires conducted on an occasional basis act to reduce leaf litter in wetlands and uplands and foster seed bank expression and species diversity.

Site Description:

The Barker Creek Fen is a 31 acre wetland located one mile south of North Down River Road at the southeast extreme of North Camp Grayling property. Northern fens are groundwater fed wetlands that are typically located in areas containing porous, calcium and magnesium rich soils. This wetland is located on a poorly drained portion of outwash deposits. Water from this wetland flows south into the Au Sable River. This is a large, sedge-dominated wetland with shrubs and scattered trees located on a few rises. Dominant herbaceous species include slender woolly sedge (*Carex lasiocarpa*), sedge (*Carex livida*), slender bulrush (*Scirpus hudsonianus*), and pitcher plant (*Sarracenia purpurea*). Common shrub and tree species include shrubby cinquefoil (*Potentilla fruticosa*), bog birch (*Betula pumila*), leatherleaf (*Chamaedaphne calyculata*), sweet bay (*Myrica gale*), sage willow (*Salix candida*), and tamarack (*Larix laricina*). A total of 34 vascular plant species were noted in this wetland. Adjacent uplands are dominated by trembling aspen (*Populus tremuloides*). Recent clearcuts are evident on the east side of the complex with approximately one hundred meters of natural buffer remaining.

These groundwater-fed wetlands are considered to be sensitive to increased nutrient run-off from adjacent land management activities. Protection of this wetland should include the establishment and maintenance of a buffer for 100 to 200 meters on all sides. The wetland contains a thick layer of leaf litter that acts to stifle seedling establishment and seed bank expression. Consider managing the adjacent uplands with prescribed fire and allowing fire to carry into wetland and reduce thickness of leaf litter and stimulate seed bank expression. Invasive species monitoring and control should be implemented within the wetland

and adjacent uplands. For additional information on conservation and management of northern fens, see the natural community abstract in Appendix 3.

Soil:
0 to 120 cm: fibric peat (pH 7.0)
120+ cm: coarse-textured gleyed sand (pH 8.0)

Water table: 3 to 5 cm of standing water covers most of sedge-dominated portions of wetland. Depth of standing water is significantly higher near Barker Creek. No standing water occurs on the scattered raised peat mounds, which are dominated by sphagnum moss and shrubs (leatherleaf, sweet bay, shrubby cinquefoil and sage willow).

Invasive species: none observed

Conservation and Management:
- Monitor for and remove invasive species
- Maintain vegetated buffer of 100 to 200 meters around wetland
- Allow fires occurring in the surrounding uplands to carry into wetland
- Prevent ORV use in wetland

6. C-shaped Depression

Community Type: northern fen
Rank: G3 S3, very rare and local throughout range
Alliance: *Carex lasiocarpa* Saturated Herbaceous Alliance (V.A.5.N.m)
Location: T27N R02W

M. Kost

Photo 9. Marl from a soil core is shown above along with silverweed, which dominates the exposed marl flats on the east side of the C-shaped depression northern fen.

M. Kost

Photo 10. Following fire, rough fescue (state threatened, foreground) and big bluestem were growing robustly among the burnt snags of jack pine above the C-shaped depression northern fen. Nearby was a robustly flowering population of Hill's thistle (special concern) also observed growing under burnt snags of jack pine.

Site Description:

This small eight acre wetland is located three miles north of North Down River Road just west of Stephans Bridge Road. It takes its name from the shape of the 50 foot deep depression where it is located. This site was originally classified as a poor fen but upon closer examination of the alkaline, organic soils, it was reclassified as a northern fen.

A narrow band of exposed sand around the margin of this wetland indicates a small degree of regular water level fluctuations. Dominant plant species in this wetland include blue-joint grass (*Calamagrostis canadensis*), wool grass (*Scirpus cyperinus*), twig rush (*Cladium mariscoides*), meadow sedge (*Carex stricta*), slender woolly sedge (*Carex lasiocarpa*), and grass-leaved goldenrod (*Euthamia graminifolia*). In 2004, the east side of the wetland contains an exposed marl flat dominated by silverweed (*Potentilla anserina*). A total of 34 vascular plant species were noted in this wetland. The surrounding steep slopes above the wetland are dominated by second growth jack pine (*Pinus banksiana*) and trembling aspen (*Populus tremuloides*). A fire burned across portions of the wetland and jack pine-forested uplands in the spring of 2004. Although many of the jack pine were killed, two rare plants, rough fescue (*Festuca scabrella*, threatened) and Hill's thistle (*Cirsium hillii*, special concern), and clumps of big bluestem (*Andropogon gerardii*) appeared to be reaping the benefits of the added sunlight and nutrients as these species were observed growing robustly and in full flower.

Protection of this wetland should include monitoring for and removing invasive species. When possible, fire occurring in the adjacent uplands should be allowed to carry into the wetland. A vegetated upland buffer should be maintained for approximately 200 meters on all sides of the wetland. For additional information on conservation and management of northern fens, see the natural community abstract in Appendix 3.

Soil:
West side:
0 to 150+ cm: fibric peat (pH 7.0)
East side:
0 to 50+ cm: marl (pH 8.0)

Water table:
West side: saturated peat throughout but standing water was observed only in one small area that contained a quaking mat of vegetation.
East side: marl was moist but no water observed

Invasive species	**Estimated Abundance**	
Scientific Name	**Common Name**	**Estimated Abundance**
Typha angustifolia	narrow-leaved cattail	uncommon
*Phalaris arundinacea**	reed canary grass*	occasional

Conservation and Management:

- Monitor for and remove invasive species
- Conduct prescribed fire in adjacent uplands on an occasional basis and allow fire to carry into wetland
- Maintain vegetated upland buffer for approximately 200 meters

7. Lovells Fen

Community Type: poor fen

Rank: G3 S3, very rare and local throughout range

Alliance: *Carex oligosperma* - *Carex lasiocarpa* Saturated Herbaceous Alliance (V.A.5.N.m)

Location: T27N R02W, T28N R02W

M. Kost

Photo 11. A fire recently burned across Lovells Fen and up the pine-dominated slopes, killing many of the pines. The leatherleaf (foreground) resprouted following burning.

Site Description:

Lovells fen is a 27 acre poor fen located two miles south of the town of Lovells. It developed in a deep depression formed by a remnant ice block that melted in sandy glacial deposits. Generally, poor fens are partially ground water-fed wetlands where soils are somewhat less rich in calcium and magnesium than those found in northern fens. As a result, they typically include zones of vegetation characteristic of both northern fens and bogs.

Lovells fen includes a small open water zone at its southern end, then grades from a sedge-dominated meadow to a more bog-like, shrub-dominated zone at the north end. Dominant plant species include water-lily (*Nymphaea odorata*), hard-stemmed bulrush (*Scirpus acutus*), blue-joint grass (*Calamagrostis canadensis*), slender woolly sedge (*Carex lasiocarpa*), twig rush (*Cladium mariscoides*), leatherleaf (*Chamaedaphne calyculata*), and pitcher plant (*Sarracenia purpurea*). A total of 55 vascular plant species were noted in this wetland. In the recent past, the steep slopes that border the fen were dominated by second-growth jack pine (*Pinus banksiana*) and red pine (*Pinus resinosa*), some of which was established by plantation. However, a fire recently burned across the wetland and up the slopes, killing many of the pines. In addition, the pine plantation along the north and east sides of the wetland was recently clearcut, disked, and planted to red pine. Signs of a small tornado touch down within the deep depression were evident in early 1993 when most of the trees along the north end of the depression were observed blown down in a northeastern direction.

Protection of this wetland should include the maintenance of a vegetated upland buffer for approximately 200 meters on all sides of the wetland. Fires occurring within the surrounding uplands should be allowed to spread into the wetland. Invasive species monitoring and control should be implemented within the wetland and adjacent uplands. For additional information on conservation and management of poor fens, see the natural community abstract in Appendix 4.

Soil: fibric sedge peat (pH 6.5)

Water table: ranges from 5 cm below soil surface on north end to a small area of standing water in the far southern portion

Invasive species	**Estimated Abundance**	
Scientific Name	**Common Name**	**Estimated Abundance**
*Phalaris arundinacea**	reed canary grass*	locally common

Conservation and Management:

- Monitor for and remove invasive species
- Maintain vegetated upland buffer
- Allow fires occurring in the surrounding uplands to carry into wetland
- Prevent ORV use in wetlands

8. Best Bog

Community Type: bog

Rank: G3 S3, very rare and local throughout range
Alliance: *Chamaedaphne calyculata* Saturated Dwarf-Shrubland Alliance (IV.A.1.N.g)
Location: T27N R01W

M. Kost

Photo 12. A small lake remains within peat-filled depression occupied by Best Bog.


M. Kost

Photo 13. Sundew and sphagnum moss were abundant, floating in 20 cm of standing water within the *Carex oligosperma*-dominated, open sedge flats at Best Bog.

Site Description:

This 25 acre bog is located just south of North Down River Road near the southeastern extreme of the camp property. It lies in a poorly drained portion of outwash deposits that drains to the southwest into Barker Creek.

The south end of this wetland includes a well developed floating mat and a small area of open water. Throughout the remainder of the wetland is a mosaic of sedge-dominated meadow, shrub-dominated rises, and several islands with black spruce (*Picea mariana*), and tamarack (*Larix laricina*). Dominant vascular plant species include leatherleaf (*Chamaedaphne calyculata*), running bog sedge (*Carex oligosperma*), white beak rush (*Rhynchospora alba*), large cranberry (*Vaccinium macrocarpon*) and, locally, round-leaved sundew (*Drosera rotundifolia*). Common sphagnum mosses in this wetland include *Sphagnum cuspidatum*, *Sphagnum papillosum*, and *Sphagnum magellanicum*. Twenty five vascular plant species were noted in this bog. When the bog was first document in 1993 the adjacent uplands were dominated by second growth jack pine (*Pinus banksiana*) and red pine (*Pinus resinosa*); since then, this forest has been clearcut, disked to create furrows, and planted with jack pine. A road passes along the southwest and western border of the wetland.

Protection of this wetland should include maintaining the culverts in the road at the south end of the wetland. A vegetated upland buffer for approximately 200 meters on all sides of the wetland should be maintained. Fires occurring in the adjacent uplands should be allowed to carry into the wetland. Invasive species monitoring and control should be implemented within the wetland and adjacent uplands. For additional information on conservation and management of bogs, see the natural community abstract in Appendix 5.

Soil: 50 to 60 cm of fibric peat with pH of peat 4.5 (4.0) over coarse-textured sand

Water table: 20 cm of standing water in sedge meadow areas dominated by *Carex oligosperma* and floating sphagnum moss and sundew

Invasive species: none observed

Conservation and Management:

- Monitor for and remove invasive species
- Maintain culverts in road at south end of the wetland
- Conducts prescribed fire in adjacent uplands on an occasional basis and allow fire to carry into wetland
- Maintain a vegetated upland buffer for approximately 200 meters on all sides of the wetland

9. Lovells Bog

Community Type: bog
Rank: G3 S3, very rare and local throughout range
Alliance: *Chamaedaphne calyculata* Saturated Dwarf-Shrubland Alliance (IV.A.1.N.g)
Location: T28N R02W

M. Kost

Photo 14. A small lake surrounded by black spruce and jack pine remain near the center of Lovells Bog. Leatherleaf (foreground) dominates much of the open bog.

Site Description:

Lovells Bog is located approximately two miles northeast of KP Lake along KP Twin Bridge Truck Trail. It lies in a shallow, poorly drained depression formed by a remnant ice block on sandy glacial deposits.

This wetland includes a two acre area of open water near the center, and is surrounded by a mosaic of sedge meadow, shrubs, and islands dominated by black spruce (*Picea mariana*) and tamarack (*Larix laricina*). Dominant vascular plant species include bulrush (*Scirpus hudsonianus*), running bog sedge (*Carex oligosperma*), sundews (*Drosera rotundifolia*, and *Drosera intermedia*), laurel (*Kalmia polifolia*), bog rosemary (*Andromeda glaucophylla*), and Labrador tea (*Ledum groenlandicum*). A total of 24 vascular plant species were noted in this wetland. An active beaver den was observed at the south end of the wetland in 1993. The adjacent uplands surrounding this bog include second growth forest of trembling aspen (*Populus tremuloides*) and red oak (*Quercus rubra*). In the early 1990s or late 1980s, much of the upland along the east side of the wetland was clearcut and now supports a dense stand of trembling aspen saplings. Jack pine (*Pinus banksiana*) has been planted in part of this area.

Protection of this wetland should include establishment of a 200 meter-wide upland vegetated buffer. Fires occurring within the adjacent uplands should be allowed to carry into the wetland. Invasive species monitoring and control should be implemented within the wetland and adjacent uplands. For additional information on conservation and management of bogs, see the natural community abstract in Appendix 5.

Soil:
0 to 150+ cm: fibric peat with pH of 4.5 (4.0)

Invasive species: none observed

Conservation and Management:
- Monitor for and remove invasive species
- Conduct prescribed fire in adjacent uplands on an occasional basis and allow fire to spread into wetland
- Maintain vegetated upland buffer for approximately 200 meters

10. Crawford Red Pines

Community Type: dry northern forest
Alliance: *Pinus resinosa* Forest Alliance (I.A.8.N.b)
Rank: G3? S3?, very rare and local throughout range
Location: T27N R01W

M. Kost

Photo 15. Large red pines, approximately 180 years old and measuring 70(±) cm in diameter, dominate the canopy of the dry northern forest at Crawford Red Pines.

M. Kost

Photo 16. At Crawford Red Pines, red maples are outcompeting red pine saplings. Prescription burning and manual removal should be used to reduce the density of red maple at this site.

Site Description:

This 14 acre tract of old growth red pine (*Pinus resinosa*) was first identified in 1954, and is considered one of the only remnant stands of its type in Lower Michigan. It is located twelve miles east of Grayling along Dyer Truck Trail at the southeastern extreme of Camp Grayling property. This site is located on a low rise in what is otherwise a poorly drained outwash plain that drains into Barker Creek.

Red pine, up to 178 years old, forms a partially closed canopy in this tract. Common plant species within this tract include blueberry (*Vaccinium angustifolium*), bunchberry (*Cornus canadensis*), bracken fern (*Pteridium aquilinum*), rough-leaved rice grass (*Oryzopsis asperifolia*), and trailing arbutus (*Epigaea repens*). Immediately surrounding portions of the old growth tract is second growth forest of red pine, northern pin oak (*Quercus ellipsoidalis*), jack pine (*Pinus banksiana*), and red maple (*Acer rubrum*). The area directly to the north was recently clear cut, disked to create furrows, and planted with jack pine. Adjacent wetlands include a bog element occurrence (Best Bog) and second growth hardwood-conifer swamp. A northern fen (Barker Creek Fen) occurs approximately one mile southwest of the site.

During the middle 1980s, camp activities were ceased around the vicinity of the tract. Long-term management of the tract should consider the removal of competing vegetation, such as red maple, which impedes the natural regeneration of red pine through creation of dense shade (Abrams 1998). Red maple seedlings were especially abundant in old abandoned trails, roads, and camping areas where sedge (*Carex pensylvanica*) is sparse and pine needles and oak leaves insulate the soil and trap moisture. Removal of red maple could be accomplished either by appropriately timed prescribed burning or mechanical means. Given the proximity of two adjacent high quality natural community occurrences (Best Bog and Barker Creek Fen), consideration should be given to developing an integrative management plan for this area of Camp Grayling. In addition to prescribed burning, invasive species monitoring and control should be implemented within this site and in adjacent wetlands. For additional information on conservation and management of dry northern forests, see the natural community abstract (Cohen 2002).

Soil: sand, pH 5.5 (5.0)

Invasive species	**Estimated Abundance**	
Scientific Name	**Common Name**	**Estimated Abundance**
Agrostis gigantea	redtop	uncommon
*Hypericum perforatum**	common St. John's wort*	occasional
*Poa compressa**	Canada bluegrass*	locally common

Conservation and Management:

- Conduct prescribed fire on an occasional basis
- Remove red maple either through cutting and herbicide or repeated prescribed fires
- Consider developing an integrated management plan for this portion of Camp Grayling that would encompass Crawford Red Pines, Best Bog, and Barker Creek Fen
- Monitor for and remove invasive species

11. Watson Swamp

Community Type: rich conifer swamp
Rank: G4 S4, apparently secure globally
Alliance: *Thuja occidentalis* Saturated Forest Alliance (I.A.8.N.g)
Location: T26N R06W

M. Kost

Photo 17. Cut stumps are common within the northeast portion of Watson Swamp where several living northern white cedars were aged to approximately 80 and 86 years old.

Site Description:

This 305 acre swamp is located eight miles northeast of Sharon along Melum Road. This swamp was formed on a poorly drained outwash plain along the Manistee River.

This very diverse swamp is dominated by northern white cedar (*Thuja occidentalis*), black spruce (*Picea mariana*), balsam fir (*Abies balsamea*), and red maple (*Acer rubrum*). Other common vascular plant species include paper birch (*Betula papyrifera*), mountain holly (*Nemopanthus mucronata*), creeping snowberry (*Gaultheria hispidula*), swollen sedge (*Carex intumescens*), and marsh marigold (*Caltha palustris*). Many diverse micro-habitats exist within this swamp, especially along the slow flowing streams found throughout the site. The northern portion of the wetland contains an old logging road. This area also contain many cut stumps of northern white cedar. Cores were taken of several live cedars and aged to 80 years (18.5 cm dbh) and 86 years (26.5 cm dbh) old. A total of 121 one vascular plant species were noted in this swamp.

Protection of this wetland should include the creation and maintenance of a vegetated, upland buffer between 100 and 200 meters wide along the east wetland edge. Culverts should be maintained along Mecum Road to maintain natural water flows through the system. Invasive species monitoring and control should be implemented within the wetland and adjacent uplands. For additional information on conservation and management of rich conifer swamps, see the natural community abstract (Kost 2002).

Soil:
0 to 30 cm: peat (pH 7.0)
30 to 150+ cm: peat and large coarse woody debris and many wood fragments

Invasive species **Estimated Abundance**

Scientific Name	**Common Name**	**Estimated Abundance**
Prunella vulgaris	lawn prunella	uncommon
Solanum dulcamara	bittersweet nightshade	uncommon
Typha angustifolia	narrow-leaved cattail	uncommon

Conservation and Management:

- Monitor for and remove invasive species
- Maintain culvert along Mecum Road to allow natural water flow through the wetland
- Maintain a vegetated, upland buffer of between 100 and 200 meters wide

12. Cannon Creek Meadow

Community Type: northern wet meadow
Rank: G4 S4, apparently secure globally
Alliance: *Calamagrostis canadensis* Seasonally Flooded Herbaceous Alliance (V.A.5.N.k)
Location: T25N R06W

M. Kost

Photo 18. The Cannon Creek Meadow is a northern wet meadow that is dominated by tussock sedge (*Carex stricta*) and occurs along Cannon Creek, a tributary to the Manistee River. Reed canary grass, an invasive species, was observed growing along South Sharon Road on the edge of the wetland and should be removed to prevent it from spreading further into the wet meadow.

Site Description:

This 149 acre northern wet meadow is located three miles south of Sharon along South Sharon Road at the southwestern extreme of Camp Grayling property. It lies within a much larger wetland complex on a poorly drained outwash plain. Cannon Creek itself drains to the west into the Manistee River.

This is a dense, sedge-dominated meadow, with meadow sedge (*Carex stricta*) and slender woolly sedge (*Carex lasiocarpa*) being most common. Scattered tamarack (*Larix laricina*), bog birch (*Betula pumila*), shrubby cinquefoil (*Potentilla fruticosa*), sweet bay (*Myrica gale*), meadowsweet (*Spiraea alba*), and blue joint grass (*Calamagrostis canadensis*) are also characteristic. Forty four vascular plant species were noted in this wet meadow. Surrounding the meadow are zones of willow (*Salix*)-dominated swamp and hardwood-conifer swamps. The immediately adjacent slopes contain many seeps with a highly diverse flora. Historically, adjacent uplands were dominated by oak and pine-dominated forest. Today, open-canopy, oak-dominated forest is characteristic.

Protection of this sensitive wetland complex should include establishing a 200 meter upland buffer where no timber management activities take place. Emphasis should be placed on protecting the seepages adjacent to the wetland complex. Invasive species monitoring and control should be implemented within the wetland and adjacent uplands. In particular, reed canary grass (*Phalaris arundinacea*), an invasive species, was observed growing along South Sharon Road on the edge of wetland and should be removed to prevent it from spreading further into the wetland. Because fire helps maintain open conditions and species diversity in wetland ecosystems, fires occurring within the uplands should be allowed to carry into the wetland. For additional information on conservation and management of northern wet meadows, see the natural community abstract in Appendix 6.

Soil:
0 to 30 (150+) cm: fibric sedge peat (i.e., depth of peat varies from 30 cm to > 150 cm)
30 to 140 cm: grey, coarse-textured sand with some organics
140 to 150+ cm: marl

Water table: 10 cm standing water above soil surface

Invasive species	**Estimated Abundance**	
Scientific Name	**Common Name**	**Estimated Abundance**
*Phalaris arundinacea**	reed canary grass*	locally abundant

Conservation and Management:
- Monitor for and remove invasive species
- Maintain a 200 meter wide vegetated buffer around wetland
- Protect seepage areas along sloping edges of wetland
- Conduct prescribed fire in adjacent uplands on an occasional basis and allow fire to spread into wetland

13. Chub Creek Swamp

Community Type: northern shrub thicket
Rank: G4 S4, apparently secure globally
Alliance: *Alnus incana* Seasonally Flooded Shrubland Alliance (III.B.2.N.e)
Location: T29N R02W

M. Kost

Photo 19. The Chub Creek Swamp is comprised of a northern shrub thicket that grades from shrubby wet meadow along Chub Creek to forested conifer swamp (rich conifer swamp) near the edge of the adjacent uplands. Periodic fires and flooding by beaver probably kept this wetland in a continual flux between wet meadow, shrub thicket, and rich conifer swamp.

Site Description:

This 123 acre wetland is located just northwest of Rosecrans Hill at the northern extreme of Camp Grayling property. It lies on a poorly drained outwash plain at the confluence of Chub creek and the North Branch of the Au Sable River. Approximately half of this wetland, north of the river, is outside of Camp Grayling.

Dominant species in this very diverse wetland include speckled alder (*Alnus rugosa*), bog birch (*Betula pumila*), sweet bay (*Myrica gale*), shining willow (*Salix lucida*), shrubby cinquefoil (*Potentilla fruticosa*), sedge (*Carex aquatilis*), sedge (*Carex flava*), slender woolly sedge (*Carex lasiocarpa*), wild rice (*Zizania aquatica*), and tall goldenrod (*Solidago altissima*). Tamarack (*Larix laricina*) is scattered throughout the shrub swamp and becomes dominant around the margins. A total of 93 vascular plant species were noted in this wetland. An active bald eagle (*Haliaeetus leucocephalus*) nest is located at the north end of this complex.

Protection of this wetland should include the maintenance of an upland buffer zone for 100 meters along all sides of the wetland. Invasive species monitoring and control should be implemented within the wetland and adjacent uplands. Fires occurring within the adjacent uplands should be allowed to carry into the wetland. For additional information on conservation and management of northern shrub thicket, see the natural community abstract in Appendix 7.

Soil:
0 to 20 cm: fibric peat
20 to 100 cm: coarse woody debris in matrix of peat
100 to 150+ cm: sapric peat (muck)

Invasive species: none observed

Conservation and Management:
- Monitor for and remove invasive species
- Maintain a 100 meter vegetated buffer around wetland
- Allow fires occurring in adjacent upland to carry into wetland

14. Beaver Creek

Natural Community Type: northern shrub thicket

Rank: G4 S4, apparently secure globally

Alliance: *Alnus incana* Seasonally Flooded Shrubland Alliance (III.B.2.N.e)

Location: T25N R04W (scale 1:24,000)

M. Kost

Photo 20. Tamarack has become very abundant within the Beaver Creek northern shrub thicket. In the absence periodic natural disturbances such as fire, beaver flooding, or insect outbreaks (e.g., larch sawfly infestation), the northern shrub thicket will eventually succeed to forested wetland.

Site Description:

This 41 acre wetland is located nearly two miles west of Military Road, and just south of Fletcher Road. It lies in a poorly drained portion of a large, flat outwash plain that is drained by Beaver Creek.

Tamarack (*Larix laricina*) and black spruce (*Picea mariana*) are found throughout the wetland, while jack pine (*Pinus banksiana*) is concentrated along the wetland edge and in the adjacent uplands. Dominant plant species in the wetland include speckled alder (*Alnus rugosa*), leatherleaf (*Chamaedaphne calyculata*), bog birch (*Betula pumila*), willow (*Salix* spp.), meadowsweet (*Spiraea alba*), black choke berry (*Aronia prunifolia*), red osier dogwood (*Cornus stolonifera*), lake sedge (*Carex lacustris*), and blue joint grass (*Calamagrostis canadensis*). Sphagnum mosses (*Sphagnum* spp.) are also abundant in this wetland. A total of 71 vascular plant species were noted. This shrub thicket is part of a larger wetland complex, which extends both to the east and west. To the west, much of the area has been logged and the water level has been impacted by road construction. The adjacent uplands contain numerous oil/gas wells scattered throughout a second growth, jack pine-dominated forest.

The steady, natural flow of water through this system is necessary to maintain the integrity of the wetland. Thus, protection of this wetland should include the installation and maintenance of culverts in the two-track road that passes along its west side. This area also contains reed canary grass (*Phalaris arundinacea*), an invasive species, that should be removed to prevent it from spreading further into the shrub swamp. Invasive species monitoring and control should be implemented within the wetland and adjacent uplands. A 100 meter wide vegetated upland buffer should be maintained on all sides of this wetland. Fires occurring within the adjacent uplands should be allowed to carry into the wetland. For additional information on conservation and management of northern shrub thicket, see the natural community abstract in Appendix 7.

Soil:
0 to 100 cm: fibric peat (pH 6.5) with large coarse woody debris
100 to 110 cm: coarse-textured, light colored sand.
pH of sphagnum hummocks: 4.0 to 4.5

Water table: varies from approximately 10 cm above surface on east side of wetland between sedge hummocks to 10 cm below soil surface on west side of wetland. Peat and underlying sand are very cold, indicating contact with flowing groundwater.

Invasive species	**Estimated Abundance**	
Scientific Name	**Common Name**	**Estimated Abundance**
*Phalaris arundinacea**	reed canary grass*	locally abundant

Conservation and Management:

- Monitor for and remove invasive species
- Consider conducting prescribed fire in some portions of the adjacent uplands on an occasional basis and allowing fire to spread into wetland. **Note**: active gas wells occur in some portions of the adjacent upland should be protected from fire.
- Install and maintain culvert in two-track road along west side of wetland
- Maintain 100 meter vegetated upland buffer around wetland

DISCUSSION

Several significant changes were observed within the 14 communities we studied. Water levels are now significantly lower in most wetlands than when first observed in the early 1990s. While invasive species have not yet caused significant degradation in any of the communities as of yet, most now contain small infestations that threaten to degrade ecological integrity. The continued affects of fire suppression were very apparent within many of the communities we surveyed. Fortunately, damage by ORVs within the high quality natural communities was not severe.

Water Level Changes

In most of the wetlands surveyed in 2004 it was very apparent that water levels were much lower than when these communities were first documented in the early 1990s. These observations are consistent with decreases in water levels recorded in wetlands throughout the Upper Great Lakes Region. Regional water levels declined sharply in the late 1990s and have since risen slightly. Our findings indicate that groundwater is an important source of water input for most wetlands at Camp Grayling.

Invasive Species

Invasive species pose a major threat to species and habitat diversity and ecological integrity within several high quality natural communities on Camp Grayling. By outcompeting and replacing native species, invasives change species composition, alter vegetation structure, and reduce native species diversity, often causing local or even complete extinction of native species (Harty 1986). Invasive exotic species can also upset delicately balanced ecological processes such as trophic relationships, interspecific competition, nutrient cycling, soil erosion, hydrologic balance, and solar insolation (Bratton 1982). Lastly, exotic invasive species often have no natural predators and spread aggressively through rapid sexual and asexual reproduction.

While numerous invasive species occur within the high quality natural communities, giant reed (*Phragmites australis*), reed canary grass (*Phalaris arundinace*a), spotted knapweed (*Centaurea maculosa*), common St. John's wort (*Hypericum perforatum*), and Canada bluegrass (*Poa compressa*) currently pose the greatest threat because of their ability to invade intact communities and quickly dominate an area. In addition to the species listed above, several other highly invasive species have the potential to become established on Camp Grayling including garlic mustard (*Alliaria petiolata*), glossy buckthorn (*Rhamnus frangula*), common buckthorn (*Rhamnus cathartica*), exotic honeysuckle (*Lonicera morrowii*, *L. tatarica L.* X*bella, L. maackii,* etc.), autumn olive (*Elaeagnus umbellata*), oriental bittersweet (*Celastrus umbellata*), and purple loosestrife (*Lathyrus salicaria*). Because new introductions of invasive, exotic species continue to occur regularly, it is imperative that a systematic and sustained effort be undertaken to monitor for and control invasive species on Camp Grayling.

Fire Suppression

Camp Grayling occurs within the High Plains Subsection, one of the most fire prone regions of Michigan (Albert 1995). Most natural communities that occur within the High Plains are well adapted to fire, which is an ecological process that maintains the biological integrity of the region's varied ecosystems. Where it can be safely implemented, prescribed fire should be used in managing both upland and wetland ecosystems on Camp Grayling. Because fire is an important ecological process for maintaining species and habitat diversity in both upland and wetland ecosystems, fires occurring within the uplands should be allowed to carry into adjacent wetlands whenever possible.

The ecological process of fire has played a critical role in shaping the vegetation of the upper Midwest region (Curtis 1959, Davis 1979, Kline and Cottam 1979, Dorney 1981, Grimm 1984, Dorney and Dorney 1989). Prior to European settlement, the occurrence of fire, whether due to lightning strikes or indigenous cultures, was frequent in many types of ecosystems (Dorney

1981, Guyette and Cutter 1991). Since then, the incidence of fire in all natural communities has been greatly reduced (Curtis 1959). As a consequence, many natural areas have experienced significant changes in their species composition (Cottam 1949, Curtis 1959, Davis 1979, Grimm 1984, McCune and Cottam 1985, Abrams and Nowacki 1992, McClain et al. 1993, Motzkin et al. 1993). In an effort to preserve biodiversity and restore natural communities, fire has been reintroduced as a management tool to many natural areas (Vogl 1964, White 1983, Vora 1993, Henderson and Statz 1995, Bowles et al. 1996).

Plant communities, whether upland or lowland, benefit from prescribed fire in several ways. Depending on the season and intensity of a burn, prescribed fire may be used to decrease the cover of exotic, cool-season grasses and woody species, and increase the cover of warm-season grasses and native forbs (White 1983, Abrams and Hulbert 1987, Tester 1989, Anderson and Schwegman 1991, Collins and Gibson 1990, Glenn-Lewin et al. 1990). Prescribed fire helps reduce litter levels, allowing sunlight to reach the soil surface and stimulate seed germination and enhance seedling establishment (Daubenmire 1968, Hulbert 1969, Knapp 1984, Tester 1989, Anderson and Schwegman 1991, Warners 1997). Important plant nutrients (e.g., N, P, K, Ca, and Mg) are elevated following prescribed fire (Daubenmire 1968, Viro 1974, Reich et al. 1990, Schmalzer and Hinkle 1992), which contributes to increased plant biomass, flowering, and seed production (Laubhan 1995, Abrams et al. 1986, Warners 1997, Kost and De Steven 2000). Prescribed fire can also significantly increase seed bank expression and help rejuvenate seed banks, which may be especially important for maintaining species diversity within wetlands (Leach and Givnish 1996, Kost and De Steven 2000).

Impacts to faunal communities should also be considered when planning a prescribed burn. Dividing a large area into smaller burn units that can be burned in alternate years or seasons can protect populations of many species. This allows unburned units to serve as refugia for immobile invertebrates and slow moving amphibian and reptile species. When burning larger areas it may be desirable to strive for patchy burns by igniting during times of high relative humidity. As mentioned above, the unburned patches may then serve as refugia and thus facilitate recolonization of burned patches by fire-sensitive species. Burning under overcast skies and when air temperatures are cool (<55°F) can help protect reptiles, since they are less likely to be found basking above the surface when conditions are cloudy and cool. Lastly, impacts to reptiles may also be minimized by conducting burns during the dormant season (late October through March).

ORV Impacts

Continued efforts to restrict ORV use to designated areas are having positive impacts on ecological integrity and should be continued. ORV use was observed in only two (14%) of the 14 natural communities we studied, both of which were intermittent wetlands (The Doughnut and Lake Margrethe North). Continuing efforts to educate ORV users and discourage their use in wetlands and other undesignated areas will be an important component of any long-term effort to maintain biodiversity on Camp Grayling.

CONCLUSION

In the decade or more since the 14 high quality natural communities were documented many have experienced relatively significant changes. Water levels have dropped significantly within most wetlands since the early 1990s. Invasive species now pose a significant threat to several natural communities. In particular, if left unchecked, leafy spurge is likely to degrade the mesic sand prairie and rare species populations at the Portage Creek Complex. The continued affects of fire suppression have resulted in canopy closure and the buildup of a thick layer of leaf litter, which stifles seed germination and establishment, especially in wetlands.

These results indicate that a systematic and sustained effort should be undertaken to monitor for and control invasives, especially within the high quality natural communities and in the surrounding landscapes. Because fire is an important ecological process for maintaining species and habitat diversity in both upland and wetland ecosystems, wherever possible, prescribed fire should be used to manage these communities and the surrounding landscape. Fires occurring in the uplands should be allowed to carry into the wetlands when possible to bolster seed bank expression and native species diversity. Thanks to ongoing control and education efforts, ORVs have caused relatively minor damage to the high quality natural communities in the past decade. Efforts to discourage ORV use in undesignated areas, especially wetlands, will be an important component of any long-term effort to maintain biodiversity on Camp Grayling.

ACKNOWLEDGEMENTS

Funding for this project was made available through a grant from the Michigan Department of Military and Veterans Affairs. We wish to extend our sincere gratitude to the many Camp Grayling staff who provided access to fields sites, logistical support, and kept us safe from harms way on a very busy military training facility. The staff at Range Control were consistently helpful and accommodating, which was a pleasant contrast to the sometimes grueling summer field conditions. Larry Jacobson, Greg Huntington, and John Hunt deserve our sincerest appreciation for initiating this project and providing guidance and support throughout its execution. We thank Phyllis Higman for taking the lead role in coordinating efforts between Camp Grayling and MNFI staff and for her expert guidance in the field and throughout this project. We are grateful for the additional administrative support provided by the following MFNI staff: Sue Ridge, Lyn Scrimger, Connie Brinson, and Pat Brown. Jeff Lee conducted final editing and formatting of the report.

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APPENDICES. NATURAL COMMUNITY ABSTRACTS

Appendix 1. Mesic Sand Prairie

Overview: Mesic sand prairie is a native grassland community that is typically dominated by little bluestem (*Andropogon scoparius*), big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*), and/or prairie dropseed (*Sporobolus heterolepis*) and occurs on sandy loam, loamy sand, or sand soils on nearly level glacial outwash. Sites that support mesic sand prairie are seasonally wet, with high water tables occurring in the spring followed by drought conditions in late summer and fall. Thus, the community contains species from a broad range of moisture classes such as those more typically associated with wet-mesic prairie, mesic prairie, woodland prairie, and dry sand prairie. Areas dominated by native grasses with less than one mature tree per acre are considered prairie (Curtis 1959).

Global and State Rank: S1/G2G3

Range: Mesic sand prairie occurs in IL, IN, MI, OH, WI, and southern Ontario. (Faber-Langendoen 2001). In Michigan, this community has been documented in both the southern and northern Lower Peninsula. In southern Lower Michigan, mesic sand prairie occurs within the Interlobate Region, where it is found on glacial outwash in Oakland, Washtenaw, and Van Buren counties. Within the northern Lower Peninsula, mesic sand prairie occurs on glacial outwash (Oceana and Lake counties) and on an old glacial lakebed within an outwash plain (Crawford County) (Higman et al 1995). Historically, the community likely occurred as small patches within fire prone landscapes on sandy soils with a high water table and as an ecotone between savanna (e.g., oak opening, oak barrens, oak-pine barrens, bur oak plains,) and non-forested wetlands.

Rank Justification: In the early to mid 1800s, the southern Lower Peninsula supported approximately 73,000 acres (29,500 ha) of upland prairie, which included pockets of mesic sand prairie, mesic prairie, woodland prairie, dry sand prairie, and hillside prairie. The Michigan Natural Features Inventory database currently includes eight element occurrences of mesic sand prairie, which total to 398 acres (161 ha) and range in size from 2 to 115 acres (>1 to 47 ha). It is difficult to reliably determine the total acreage of mesic sand prairie in Michigan in the 1800s. However, based on comparisons of the total acreage of all upland prairie element occurrences in Lower Michigan today (1,463 acres, 592 ha) with that found in the early to mid 1800s (provided above), it appears that only 2% of the original upland prairie remains intact in all of Lower Michigan.

Landscape and Abiotic Context: Mesic sand prairie and lakeplain mesic sand prairie, which has been documented on the lakeplain in southeast Michigan, differ in that the hydrology of lakeplain mesic sand prairie is strongly influenced by changes in the Great Lakes water levels (Albert and Kost 1998). However, both communities experience seasonal water table fluctuations, with the wettest conditions occurring in spring and driest periods in late summer and fall. Prolonged spring inundation may occur in the wettest portions of some mesic sand prairies.

Soils supporting mesic sand prairie are sandy loam or occasionally loamy sand, loamy fine sand, or fine sand, with pH ranging form 5.4 to 7.3 (ave. pH 5.5) and water retaining capacity ranging from 31% to 62% (ave. 43%) (Chapman 1984). The mesic condition of the sandy soils is facilitated by a high water table and, in some sites, by a relatively high organic content within the sand matrix, which increases the water holding capacity of soil.

In the 1800s, mesic sand prairie in Michigan occurred as small patches of grassland within and between fire prone communities. The community occupied sandy sites with high water tables such as those occurring in shallow depressions within outwash plains and on old glacial lakebeds, abandoned stream channels, and river terraces. Mesic sand prairie also occurred as an ecotone between fire-dependent uplands and open wetlands (e.g., wet-mesic prairie, wet prairie, prairie fen, northern fen, southern wet meadow, northern wet meadow, intermittent wetland, coastal plain marsh, emergent marsh).

Natural Processes: A high water table in the spring followed by drought-like conditions in the late summer and fall produces a diverse floristic composition of species for mesic sand prairie with species representing a broad range of moisture tolerances. In addition to seasonal water level fluctuations, longer term changes in the regional water table also influence the community composition.

As in other prairie and savanna communities, fire played a critical role in maintaining open conditions in mesic sand prairie. The frequency and intensity of fire depended on a variety of factors including the type and volume of fuel, topography, presence of natural firebreaks, and density of Native Americans (Chapman 1984). In general, the probability of wide-ranging fire increases in level topography like large outwash plains (Chapman 1984). Carried by wind, fires moved across the outwash plains, through graminoid-dominated wetlands, and up slopes of end moraines and ground moraines.

While occasional lightning strikes resulted in fires that spread across the landscape, Native Americans were the main sources of ignition. There are many early accounts of Native Americans intentionally setting fires to accomplish specific objectives (see Day 1953, Curtis 1959, Thompson and Smith 1970, Chapman 1984, Denevan 1992, Kay 1995). Native Americans intentionally set fires in the fall to clear briars and brush and make the land more easily passable. Frequent fires kept the land open, increasing both short- and long-range visibility, which facilitated large game hunting and provided a measure of safety from surprise attacks by neighboring tribes. Fire was used to increase productivity of berry crops and agricultural fields. As a habitat management tool, fires were used to maintain high quality forage for deer, elk, woodland caribou, bison and other game species. It was also used as a hunting tool to both drive and encircle game. During warfare, fire was strategically employed to drive away advancing enemies, create cover for escape, and for waging attacks.

In addition to maintaining open conditions, fire plays a critical role in maintaining species diversity. A recensus of 54 prairie remnants in Wisconsin found that 8% to 60% of the original plant species recorded at the sites had been lost over time (32 to 52 years) even though the sites appeared relatively undisturbed (Leach and Givnish 1996). The authors suggest the decline in diversity was a result of taller vegetation outcompeting species with small stature, those with small seeds (e.g., orchids), and those that rely on nitrogen-fixing symbioses such as members of the legume family (*Fabaceae*) (e.g., lupine (*Lupinus perennis*), wild indigo (*Baptisia* spp.), bush clover (*Lespedeza* spp.), and tick-trefoil (*Desmodium* spp.)). Because fire maintains open conditions and burns off accumulated leaf litter, species that require open microsites for seedling establishment and growth such as those with small seeds or small statures, are able to garner enough space and light to coexist with taller, denser vegetation. In the absence of frequent fires, small species are outcompeted by taller and denser vegetation, and small-seeded species with low food reserves have difficulty growing through thick litter. The decline in species diversity is especially pronounced in mesic and wet community types where biomass accumulates rapidly. Because fire volatilizes much of the nitrogen stored in combustible vegetation, frequent burning also favors species that form nitrogen-fixing symbioses (e.g., legumes and rhizobium bacteria) by providing a competitive edge not found in unburned sites (Leach and Givnish 1996).

Fire also helps maintain species diversity by facilitating expression of the soil seed bank and promoting seed germination and establishment. By consuming accumulated and standing leaf litter, fire increases light availability to the soil surface and increases diurnal temperature fluctuations, both of which trigger seed germination. Critical microsites for seed germination and seedling establishment are also created when litter levels are reduced by fire.

Through burning accumulated litter and dead, standing vegetation, fire increases the availability of many important plant nutrients (e.g., N, P, K, Ca and Mg), which are thought to contribute to higher plant biomass, increased flowering and seed production, and greater palatability to herbivores following a burn (Vogl 1964, Daubenmire 1968, Viro 1974, Vogl 1974, Smith and Kadlec 1985, Abrams et al. 1986, Collins and Gibson 1990, Reich et al. 1990, Schmalzer and Hinkle 1992, Timmins 1992, Laubhan 1995, Warners 1997).

While this discussion has focused on plants it is important to note that these species serve as host plants for a variety of insects and the structure of open grasslands is critical to a wide variety of animal species, many of which are considered rare or declining today (see Other Noteworthy Species section).

Ants, particularly the genus *Formica*, play an important role in mixing and aerating prairie soils (Curtis 1959, Trager 1998). Large ant mounds, which may measure half a meter in height and over one meter wide and number 40 to 50 per acre are especially conspicuous following a prairie fire (Curtis 1959). Because of their abundance and frequent habit of abandoning old mounds and building of new ones, ants overturn large portions of prairies in a relatively short time (Curtis 1959). Other important species contributing soil mixing and aeration include moles, voles, mice, skunks, ground hogs, ground squirrels, and badgers (Curtis 1959).

Historically, large herbivores such as bison significantly influenced plant species diversity in Michigan prairie and oak savanna ecosystems. The diet of bison consists of 90% to 95% grasses and sedges (Steuter 1997). As bison selectively forage on grasses and sedges, they reduce the dominance of graminoids and provide a competitive advantage to forb species. The activities of bison, which includes wallowing and trampling, promotes plant species diversity by creating microsites for seed germination and seedling establishment and reducing the dominance of robust perennials (Steuter 1997).

Vegetation Description: Unfortunately, no detailed ecological study of mesic sand prairie was completed in Michigan before the nearly total demise of the community. What information is available comes from a detailed study of prairie communities in Michigan by Chapman (1984) and data from Michigan Natural Features Inventory element occurrence records.

The vegetation of mesic sand prairie supports a sparse to moderately dense growth of low to medium height vegetation with patches of bare soil evident (Chapman 1984). The community is dominated by the following prairie grasses, which can occur in varying degrees of dominance to one another: little bluestem, big bluestem, Indian grass, and prairie dropseed. Pennsylvania sedge (*Carex pensylvanica*) may also be co-dominant where drought-like conditions in late summer and fall are a common occurrence. Within Michigan, species composition varies across ecoregions. The table below summarizes species composition of mesic sand prairie for the High Plains subsection in northern Lower Michigan, the western northern Lower Peninsula (Lake and Oceana counties), and the Interlobate Region of southern Lower Michigan. While species composition varies regionally, it is clear that much overlap exists among regions. Also evident from the list below is that within each region, the community is comprised of species with a wide range of wetland coefficients (e.g., moisture tolerances), indicating that large fluctuations in local and regional water tables strongly influences community composition.

Table 1. Mesic sand prairie species composition by region.

Scientific Name	**Common Name**	**High Plains**	**Western Lower Peninsula**	**Southern Interlobate**
Grasses, Sedges, and Rushes				
Agropyron trachycaulum	slender wheat grass	x		
Andropogon gerardii	big bluestem	x	x	x
Andropogon scoparius	little bluestem grass	x	x	x
Aristida purpurascens	three awned grass		x	x

Table 1. (continued)

Scientific Name	Common Name	High Plains	Western Lower Peninsula	Southern Interlobate
Grasses, Sedges, and Rushes				
Calamagrostis canadensis	blue joint grass	x	x	x
Danthonia spicata	poverty grass; oatgrass	x	x	x
Eragrostis spectabilis	purple love grass		x	x
Glyceria striata	fowl manna grass	x	x	
Panicum boreale	northern panic grass	x	x	
Panicum implicatum	panic grass	x		x
Panicum virgatum	switch grass	x	x	
Sorghastrum nutans	Indian grass		x	x
Spartina pectinata	cordgrass		x	x
Sporobolus heterolepis	prairie dropseed	x	x	x
Carex buxbaumii	sedge	x	x	
Carex flava	sedge	x	x	
Carex pellita	sedge	x	x	
Carex pensylvanica	sedge	x	x	x
Carex stricta	sedge	x	x	
Eleocharis elliptica	golden seeded spike rush	x	x	
Schoenoplectus tabernaemontani	softstem bulrush		x	x
Scirpus cyperinus	wool grass	x	x	
Juncus balticus	rush	x	x	x
Juncus canadensis	Canadian rush		x	x
Juncus effusus	soft stemmed rush	x	x	
Juncus greenei	Greene's rush	x	x	
Juncus tenuis	path rush		x	x
Juncus vaseyi	Vasey's rush	x	x	
Forbs				
Artemisia campestris	wormwood		x	x
Aster ericoides	heath aster		x	x
Aster umbellatus	tall flat top white aster	x		x
Campanula rotundifolia	harebell	x	x	x
Castilleja coccinea	Indian paintbrush	x		x
Comandra umbellata	bastard toadflax	x	x	x
Coreopsis lanceolata	sand coreopsis	x		
Coreopsis tripteris	tall coreopsis			x
Euphorbia corollata	flowering spurge		x	x
Euthamia graminifolia	grass leaved goldenrod	x	x	x
Fragaria virginiana	wild strawberry	x	x	x
Galium boreale	northern bedstraw			x
Helianthemum canadense	common rockrose	x		x
Helianthus divaricatus	woodland sunflower		x	x
Helianthus giganteus	tall sunflower			x
Helianthus occidentalis	western sunflower		x	x
Heuchera americana	alum root			x
Hieracium gronovii	hairy hawkweed		x	
Hieracium longipilum	long bearded hawkweed		x	x

Table 1. (continued)

Scientific Name	Common Name	High Plains	Western Lower Peninsula	Southern Interlobate
Forbs				
Hieracium venosum	rattlesnake weed	x		
Houstonia longifolia	long leaved bluets	x		
Iris versicolor	wild blue flag	x		
Iris virginica	southern blue flag		x	x
Krigia biflora	false dandelion			x
Lechea villosa	hairy pinweed		x	x
Liatris aspera	rough blazing star	x	x	x
Lithospermum caroliniense	plains puccoon		x	x
Lobelia cardinalis	cardinal flower	x	x	
Lobelia spicata	pale spiked lobelia	x	x	x
Lupinus perennis	wild lupine		x	x
Lycopus americanus	common water horehound	x	x	
Maianthemum canadense	Canada mayflower	x		x
Monarda fistulosa	wild bergamot	x	x	x
Oenothera perennis	small sundrops	x		x
Phlox pilosa	prairie phlox			x
Polygonum amphibium	water smartweed		x	
Potentilla simplex	old field cinquefoil	x		x
Pycnanthemum virginianum	common mountain mint		x	x
Rubus pubescens	dwarf raspberry	x		x
Rudbeckia hirta	black eyed susan		x	x
Senecio pauperculus	balsam ragwort	x	x	x
Sisyrinchium albidum	common blue eyed grass		x	x
Solidago canadensis	Canada goldenrod		x	x
Solidago houghtonii	Houghton's goldenrod	x		
Solidago juncea	early goldenrod		x	x
Solidago nemoralis	old field goldenrod		x	x
Solidago rigida	stiff goldenrod			x
Solidago uliginosa	bog goldenrod	x	x	
Tephrosia virginiana	goat's rue		x	x
Triadenum fraseri	marsh St. John's wort		x	
Vernonia missurica	Missouri ironweed			x
Zigadenus glaucus	white camas	x		
Ferns and Fern Allies				
Thelypteris palustris	marsh fern	x	x	
Equisetum hyemale	scouring rush		x	x
Equisetum laevigatum	smooth scouring rush	x		x
Trees and Shrubs				
Pinus strobus	white pine	x	x	x
Pinus banksiana	jack pine	x	x	x
Pinus resinosa	red pine	x	x	
Prunus serotina	wild black cherry	x		x
Larix laricina	tamarack	x		
Quercus ellipsoidalis	Hill's oak		x	

Table 1. (continued)

Scientific Name	Common Name	High Plains	Western Lower Peninsula	Southern Interlobate
Trees and Shrubs				
Quercus macrocarpa	bur oak		x	
Quercus alba	white oak		x	x
Populus tremuloides	quaking aspen		x	x
Quercus velutina	black oak		x	
Chamaedaphne calyculata	leatherleaf	x		
Hypericum kalmianum	Kalm's st. john's wort	x	x	x
Rosa carolina	pasture rose	x	x	x
Rubus flagellaris	northern dewberry	x	x	x
Rubus hispidus	swamp dewberry	x	x	
Salix humilis	prairie willow	x	x	x
Spiraea alba	meadowsweet	x	x	x

Michigan Indicator Species:
High Plains Subsection: prairie dropseed (SC), Vasey's rush (*Juncus vaseyi*) (T), Clinton's bulrush (*Trichophorum clintonii*) (SC), and Houghton's goldenrod (*Solidago houghtonii*) (T, LT).

Western Northern Lower Peninsula: prairie dropseed (SC) and Greene's rush (*Juncus greenei*).

Southern Interlobate Region: prairie dropseed (SC), Clinton's bulrush (*Trichophorum clintonii*) (SC), and colic root (*Aletris farinosa*).

Other Noteworthy Species: Rare plant species associated with mesic sand prairie are listed below along with their status, which is indicated by the following abbreviations: X, extirpated from state; E, State Endangered; T, State Threatened; SC, State Species of Special Concern; LT, Federally Threatened.

Scientific Name	Common Name	Status
Asclepias hirtella	tall green milkweed	T
Baptisia lactea	white false indigo	SC
Eryngium yuccifolium	rattlesnake-master	T
Helianthus mollis	downy sunflower	T
Juncus vaseyi	Vasey's rush	T
Scleria triglomerata	tall nut-rush	SC
Solidago houghtonii	Houghton's goldenrod	T, LT
Sporobolus heterolepis	prairie dropseed	SC
Strophostyles helvula	trailing wild bean	SC
Trichophorum clintonii	Clinton's bulrush	SC
Trichostema dichotomum	bastard pennyroyal	T
Viola novae-angliae	New England violet	T

Rare animal species associated with mesic sand prairie include the following:

Grassland birds: Henslow's sparrow (*Ammodramus henslowii*) (SC), grasshopper sparrow (*Ammodramus savannarum*) (SC), short-eared owl (*Asio flammeus*) (E), long-eared owl (*Asio otus*) (T), northern harrier (*Circus cyaneus*) (SC), migrant loggerhead shrike (*Lanius ludovicianus migrans*) (E), Dickcissel (*Spiza americana*) (SC), western meadowlark (*Sturnella neglecta*) (SC), and barn owl (*Tyto alba*) (E).

Insects: American burying beetle (*Nicrophorus americanus*) (E/LE), blazing star borer (*Papaipema beeriana*) (SC), Culver's root borer (*Papaipema sciata*) (SC), Silphium borer (*Papaipema silphii*) (T), red-legged spittlebug (*Prosapia ignipectus*) (SC), Sprague's pygarctia (*Pygarctia spraguei*) (SC), grizzled skipper (*Pyrgus centaureae wyandot*) (SC), phlox moth (*Schinia indiana*) (E), and Spartina moth (*Spartiniphaga inops*) (SC).

Mammals: prairie vole (*Microtus ochrogaster*) (E).

Reptiles: eastern massasauga (*Sistrurus c. catenatus) (SC and Federal Candidate Species)*, black rat snake *(Elaphe o. obsoleta*) (SC), Kirtland's snake (*Clonophis kirtlandii*) (T), and eastern box turtle (*Terrapene c. carolina*) (SC). Spotted turtle (*Clemmys guttata*) and Blanding's turtle (*Emydoidea blandingii*) may nest in mesic sand prairie when it occurs adjacent to wetlands.

Conservation and Management: Efforts should be made to identify, protect, and manage remnants of mesic sand prairie. Several studies to identify prairie remnants in Michigan have been undertaken and most remnants are very small and/or occur as narrow strips adjacent to railroads (Hauser 1953, Scharrer 1972, Thompson 1970, 1975, and 1983, Chapman 1984). The small size and poor landscape context of most prairie remnants makes large-scale restoration of existing prairies nearly impossible.

Managing mesic sand prairie requires frequent burning, from annual to every two to three years. Longer burn intervals will result in tree and tall shrub encroachment. Prescribed burning is required to protect and enhance plant species diversity and prevent encroachment of trees and tall shrubs, which outcompete light demanding prairie plants. In prairie remnants where fire has been excluded for long periods (e.g., decades), local extinctions of plant species are common (Leach and Givnish 1996).

In addition to prescribed fire, brush cutting accompanied by herbicide application to cut stumps is an important component of prairie restoration. While fires frequently kill woody seedlings, long established trees and tall shrubs like black cherry (*Prunus serotina*) and dogwoods (*Cornus* spp.) typically resprout and can reach former levels of dominance within two to three years. Applying herbicide to the cut stumps will prevent resprouting.

To reduce the impacts of management on fire-intolerant species it will be important to consider a rotating schedule of prescribed burning in which adjacent management units are burned in alternate years. This is especially important when planning burns in remnant prairies. Insect species that are restricted to these habitats have already experienced severe losses in the amount of available habitat due to forest succession brought on by years of fire suppression. By burning adjacent management units in alternate years, insect species from unburned units may be able to recolonize burned areas (Panzer et al. 1995). Avian species diversity is also thought to be enhanced by managing large areas of grassland as a mosaic of burned and unburned patches (Herkert et al. 1993).

Prairie ants (*Formica*) are an extremely important component of grassland communities and research indicates that they respond with population increases to restoration activities, especially prescribed fire (Trager 1998). Prescribed burning precipitates changes in the dominance of ant species from carpenter and woodland ants (*Camponotus* and *Aphaenogaster*) to prairie ants because it reduces woody vegetation and detritus used by the arboreal and litter- and twig-nesting species in favor of species restricted to grassland habitats (Trager 1998). Restorations involving prairie plantings near old fields or remnant prairies are typically colonized by several species of prairie ants within a few years (Trager 1990).

Controlling invasive species is a critical step in restoring and managing mesic sand prairie. By outcompeting native species, invasives alter vegetation structure, reduce species diversity, and upset delicately balanced ecological processes such as trophic relationships, interspecific competition, nutrient cycling, soil erosion, hydrologic balance, and solar insolation (Bratton 1982, Harty 1986). At present some of the most aggressive invasive species that threaten biodiversity of grassland communities include reed canary grass (*Phalaris arundinacea*), white and yellow sweet clover (*Melilotus alba* and *M. officinalis*), autumn olive (*Elaeagnus umbellata*), multiflora rose (*Rosa multiflora*), common buckthorn (*Rhamnus cathartica*), Eurasian honeysuckles (*Lonicera maakii*, *L. morrowii*, *L. tartarica*, *L.* x *bella*.), and black locust (*Robinia pseudoacacia*).

In addition to reestablishing ecological processes such as fire, most restoration sites will require the reintroduction of appropriate native species and genotypes. Plants can be reintroduced through both seeding and seedling transplants. Small, isolated prairie remnants may harbor plant populations that have suffered from reduced gene flow. Restoration efforts at isolated prairie remnants should consider introducing seeds collected from nearby stocks to augment and maintain genetic diversity of remnant plant populations. The Michigan Native Plant Producers Association may be a helpful resource for locating sources prairie plants with Michigan genotypes (http://www.nohlc.org/MNPPA.htm).

Several helpful guides are available for restoring prairies and starting prairie plants from seed (Packard and Mutel 1997, Nuzzo 1976, Schulenberg 1972). See Packard and Mutel (1997) for a comprehensive treatment of the subject and additional references.

Restoration and management of grasslands such as mesic sand prairie are critically important to grassland birds, which have suffered precipitous population declines due to habitat loss and changing agricultural practices (e.g., early mowing of hay fields). Detailed habitat management guidelines for grassland birds have been developed by Herkert et al. (1993) and Sample and Mossman (1997). Listed below are several of the recommendations suggested by Herkert et al. (1993) (see publication for complete list of management guidelines).

1. Avoid fragmentation of existing grasslands.
2. Grassland restorations aimed at supporting populations of the most area-sensitive grasslands birds should be at least 125 acres and preferably more than 250 acres in size. Area sensitive species requiring large patches of grassland (>100 acres) include northern harrier (SC), bobolink (*Dolichonyx oryzivorus*), savannah sparrow (*Passerculus sandwichensis*), Henslow's sparrow (SC), short-eared owl (E), and barn owl (E) (Herkert et al. 1993, Sample and Mossman 1997). Patches of grassland less than 50 acres will benefit the least area-sensitive grassland birds such as northern bobwhite (*Colinus virginianus*), red-winged black bird (*Agelaius phoeniceus*), American goldfinch (*Carduelis tristis*), Vesper sparrow (*Pooecetes gramineus*), field sparrow (*Spizella pusilla*), song sparrow (*Melospiza melodia*), dickcissel (SC), and common yellowthroat (*Geothlypis trichas*) (Herkert et al. 1993).
3. Maximize interior grassland habitat by establishing circular (best) or square grassland plantings and avoiding long, narrow plantings, which increase edge habitat.
4. Where grassland habitats border forests, strive to create a feathered edge by allowing prescribed fires to burn through adjacent forests as opposed to installing firebreaks along the forest edge. Grasslands with feathered edges experience lower rates of nest predation than those with sharply contrasting edges (Ratti and Reese 1988).

Research Needs: Remaining remnants of mesic sand prairie need to be identified, protected, and managed. Further research on the historical plant species composition of mesic sand prairie in Michigan would be useful for developing seed mixes for restoration. Studies designed to compare plant species composition and abiotc factors (soils, landscape position, etc.) among prairie types in Michigan are needed to improve community classification. In particular, further research is needed to elucidate differences between northern wet-mesic prairie and mesic sand prairie. Studies aimed at understanding the effects of small, isolated populations on plant species genetic diversity will provide important information on managing prairie remnants. Research on the utilization of restored and remnant prairies by grassland birds and insects will provide useful information for understanding how mesic sand prairies contribute to biodiversity. Studies on methods of prairie establishment and management, including controlling invasive species, will benefit both ongoing and new efforts to restore mesic sand prairie. Conservation and management efforts will benefit from further study of how species composition is influenced by fire frequency, intensity, and periodicity.

Similar Communities: Lakeplain mesic sand prairie, northern wet-mesic prairie, wet-mesic prairie, mesic prairie, woodland prairie, dry sand prairie, bur oak plains, and oak openings

Other Classifications:

Michigan Natural Features Inventory circa 1800s Vegetation (MNFI): Grassland

Michigan Department of Natural Resources (MDNR): G

The Nature Conservancy U.S. National Vegetation Classification and International Classification of Ecological Communities (Faber-Langendoen 2001, NatureServe 2004):
CODE; ALLIANCE; ASSOCIATION; COMMON NAME:

V.A.5.N.a; *Andropogon gerardii* – (*Sorghastrum nutans*) Herbaceous Alliance; V.A.5.N.a; *Andropogon gerardii – Sorghastrum nutans – Schizachyrium scoparium – Aletris farinosa* Herbaceous Vegetation; Big Bluestem – Yellow Indiangrass – Little Bluestem– Northern White Colicroot Herbaceous Vegetation

V.A.5.N.a; *Schizachyrium scoparium - Sorghastrum nutans* Herbaceous Alliance; *Schizachyrium scoparium - Sorghastrum nutans - Andropogon gerardii - Lespedeza capitata* Sand Herbaceous Vegetation; Little Bluestem - Yellow Indiangrass - Big Bluestem - Roundhead Bushclover Sand Herbaceous Vegetation

V.A.5.N.a; *Andropogon gerardii* - (*Calamagrostis canadensis, Panicum virgatum*) Herbaceous Alliance; *Andropogon gerardii - Panicum virgatum - Helianthus grosseserratus* Herbaceous Vegetation; Big Bluestem - Switchgrass - Sawtooth Sunflower Herbaceous Vegetation

Related Abstracts: dry sand prairie, woodland prairie, mesic prairie, bur oak plains, oak openings, oak barrens, lakeplain wet-mesic prairie, Culver's root borer, eastern box turtle, eastern massasauga, Henslow's sparrow, migrant loggerhead shrike, northern harrier, red-legged spittlebug, prairie dropseed and Houghton's goldenrod.

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Abstract Citation:

Kost, M.A. 2005. Natural community abstract for mesic sand prairie. Michigan Natural Features Inventory, Lansing, MI. 11 pp.

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Michigan State University Extension is an affirmative-action, equal-opportunity organization.

Funding for abstract provided by Michigan Department of Military and Veterans Affairs.

Appendix 2. Intermittent Wetland

Overview: An herb or herb-shrub wetland found along lakeshores or in depressions and characterized by fluctuating water levels seasonally and from year to year. Intermittent wetlands occur in depressions in glacial outwash and sandy glacial lake plains and in kettles on pitted outwash. Soils range from loamy sand and peaty sand to peaty muck and are very strongly acid to strongly acid. Characteristic vegetation includes *Carex* spp. (sedges), *Juncus* spp. (rushes), sphagnum mosses, and ericaceous shrubs. Intermittent wetlands exhibit characteristics of both peatlands and marshes. Some sites were created when fire burned bogs.

Global and State Rank: G3/S3

Range: Intermittent wetlands are an uncommon feature of glaciated landscapes of the northern Great Lakes basin, occurring in Michigan, Wisconsin, New York, and Ontario (NatureServe 2005). Within Michigan, intermittent wetlands occur in the Lower Peninsula, almost exclusively north of the climatic tension zone, and across the Upper Peninsula but primarily in the eastern portion. Intermittent wetlands and other peatland systems occur where excess moisture is abundant (where precipitation is greater than evapotranspiration) (Mitsch and Gosselink 2000). Conditions suitable for the development of intermittent wetlands have occurred in the northern Lake States for the past 3000-5000 years following climatic cooling (Heinselman 1970, Boelter and Verry 1977). Several natural peatland communities that share similarities with intermittent wetlands also occur in Michigan and can be distinguished from them based on comparisons of hydrology, nutrient levels, flora, and distribution. Open wetlands occurring on peat include bog, northern fen, and poor fen, all of which are characterized by stable water levels. Coastal plain marsh, a grass and rush dominated wetland that also experiences yearly and seasonal water level fluctuation, occurs south of the climatic tension zone and is characterized by a flora with numerous coastal plain disjuncts (Kost and Penskar 2000).

Rank Justification: Intermittent wetlands are rare in the Great Lakes region and typically occur as small (e.g. less than 60 acres), isolated depressions. In Michigan, 29 intermittent wetlands have been identified, occupying less than 1,800 acres in all. Across the Great Lakes basin, fewer than 10,000 acres of intermittent wetland persist in the Great Lakes basin (NatureServe 2005). Historically, widespread fires following the turn of the century logging drastically altered many peatlands, either converting poor conifer swamp to open peatland systems or destroying the peat and converting peatlands to wetlands without organic soils (mineral soil wetlands) (Dean and Coburn 1927, Gates 1942, Curtis 1959). It is possible that some of the current intermittent wetlands are the products of intense fires within bogs that destroyed or partially destroyed surface peats. Beginning in the 1920s, effective fire control by the U.S. Forest Service and state agencies reduced the acreage of fires ignited by man or lightning (Swain 1973). In landscapes where frequent fire was the prevalent disturbance factor, fire suppression has caused shrub and tree encroachment within intermittent wetlands and has likely led to the conversion of some to closed canopy wetlands (Curtis 1959, Riley 1989). Currently, intermittent wetlands are primarily threatened by draining, flooding, filling, development, off-road-vehicle (ORV) activity, peat mining, logging, and agricultural runoff and enrichment (Bedford and Godwin 2003, NatureServe 2005). Peat mining and cranberry farming have degraded numerous peatlands throughout the region (Gates 1942, Curtis 1959, Eggers and Reed 1997, Chapman et al. 2003). Michigan, along with Florida and Minnesota, are leaders in peat production in the U.S. (Miller 1981). In addition to direct impacts to vegetation, alteration of hydrology from road building, ORV activity, creation of drainage ditches and dams, and runoff from logging has led to the drastic change of intermittent wetland composition and structure (Schwintzer and Williams 1974, Riley 1989, Chapman et al. 2003). Intermittent wetland vegetation is extremely sensitive to minor changes in water levels and chemistry (Siegel 1988, Riley

1989). Succession to more eutrophic wetlands can occur as the result of increased alkalinity and permanently raised water levels, which can cause the increased decomposition of acidic peats. Eutrophication from pollution and altered hydrology has detrimentally impacted intermittent wetlands by generating conditions favorable for the invasion of exotic species (Riley 1989, Bedford and Godwin 2003) and dominance by aggressive, common natives such as *Phalaris arundinaceae* (reed canary grass) and *Typha* spp. (cat-tails) (Richardson and Marshall 1986, Almendinger and Leete 1998). Permanent lowering of water tables from drainage can allow for tree and shrub encroachment into intermittent wetlands and the eventual succession to closed canopy peatland. The acidity of intermittent wetlands makes them especially susceptible to acid rain and air pollution (Siegel 1988, Chapman et al. 2003). Atmospheric deposition can contribute nitrogen, sulphur, calcium and heavy metals to intermittent wetlands (Damman 1990, Chapman et al. 2003). Dust-fall and atmospheric deposition from air pollution are particularly threats to wetland systems that are surrounded by cultivated land and close to industrial and urban centers (Damman 1990).

Landscape Context: Intermittent wetlands occur on poorly-drained flat areas or mild depressions of sandy glacial outwash and sandy glacial lake plains and in kettle depressions on pitted outwash (Michigan Natural Features Inventory 2003, NatureServe 2005). This community is found in depressions and along the shores of softwater seepage lakes and ponds where water levels fluctuate both seasonally and yearly. The sandy soils underlying intermittent wetlands are strongly to very strongly acidic and are primarily sands but can also range to loamy sands. Shallow organic deposits of peat, muck, or sandy peat may overlay the sandy substrate.

Intermittent wetland may be bordered by several other wetland communities. For example, intermittent wetland along lakeshores can neighbor submergent marsh, emergent marsh or a floating bog mat. Along the upper margin of the wetland, northern wet meadow, northern shrub thicket or poor conifer swamp may occur. The sandy outwash, pitted outwash and lakeplains that contain intermittent wetlands support well drained and droughty upland communities. The uplands surrounding intermittent wetlands are dominated by fire-dependent conifer systems (i.e., pine barrens, dry northern forest, and dry-mesic northern forest).

Peatlands develop in humid climates where precipitation exceeds evapotranspiration (Boelter and Verry 1977, Gignac et al. 2000). The northern Lake States are characterized by a humid, continental climate with long cold winters and short summers that are moist and cool to warm (Gates 1942, Boelter and Verry 1977, Damman 1990, Mitsch and Gosselink 2000). The Michigan range of intermittent wetlands falls within the area classified by Braun (1950) as the Northern Hardwood-Conifer Region (Hemlock/White Pine/Northern Hardwoods Region) and within the following regions classified by Albert et al. (1986) and Albert (1995): Region I, Southern Lower Michigan; Region II, Northern Lower Michigan; Region III, Eastern Upper Michigan; and Region IV, Western Upper Michigan. The Northern Hardwood-Conifer Region has a cool snow-forest climate with warm summers. The mean number of freeze-free days is between 90 and 220, and the average number of days per year with snow cover of 2.5 cm or more is between 10 and 140. The normal annual total precipitation ranges from 740 to 900 mm with a mean of 823 mm. The daily maximum temperature in July ranges from 24 to 32 °C (75 to 90 °F), the daily minimum temperature in January ranges from –21 to –4 °C (-5 to 25 °F) and the mean annual temperature is 7 °C (45 °F) (Albert et al. 1986, Barnes 1991).

Natural Processes: Water level fluctuations occur both seasonally and yearly within intermittent wetlands. Seasonally water levels tend to be highest during the winter and spring and lowest in late summer and fall. The yearly oscillations are less predictable. Studies of hydrology in related coastal plain marsh systems have found a pattern of short drawdowns of one to three years followed by extensive periods of inundation (Schneider 1994). Fluctuations of water level within intermittent wetlands allow for temporal variability of the accumulation and decomposition of organic matter. Stable periods of saturated and inundated conditions inhibit organic matter decomposition and allow for the accumulation of peat (Almendinger and Leete 1998). Under cool, anaerobic, and acidic conditions, the rate of organic matter accumulation exceeds organic decay (Schwintzer and Williams 1974, Damman 1990, Mitsch and Gosselink 2000). Low levels of oxygen protect plants from microorganisms and chemical actions that cause decomposition and high levels of acidity have inhibitory effects on decay organisms (Heinselman 1963, Miller 1981, Mitsch and Gosselink 2000). Dam-building activities of beaver can result in blocked drainage and flooding which facilitate sphagnum peat development and expansion (Heinselman 1963, Heinselman 1970). High decomposition rates within intermittent wetlands are correlated with periods of water level fluctuation which promote oxidation and the loss of organic material that would otherwise form peat (Miller 1981, Zoltai and Vitt 1995). Water level fluctuations limit the amount of organic matter that can accumulate. As noted above, intermittent wetlands often contain a shallow layer of organic peat or muck overlaying the sand substrate.

Water level fluctuation in intermittent wetlands also facilitates seed germination and seed dispersal, and reduces competition from woody plants. Seasonal drawdowns are critical to the survival of many intermittent wetland species (especially annuals) that depend on these fluctuations for seed germination. As water levels begin to recede in early and mid-summer, direct sunlight penetrates the exposed substrate and triggers seed germination (van der Valk 1981). In addition, the sunlight warming the soils during the day results in soil temperatures rising during the day before cooling at night. Diurnal temperature fluctuation also stimulates seed germination for many wetland species (Thompson and Grime 1983). Season water level fluctuations act as an important mechanism for seed dispersal (Schneider 1994). During the winter and spring when water levels rise, seeds deposited along the ponds low-water line float to the surface and are carried by wave action to the wetland basin's outer margin. In addition to carrying dormant seeds, rising water levels also move sprouting seeds and organic matter into the upper shoreline in early spring. This seasonal movement of plant propagules and organic matter acts to maintain diversity and nutrient levels at the upper elevations of the wetland basin (Schneider 1994). In addition, high water levels can limit tree and shrub encroachment into intermittent wetlands since prolonged flooding can result in tree and shrub mortality.

Fire is also an important component of the disturbance regime of intermittent wetlands. Surface fire can contribute to the maintenance of open conditions by killing encroaching trees and shrubs without completely removing the organic soils (Curtis 1959, Vitt and Slack 1975). Fire severity and frequency in intermittent wetlands is closely related to fluctuations in water level. Prolonged periods of lowered water table can allow the vegetation and surface peat to dry out enough to burn (Schwintzer and Williams 1974). When the surface peat of intermittent wetlands burns, the fire releases organic matter from the peat, kills seeds and latent buds, stimulates decay, and slows peat accumulation (Damman 1990, Jean and Bouchard 1991). Peat fires likely convert bogs to more graminoid dominated peatlands such as intermittent wetlands and poor fens or if the peat is completely destroyed, to mineral soil wetlands such as northern wet meadow (Curtis 1959). Because fire has been shown to increase seed germination, enhance seedling establishment, and bolster flowering, fire likely acts as an important mechanism for maintaining plant species diversity and replenishing the seed bank of intermittent wetlands (Warners 1997).

Vegetation Description: Intermittent wetlands are herb or herb-shrub dominated with a graminoid dominated herbaceous layer, low ericaceous, evergreen shrubs, and widely scattered and stunted conifer trees (Michigan Natural Features Inventory 2003, NatureServe 2005). The flora of intermittent wetlands is characteristically dominated by monocotyledons, with annual species contributing significantly to overall species diversity. For the majority of species, flowering and seed set occurs in late summer and fall, when water levels are lowest. However, species with bog affinities found on bog mats within these wetlands tend to be spring flowering (Curtis 1959). Intermittent wetlands typically contain several vegetation zones, especially when they are adjacent to a lake or pond. The deepest portion of the depression is usually inundated and supports floating aquatic plants including *Brasenia schreberi* (water shield), *Nuphar variegata* (bull-head pond-lily), *Nymphaea odorata* (sweet-scented water-lily), *Potamogeton* spp. (pondweeds), and *Utricularia* spp. (bladderworts). Occurring along the lower shores and pond margins is a seasonally flooded zone with sparse graminoid cover with species such as *Eleocharis olivacea* (bright green spike-rush), *E. robbinsii* (Robbin's spike-rush), *Fimbrystilis autumnalis* (slender fimbry), *Juncus* spp. (rush), and *Scirpus* spp. (bulrush). In the saturated soil further from the shore, where the seasonal water levels typically reach their peak, is a dense graminoid-dominated zone. This is the most floristically diverse zone and typically includes species such *Calamagrostis canadensis* (blue-joint grass), *C. stricta* (reedgrass), *Carex oligosperma* (few-seed sedge), *Cladium marisicoides* (twig-rush), *Dulichium arundinaceum* (three-way sedge), *Eriocaulon septangulare* (seven-angle pipewort), *Euthamia graminifolia* (flat-topped goldenrod), *Iris versicolor* (wild blue flag), *Lysimachia terrestris* (swamp candles), and *Rhynchospora* spp. (beak-rush). Many intermittent wetlands contain a bog mat (often floating) with vegetation typical of an ombrotrophic bog. These bog mats are characterized by sphagnum mosses and low, ericaceous shrubs with *Chamaedaphne calyculata* (leatherleaf) being the most prevalent. Trees within intermittent wetlands are either absent or widely scattered and stunted. The most common canopy dominants are *Picea mariana* (black spruce) and *Larix laricina* (tamarack). Additional associates include *Pinus banksiana* (jack pine) and *Pinus strobus* (white pine).

Michigan Indicator Species: *Bartonia paniculata* (panicled screwstem, state threatened), *Carex nigra* (black sedge, state endangered), *Carex wiegandii* (Wiegand's sedge, state threatened), *Eleocharis melanocarpa* (black-fruited spike-rush, state special concern), *Eleocharis robbinsii*, *Eriocaulon septangulare*, *Gratiola virginiana* (round-fruited hedge hyssop, state threatened), *Hemicarpha micrantha* (dwarf bulrush, state special concern), *Juncus vaseyi* (Vasey's rush, state threatened), *Polygonum careyi* (Carey's smartweed, state threatened), *Potamogeton bicupulatus* (waterthread pondweed, state threatened), *Pycnanthemum verticillatum* (whorled mountain mint, state threatened), *Ranunculus cymbalaria* (seaside crowfoot, state threatened), *Schoenoplectus torreyi* (Torrey's bulrush, state special concern), and *Trichophorum clintonii* (Clinton's bulrush state special concern).

Other Noteworthy Species: Intermittent wetlands provide habitat for numerous rare insect species including *Appalachia arcana* (secretive locust, state special concern), *Boloria freija* (Freija fritillary, state special concern butterfly), *Boloria frigga* (Frigga fritillary, state special concern butterfly), *Erebia discoidalis* (red-disked alpine, state special concern butterfly), *Merolonche dollii* (Doll's merolonche moth, state special concern), *Somatochlora incurvata* (incurvate emerald, state special concern dragonfly), and *Williamsoni fletcheri* (ebony boghaunter, state special concern dragonfly). Rare herptiles that utilize intermittent wetlands include *Clemmys guttata* (spotted turtle, state threatened), *Elaphe obsoleta obsolete* (black rat snake, state special concern), *Emys blandingii* (Blanding's turtle, state special concern), *Sistrurus catenatus catenatus* (eastern massasauga, state special concern), and *Terrapene carolina carolina* (eastern box turtle, state special concern). If suitable nesting trees or snags are available, *Haliaeetus leucocephalus* (bald eagle, state threatened), *Falco columbarius* (merlin, state threatened), and *Pandion haliaetus* (osprey, state threatened) can be found nesting in these systems and *Ardea herodias* (great blue heron, protected by the Migratory Bird Treaty Act of 1918) can establish rookeries. Other rare birds that could occur in intermittent wetlands are *Asio flammeus* (short-eared owl, state endangered), *Botaurus lentiginosus* (American bittern, state special concern), *Circus cyaneus* (northern harrier, state special concern), *Coturnicops noveboracensis* (yellow rail, state threatened), *Gallinula chloropus* (common moorhen, state special concern), *Ixobrychus exilis* (least bittern, state threatened), *Phalaropus tricolor* (Wilson's phalarope, state special concern), and *Rallus elegans* (king rail, state endangered). *Gavia immer* (common loon, state threatened) establish nest sites on natural islands and bog-mats. *Alces alces* (moose, state threatened), *Canis lupus* (gray wolf, state threatened), and *Lynx canadensis* (lynx, state endangered) could utilize intermittent wetland habitat.

Intermittent wetlands support a large number of rare plants, including *Bartonia paniculata* (panicled screwstem, state threatened), *Carex nigra* (black sedge, state endangered), *Carex wiegandii* (Wiegand's sedge, state threatened), *Eleocharis melanocarpa* (black-fruited spike-rush, state special concern), *Gentiana linearis* (linear-leaved gentian, state threatened), *Gratiola virginiana* (round-fruited hedge hyssop, state threatened), *Hemicarpha micrantha* (dwarf bulrush, state special concern), *Huperzia selago* (fir clubmoss, state special concern), *Juncus vaseyi* (Vasey's rush, state threatened), *Ludwigia alternifolia* (seedbox, state special concern), *Lycopodiella margueriteae* (northern prostrate clubmoss, state special concern), *Lycopodiella subappressa* (northern appressed clubmoss, state threatened), *Polygonum careyi* (Carey's smartweed, state threatened), *Potamogeton bicupulatus* (waterthread pondweed, state threatened), *Pycnanthemum verticillatum* (whorled mountain mint, state threatened), *Ranunculus cymbalaria* (seaside crowfoot, state threatened), *Sabatia angularis* (rose-pink, state threatened), *Schoenoplectus torreyi* (Torrey's bulrush, state special concern), and *Trichophorum clintonii* (Clinton's bulrush state special concern).

Conservation and Biodiversity Management: Intermittent wetland is an uncommon community type in the Great Lakes region that contributes significantly to the overall biodiversity of Michigan by providing habitat for a unique suite of plants and wide variety of animal species. Numerous rare species are associated with intermittent wetlands. Protection of the regional and local hydrologic regime is critical to the preservation of intermittent wetlands (Schneider 1994). Stabilization of water levels can allow for the establishment of perennials and woody species which can displace less competitive annuals. Even small changes in hydroperiod may cause significant shifts in wetland community composition and structure. Resource managers operating in uplands adjacent to intermittent wetlands should take care to minimize the impacts of management to hydrologic regimes, especially increased surface flow and alteration of groundwater recharge. This can be accomplished by establishing a no-cut buffer around intermittent wetlands and avoiding road construction and complete canopy removal in adjacent stands. A serious threat to intermittent wetland hydrology and species diversity is posed by ORV traffic, which can drastically alter the hydrology through rutting and erosion. Soil erosion resulting from ORV use within the wetland or surrounding uplands may greatly disturb the seed bank, reducing plant density and diversity (Wisheu and Keddy 1989). For species that depend on recruitment from the seed bank such as annuals, significant soil disturbance may result in extirpation from the site. Reduction of access to wetland systems will help decrease detrimental impacts from ORVs. Where shrub/tree encroachment threatens to convert open wetlands to shrub-dominated systems or forested swamps, prescribed fire can be employed to maintain open conditions. Prescribed fires should be carried out in intermittent wetlands during droughts or in the late summer and fall when water levels are lowest. In addition to controlling woody invasion, fire will likely promote seed bank expression and rejuvenation.

Research Needs: Intermittent wetland is one of the least studied wetland community types of the Great Lakes region. Classification research is needed that explores the interrelationship between floristic composition and structure and physiography, hydrology, and fire. Intermittent wetland and related community types (bog, poor fen, and northern fen) are frequently difficult to differentiate. Research on abiotic and biotic indicators that help distinguish related wetlands would be useful for field classification. Systematic surveys for intermittent wetlands and related wetlands are needed to help prioritize conservation and management efforts.

Little is known about the hydrologic and fire regimes of intermittent wetlands and the interaction of disturbance factors within these systems. An important research question to address is how so fire and flooding influence species diversity of intermittent wetlands. As noted by Hammerson (1994), beaver significantly alter the ecosystems they occupy. An important research question to examine is how the wetland ecosystems of the Great Lakes have been and continue to be affected by fluctuations in populations of beaver. Experimentation is needed to determine how best to prevent shrub and tree encroachment in intermittent wetlands that are threatened by conversion to shrub thicket or conifer swamp. A better understanding is needed of the influence of direct and indirect anthropogenic disturbance on intermittent wetlands. Effects of management within intermittent wetlands should be monitored to allow for assessment and refinement. Monitoring should also focus on how intermittent wetland succession and management influence populations of rare species. Given the sensitivity of peatlands to slight changes in hydrology and nutrient availability, it is important for scientists to predict how peatlands will be affected by global warming and atmospheric deposition of nutrients and acidifying agents (Heinselman 1970, Riley 1989, Bedford et al. 1999, Gignac et al. 2000, Mitsch and Gosselink 2000).

Similar Communities: bog, coastal plain marsh, emergent marsh, northern fen, northern wet meadow, poor fen.

Other Classifications:

Michigan Natural Features Inventory Circa 1800 Vegetation (MNFI): Intermittent Wetland (6228)

Michigan Department of Natural Resources (MDNR): D-treed bog, V-bog, N-marsh

Michigan Resource Information Systems (MIRIS): 62 (non-forested wetland), 621 (aquatic bed wetland), and 622 (emergent wetland)

The Nature Conservancy National Classification: CODE; ALLIANCE; ASSOCIATION; COMMON NAME

IV.A.1.N.f; *Chamaedaphne calyculata* – (*Kalmia angustifolia*) Seasonally Flooded Dwarf-Shrubland Alliance; *Chamaedaphne calyculata / Carex oligosperma / Sphagnum* spp. Dwarf-shrubland; Leatherleaf / Few-seed Sedge / Peatmoss Species Dwarf-shrubland; Great Lakes Leatherleaf Intermittent Wetland

Related Abstracts: American bittern, Blanding's turtle, bog, coastal plain marsh, common moorhen, eastern box turtle, eastern massasauga, great blue heron rookery, incurvate emerald, king rail, least bittern, merlin, northern appressed clubmoss, northern fen, northern harrier, northern wet meadow, panicled screw-stem, poor fen, prairie fen, rich conifer swamp, secretive locust, spotted turtle, and yellow rail.

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Abstract Citation:

Cohen, J.G, and M.A. Kost. 2005. Natural community abstract for intermittent wetland. Michigan Natural Features Inventory, Lansing, MI. 8 pp.

Appendix 3. Northern Fen

Overview: A sedge and rush dominated wetland on neutral to slightly alkaline saturated peat influenced by groundwater rich in calcium and magnesium carbonates. Occurs north of the climatic tension zone where calcareous bedrock underlies a thin mantle of glacial drift on flat areas or mild depressions of glacial outwash and glacial lake plains.

Global and State Rank: G4G5/S3

Range: Northern fen is a peatland type of glaciated landscapes of the northern Great Lakes region, ranging from Michigan west to Minnesota and northward into central Canada (Ontario, Manitoba, and Quebec) (Gignac et al. 2000, Faber-Langendoen 2001, Amon et al. 2002, NatureServe 2005a). Northern fen may also occur in parts of the northeastern U.S. (i.e., New York and Maine). In Michigan, northern fens occur in the northern Lower Peninsula and the Upper Peninsula, most frequently in close proximity to Great Lakes coast. Most documented occurrences from the U.P. are known from the eastern portion. Fens and other peatlands occur where excess moisture is abundant (where precipitation is greater than evapotranspiration) (Mitsch and Gosselink 2000). Conditions suitable for the development of fens have occurred in the northern Lake States for the past 8000 years. Expansion of peatlands likely occurred following climatic cooling, approximately 5000 years ago (Heinselman 1970, Boelter and Verry 1977, Riley 1989).

Several other natural peatland communities also occur in Michigan and can be distinguished from minerotrophic (nutrient-rich) northern fens, based on comparisons of nutrient levels, flora, canopy closure, distribution, and ground-water influence. Northern fens are dominated by sedges, rushes, and grasses (Mitsch and Gosselink 2000). Additional open wetlands occurring on peat include bog, poor fen, and prairie fen. Bogs, peat-covered wetlands raised above the surrounding groundwater by an accumulation of peat, receive inputs of nutrients and water primarily from precipitation and are classified as ombrotrophic (nutrient-poor) (Gignac et al. 2000). The hydrology of fens is influenced by ground-water and as a result, fens have higher nutrient availability, increased alkalinity (less acidity), and greater species richness compared to bogs, with poor fens being most similar to bogs in terms of these factors and species composition. Like northern fen and poor fen, prairie fens are graminoid dominated and groundwater influenced, however prairie fens are restricted to south of the climatic tension zone. In addition to a greater importance by graminoids in fens versus bogs, nutrient-rich fens also are less dominated by sphagnum mosses (*Sphagnaceae*) with brown mosses (*Amblystegiaceae*) being more prevalent. Intermittent wetlands are herb or herb-shrub dominated wetlands that experience fluctuating water levels seasonally and yearly and have soils that range from loamy sand and peaty sand to peaty muck and are very strongly acid to strongly acid. Like bogs, muskegs and poor conifer swamp are nutrient-poor, acidic wetlands. However, these ombrotrophic peatlands exhibit a greater degree of canopy closure than bogs (muskegs having clumped and scattered conifers and poor conifer swamp being a closed canopy system). Closed canopy, minerotrophic peatlands include rich conifer swamp, a *Thuja occidentalis* (northern white cedar) dominated system found north of the tension zone, and relict conifer swamp, which is dominated by *Larix laricina* (tamarack) and occurs primarily south of the tension zone (Kost 2001).

Rank Justification: Northern fens are uncommon features of the northern Great Lakes region, occurring sporadically in Michigan's northern Lower Peninsula and the Upper Peninsula. The northern lake states contain over six million hectares (15 million acres) of peatland (Boelter and Verry 1977). What percentage of that area is northern fen has yet to be determined. Likewise, the current status of fens relative to their historical status is unknown (Bedford and Godwin 2003). Peatland scientists concur that fens have always been localized and not very abundant but have suffered from extensive loss, fragmentation, and degradation (Bedford and Godwin 2003, NatureServe 2005a). Historically, widespread fires following the turn of the century logging drastically altered many peatlands, either converting conifer swamp to open fen systems or destroying the peat and converting peatlands to wetlands without organic soils (mineral soil wetlands) (Dean and Coburn 1927, Gates 1942, Curtis 1959). Logging of cedar and tamarack from peatland systems also favored the conversion of forested peatlands to open peatlands (Gates 1942, Dansereau and Segadas-Vianna 1952, Riley 1989). Beginning in the 1920s, effective fire control by the U.S. Forest Service and state agencies reduced the acreage of fires ignited by man or lightning (Swain 1973). In landscapes where frequent fire was the prevalent disturbance factor, fire suppression has led to the conversion of open fens to closed canopy peatlands or shrub thickets (Curtis 1959, Schwintzer 1981, Riley 1989).

Currently, fens are primarily threatened by peat mining, logging, quarrying, agricultural runoff and enrichment, draining, flooding, off-road-vehicle (ORV) activity, and development (Bedford and Godwin 2003, NatureServe 2005a). Peat mining and cranberry farming have degraded numerous peatlands throughout the region (Gates 1942, Curtis 1959, Eggers and Reed 1997, Chapman et al. 2003). Michigan, along with Florida and Minnesota, are leaders in peat production in the U.S. (Miller 1981). In addition to direct impacts to vegetation, alteration of peatland hydrology from road building, quarrying, ORVs, creation of drainage ditches and dams, and runoff from logging has led to the drastic change of peatland composition and structure (Schwintzer and Williams 1974, Schwintzer 1978a, Riley 1989, Bedford and Godwin 2003, Chapman et al. 2003). Fen vegetation is extremely sensitive to minor changes in water levels and chemistry, ground water flow, and nutrient availability (Siegel 1988, Riley 1989). A reduction in groundwater flow and subsequent decrease in nutrients in northern fens can result in the shift to less minerotrophic wetlands such as a poor fens or even a bog. Conversion to more eutrophic wetlands has occurred as the result of nutrient enrichment and raised water levels, which cause increased decomposition of peat. Eutrophication from pollution and altered hydrology has detrimentally impacted fens by generating conditions favorable for the invasion of exotic species (Riley 1989, Bedford and Godwin 2003) and dominance by aggressive, common natives such as *Phalaris arundinaceae* (reed canary grass) and *Typha* spp. (cat-tails) (Richardson and Marshall 1986, Almendinger and Leete 1998b). Bedford et al. (1999) have noted a widespread decline in wetland species richness associated with the overall eutrophication of the landscape: nutrient enrichment has converted numerous species rich wetlands such as northern fen into monospecific stands of nitrophilic species. Lowering of water tables from drainage has allowed for tree and shrub encroachment into open fens and the eventual succession to closed canopy peatland (Almendinger and Leete 1998b). Increased shrub and tree canopy cover typically results in decreased species richness of fen systems (Bowles et al. 1996). In addition, lowering of the water table can reduce carbonate deposition at the fen surface and thereby alter the growing conditions, causing a loss in rare calciphilic vegetation and an increase in more common plants (Almendinger and Leete 1998b). The high alkalinity of fens makes them especially susceptible to acid rain and air pollution (Siegel 1988, Chapman et al. 2003). Atmospheric deposition can contribute Nitrogen, Sulphur, Calcium, and heavy metals to fens (Damman 1990, Chapman et al. 2003). Dust-fall and atmospheric deposition from air pollution are particularly threats to fen systems that are surrounded by cultivated land and close to industrial and urban centers (Damman 1990).

Physiographic Context: Two landscape features are conducive to the development of peat; poorly-drained, level terrain and small ice-block basins (Boelter and Verry 1977). Northern fen occur on flat areas or mild depressions of glacial outwash and glacial lake plains, often in close proximity to the Great Lakes shoreline, and also in kettle depressions on pitted outwash and moraines (Gates 1942, Verry 1975, Vitt and Slack 1975, Boelter and Verry 1977, Schwintzer 1978a, Siegel 1988, Michigan Natural Features Inventory 2003, NatureServe 2005a). The overall topography of fens is flat to gently undulating with microtopography characterized by hummocks and hollows (Heinselman 1963, Vitt and Slack 1975, Wheeler et al. 1983, Siegel 1988, NatureServe 2005a). Fens found in kettle depressions are associated with active or extinct glacial lakes that are alkaline (Vitt and Slack 1975). Within kettle depressions, fens can occupy the entire basin or frequently occur as a floating mat on the margin of the remaining glacial lake (Vitt and Slack 1975, Schwintzer 1978a, Schwintzer 1978b). When fens occur along the edge of large bodies of water, they are found in sheltered bays or coves that are protected from wave and ice action, which can prevent the development of peat or erode existing peat mats (Gates 1942, NatureServe 2005a). Fens occurring on former glacial lake beds and drainageways tend to be more extensive than kettle fens, which are limited in area by the size of the glacial ice-block which formed the basin (Lindeman 1941): the large peatlands of lakeplains and outwash plains are often over 100 acres while fens found in kettle depressions typically range from 10 to 50 acres. Northern fens occurring on glacial outwash and glacial lake plains occur on sapric to fibric peat or marly flats overlaying calcareous bedrock, typically dolomite or limestone of Devonian age (Heinselman 1970, Schwintzer 1978b, Schwintzer 1981, Amon et al. 2002, NatureServe 2005a). The majority of documented northern fens within Michigan occur on old glacial lake beds in close proximity to a Great Lakes shoreline.

Northern fens often occur within large wetland complexes, typically adjacent to other peatland communities, grading into rich conifer swamp, poor fen, bog, muskeg, and poor conifer swamp. Northern fens within kettle depressions that contain active glacial lakes and ponds often border aquatic communities such as submergent marsh and emergent marsh. Northern fen can also occur as one of many zones within matrix communities such as Great Lakes marsh and wooded dune and swale complex. Upland community types are found adjacent to northern fen include dry-mesic northern forest, dry northern forest, pine barrens, and boreal forest.

Hydrology: Northern fens are minerotrophic peatlands, receiving inputs of water and nutrients primarily from nutrient-rich groundwater (Heinselman 1970, Vitt and Slack 1975, Boelter and Verry 1977, Schwintzer 1981, Schwintzer and Tomberlin 1982, Riley 1989, Bedford and Godwin 2003). Ground-water discharge produces continuously saturated conditions in the rooting zone. The water table of fens is stable, typically at the soil surface with the peat soils saturated but seldom flooded (Heinselman 1970, Schwintzer 1978b, Schwintzer 1981, Riley 1989, Amon et al. 2002, Bedford and Godwin 2003). The cool ground water which enters fens is telluric, having moved over or percolated through base-rich bedrock, calcareous glacial deposits, or mineral soil (Schwintzer 1978b, Bedford and Godwin 2003). As a result, the ground water discharge into fens is mineral rich, carrying high concentrations of calcium and magnesium carbonates (Curtis 1959, Heinselman 1970, Verry 1975, Boelter and Verry 1977, Schwintzer 1978b, Schwintzer 1981, Almendinger et al. 1986, Almendinger and Leete 1998b, Mitsch and Gosselink 2000, Amon et al. 2002, Bedford and Godwin 2003, NatureServe 2005a). In addition to high levels of dissolved minerals, the groundwater of fens is alkaline to circumneutral and characterized by high specific conductivity, cool temperature, and a clear color resulting from low levels of dissolved organic matter (Verry 1975, Glaser et al. 1981, Wheeler et al. 1983, Riley 1989, Glaser et al. 1990). Scientists studying minerotrophic fens in the Great Lakes have reported a wide range of pH values (5.0-8.0) (Heinselman 1970, Boelter and Verry 1977, Schwintzer 1978b, Glaser et al. 1981, Wheeler et al. 1983, Siegel and Glaser 1987, Riley 1989, Glaser et al. 1990). Within northern fens of Michigan, recorded pH values range between 5.6 and 8.0. The degree of minerotrophy of a given fen and within a fen depends on the kind and amount of groundwater discharge, degree of dilution from precipitation, the characteristics of the bedrock and/or glacial deposits the groundwater has percolated through (i.e., older glacial sediments have less dissolved minerals due to prior leaching), the distance the water has traveled through the peatland, and the thickness and character of the peat (Heinselman 1963, Heinselman 1970, Boelter and Verry 1977, Siegel and Glaser 1987, Amon et al. 2002).

Soils: The organic soils of fens are composed primarily of peat which frequently forms a shallow, continuous mat and is typically 1-3 meters deep (Glaser et al. 1981). Peat is a fibrous network of partially decomposed organic material that is formed under anaerobic conditions (Almendinger et al. 1986, Heinselman 1963). The surface peats of fens are saturated, range from sapric to fibric peat, and like the surface water, are alkaline to neutral and characterized by high nutrient availability (Curtis 1959, Heinselman 1963, Heinselman 1970, Schwintzer and Williams 1974, Boelter and Verry 1977, Almendinger et al. 1986, Swanson and Grigal 1989, NatureServe 2005a). Sapric peat, which is held together by roots and rhizomes, is highly decomposed with occasional fragments of sedge, reed, and shrub. Fibric peat, which is loosely compacted, contains partially decomposed mosses with fragments of wood and occasionally sedge. Fibric peat has high water retaining capacity and large intercellular pores that permit rapid water movement (The rate of water movement through saturated fibric peat is 1000 times faster than water movement through sapric peats) (Boelter and Verry 1977). Hemic peats are intermediate between sapric and fibric peats in terms of decomposition and water retaining capacity (Boelter and Verry 1977, Miller 1981, Swanson and Grigal 1989). Peats of fens tend to have lower water retaining capacity compared to the peats of bogs (Miller 1981). Peat composition changes with depth and depending on the successional history of a given fen. Generally, fiber content and hydraulic conductivity usually decreases with depth; deeper peats are more decomposed, retain more water, and drain slower than surface peats (Verry 1975, Boelter and Verry 1977). In addition to peat, northern fens often contain or develop over extensive areas of marl, an organic soil with smooth silty texture that develops when Calcium and Magnesium carbonate aquatically precipitate (Almendinger and Leete 1998b, Amon et al. 2002, Bedford and Godwin 2003, NatureServe 2005a). While levels of available Calcium, Magnesium, and Nitrogen are typically high within northern fens, Phosphorous can be limiting (Richardson and Marshall 1986, Riley 1989, Bedford et al. 1999, Mitsch and Gosselink 2000, Amon et al. 2002). Low concentrations of Phosphorous can result from co-precipitation with carbonate, microbial immobilization, reduced aeration of the rooting zone, and iron toxicity (Richardson and Marshall 1986, Almendinger and Leete 1998, Amon et al. 2002, Bedford et al. 1999).

Climate: Peatlands develop in humid climates where precipitation exceeds evapotranspiration (Boelter and Verry 1977, Gignac et al. 2000, Bedford and Godwin 2003). The northern Lake States are characterized by a humid, continental climate with long cold winters and short summers that are moist and cool to warm (Gates 1942, Boelter and Verry 1977, Damman 1990, Mitsch and Gosselink 2000). The Michigan range of northern fen falls within the area classified by Braun (1950) as the Northern Hardwood-Conifer Region (Hemlock/White Pine/Northern Hardwoods Region) and within the following regions classified by Albert et al. (1986) and Albert (1995): Region II, Northern Lower Michigan; Region III, Eastern Upper Michigan; and Region IV, Western Upper Michigan. The Northern Hardwood-Conifer Region has a cool snow-forest climate with short, warm summers, cold winters, and a large number of cloudy days. The mean number of freeze-free days is between 90 and 160, and the average number of days per year with snow cover of 2.5 cm or more is between 80 and 140. The normal annual total precipitation ranges from 740 to 900 mm with a mean of 823 mm. The daily maximum temperature in July ranges from 24 to 29 °C (75 to 85 °F), the daily minimum temperature in January ranges from -21 to -9 °C (-5 to 15 °F) and the mean annual temperature is 7 °C (45 °F) (Albert et al. 1986, Barnes 1991). Temperatures vary less in peatlands compared to the surrounding landscape because of ground-water influence, the insulating effect of fens' saturated peat carpet in the growing season, and snow cover in the winter (Burns 1906, Heinselman 1963, Curtis 1959, Glaser 1992). Fens are characterized by microclimates that are cooler in the summer and warmer in the winter compared to the regional climate (Heinselman 1963, Bedford and Godwin 2003).

Natural Processes: Peat establishment requires an abundant supply of water: peatlands occur in regions where precipitation is greater than evapotranspiration producing substantial groundwater discharge (Dansereau and Segadas-Vianna 1952, Boelter and Verry 1977, Almendinger and Leete 1998b, Mitsch and Gosselink 2000). Saturated and inundated conditions inhibit organic matter decomposition and allow for the accumulation of peat (Almendinger and Leete 1998b, Amon et al. 2002). Under cool and anaerobic conditions, the rate of organic matter accumulation exceeds organic decay (Schwintzer and Williams 1974, Damman 1990, Mitsch and Gosselink 2000). Low levels of oxygen protect plants from microorganisms and chemical actions that cause decay (Miller 1981). Fens have greater levels of microbial activity compared to bogs because of the lesser acidity and higher base status of minerotrophic waters. As a result, organic matter decay is greater while peat accumulation is lesser in fens versus bogs (Heinselman 1970). Development and expansion of fens occurs via two different processes in kettle depressions versus glacial lakeplain and outwash. Fens develop in glacial lakeplain and outwash where groundwater influence maintains saturated conditions which partially inhibit organic matter decomposition and allow peat accumulation (Almendinger and Leete 1998b). Peat develops vertically and spreads horizontally (Boelter and Verry 1977). Estimates of vertical accumulation of peat range between 100 to 200cm/1000 years (Mitsch and Gosselink 2000). Lake-filling or terrestrialization occurs in small kettle lakes with minimal wave action where gradual peat accumulation results in the development of a sedge mat that can fill the basin or occur as a floating mat in the lake or as a grounded mat along the water’s edge (Gates 1942, Bay 1967, Curtis 1959, Heinselman 1963, Mitsch and Gosselink 2000). Floating mats of fen sedges (i.e., *Carex lasiocarpa*) pioneer open water or emergent marsh. *Carex lasiocarpa* (wiregrass sedge) possesses rhizomes which can grow out into open water. The interlacing of rhizomes and roots forms a floating mat that is buoyed up in water and accumulates organic matter in the form of sapric peat (Gates 1942). Over time fen mats are often invaded by ericaceous shrubs and acidifying sphagnum mosses (Osvald 1935, Gates 1942, Schwintzer and Williams 1974, Swineheart and Parker 2000).

The invasion of sphagnum moss into fen systems often results in the conversion of fens to more acidic communities such as poor fen or bog. Succession in lake-filled fens typically proceeds from lake to marsh to fen to poor fen or bog (Heinselman 1963, Boelter and Verry 1977, Schwintzer 1981, Swineheart and Parker 2000). Once Sphagnum mosses become established on fen peat, they maintain and enhance saturated and acidic conditions which in turn promote continued sphagnum peat development (Heinselman 1963). The ability of sphagnum to absorb and hold cations increases the acidity and low nutrient availability of peatlands (Osvald 1935, Curtis 1959, Verry 1975, Vitt and Slack 1975, Boelter and Verry 1977). In addition, accumulating sphagnum peat can dilute groundwater influence by absorbing large amounts of precipitated water, impeding drainage, and increasing the distance of the rooting zone from telluric water (Dansereau and Segadas-Vianna 1952, Vitt and Slack 1975, Schwintzer 1981). Sphagnum moss, which has numerous pores, partitions, and capillary space, has an enormous water-holding capacity (Osvald 1935, Dansereau and Segadas-Vianna 1952, Curtis 1959): sphagnum peat can hold 15 to 30 times its own weight in water (Miller 1981, Mitsch and Gosselink 2000). In addition to sphagnum peat accumulation, beaver dams can also cause blocked drainage in fens and the subsequent succession of fens to bogs (Heinselman 1963, Heinselman 1970).

Fens frequently succeed to northern shrub thicket or rich conifer swamp. Lowering of the water table of fens results in the increase in decomposition rates of organic matter and the consequent accumulation of compact peat, which is more conducive to shrub and tree growth (Schwintzer and Williams 1974, Schwintzer 1981, Riley 1989, Almendinger and Leete 1998b, Gignac et al. 2000). Conversions of bog to fen can also occur, however with far less frequency (Glaser et al. 1990). A discharge of alkaline groundwater at the peat surface of a bog, caused by a change in hydraulic head, can result in the conversion of bog vegetation to fen vegetation (Siegel and Glaser 1987, Glaser et al. 1990). Mixing of as little as 10% groundwater from underlying calcareous parent material with acid bog water is sufficient to raise the peatland pH from 3.6 to 6.8 (Glaser et al. 1990). Fens and bogs are very sensitive to changes in pH and subsequent availability of nutrients: fen vegetation can replace bog flora when pH increases above 4.5 (Siegel 1988).

Disturbance factors influencing fens include fire, flooding, windthrow, and insects. Numerous fens contain charcoal within their peat profile (Curtis 1959, Heinselman 1963) and many researchers have reported fire as a prevalent part of fen's disturbance regime (Gates 1942, Curtis 1959, Vitt and Slack 1975). Surface fire can contribute to the maintenance of fens by killing encroaching trees and shrubs without completely removing the peat, which is normally saturated (Curtis 1959, Vitt and Slack 1975). Graminoid dominance of fen systems can be perpetuated by surface fires (Bowles et al. 1996). In addition, many of the ericaceous plants that thrive in fens are fire adapted and often grow densely following fire (Wheeler et al. 1983). Fire severity and frequency in fens is closely related to fluctuations in water level. Prolonged periods of lowered water table can allow the surface peat to dry out enough to burn (Schwintzer and Williams 1974). When the surface peat of fens burns, the fire releases organic matter from the peat, kills seeds and latent buds, stimulates decay, and slows peat accumulation (Damman 1990, Jean and Bouchard 1991). Such peat fires can result in the conversion of peatland to mineral soil wetland.

As noted above, flooding can result in the conversion of fens to bogs. Flooding can also contribute to fen maintenance. Roots of peatland trees are physiologically active near the surface and are quickly killed when the water table rises following flooding (Glaser and Janssens 1986). Within kettle fens, flooding-induced tree mortality is likely greater on grounded mats compared to free floating mats: free mats float up with rising water table while grounded mats become inundated and have shallower aerobic zones (Schwintzer 1978a, Schwintzer 1978b, Schwintzer 1979). In addition to flooding, kettle fens can be influenced by waves and ice. Wave and ice action can prevent the expansion of fen mats by eroding the shoreline vegetation (Gates 1942).

The natural disturbance regime in fens is also influenced by wind. The Great Lakes region is one of the most active weather zones in the northern hemisphere, with polar jet streams positioned overhead much of the year. More cyclones pass over this area than any other area in the continental U.S. (Frelich and Lorimer 1991). Trees growing in fens are particularly susceptible to windthrow because peat provides a poor substrate for anchoring trees (Burns 1906). The living roots of woody peatland plants occur in a shallow rooting zone, generally restricted to the uppermost few centimeters where there is sufficient oxygen to maintain aerobic respiration (Glaser and Janssens 1986). The superficial rooting of trees results in numerous windthrows (Dansereau and Segadas-Vianna 1952). Tree survival in bogs is also limited by insects and parasites. Insect outbreaks of the *Pristiphora erichsonii* (larch sawfly) cause heavy mortality of *Larix laricina* (tamarack) while, the plant parasite *Arceuthobium pusillum* (dwarf mistletoe) kills *Picea mariana* (black spruce) (Coburn et al. 1933, Gates 1942, Heinselman 1963).

Vegetation Description: Northern fens are characterized by a unique and diverse heliophilus flora with a rich herbaceous layer dominated by graminoids, a patchy to continuous moss carpet with brown mosses (*Amblystegiaceae*) more prevalent than sphagnum mosses (*Sphagnaceae*), low ericaceous, evergreen shrubs, and widely scattered and often stunted conifer trees (Gates 1942, Curtis 1959, Vitt and Slack 1975, Mitsch and Gosselink 2000, Amon et al. 2002, Bedford and Godwin 2003, NatureServe 2005a). Floristically fens are among the most diverse of all wetland types in the United States, exhibiting high within-plot species diversity and high site-level species richness, and also supporting numerous rare and uncommon bryophytes and vascular plants, particularly calciphiles (Almendinger and Leete 1998a, Almendinger and Leete 1998b, Bedford and Godwin 2003, NatureServe 2005a). Species richness of fens is related to geographical location, climatic factors, nutrient availability, and habitat heterogeneity (Glaser et al. 1990, Glaser 1992). Floristic diversity within northern fens is correlated with high levels of available nutrients and microtopography (Riley 1989, Glaser et al. 1990). The high degree of small scale environmental heterogeneity results in strong vegetational zonation (Amon et al. 2002, Bedford and Godwin 2003). Vegetational zones that frequently occur within northern fens include sedge lawns, sparsely vegetated marl flats, and shrub thickets, which often occur as narrow bands on the upland margin. Floristic composition is determined by gradients in pH, light, soil moisture, and cation concentrations (nutrient availability) (Heinselman 1970, Vitt and Slack 1975, Schwintzer 1978a, Glaser et al. 1981, Glaser et al. 1990, Siegel 1988, Anderson et al. 1996, Bedford et al. 1999). The mean number of vascular species per plot in northern fens in the northern Lower Peninsula of Michigan was found to be 29 by Vitt and Slack (1975) and 30 by Schwintzer (1978b) with a range of 10-53. For northern fens within Michigan Natural Features Inventory's database, the mean number of species per northern fen is approximately 48. Very few introduced, weedy species are able to establish within bogs and fens, likely because of the unique growing conditions and competition from the adapted flora. Northern fens are dominated by plants that thrive under minertrophic conditions. Occasionally ombrotrophic indicators may be present in fens at low cover. The tops of hummocks can support sphagnum mosses and a more acidic micro-environment where these ombrotrophic species can occur isolated from the influence of mineral-rich ground water (Wheeler et al. 1983, Amon et al. 2002).

The patchy to continuous surface carpet of mosses in northern fens is dominated by calcicolous brown mosses of the family *Amblystegiaceae* (Glaser et al. 1990, Zoltai and Vitt 1995, Swinehart and Parker 2000, Amon et al. 2002). Typical minerotrophic bryophytes of northern fen include the following brown mosses: *Calliergon trifarium*, *Campylium stellatum*, *Drepanocladus revolvens*, and *Scorpodium scorpoides* (Crum 1983, Riley 1989, Glaser et al. 1990). Sphagnum mosses are either absent from northern fens or subordinate to the Amblystid mosses (Schwintzer 1978). *Bryum pseudotriquetrum* can also occur within northern fen. *Sphagnum teres* thrives in alkaline conditions and is often found in association with *Carex lasiocarpa* (wiregrass sedge) (Vitt and Slack 1975). Other sphagnum mosses that could occur within northern fens include *Sphagnum angustifolium*, *S. capillifolium*, *S. centrale*, *S. magellanicum*, *S. subsecundum*, *S. warnstorfii* (Vitt and Slack 1975, Glaser et al. 1990, NatureServe 2005a). Hummock and hollow microtopography often occurs in northern fens and allows for high levels of bryophyte diversity since individual species of moss can occur at specific elevations (Vitt and Slack 1975, Wheeler et al. 1983, Riley 1989). The vertical zonation of species corresponds to gradients in pH and moisture with the hollows being wetter and more alkaline than the drier and more acidic tops of the hummocks (Vitt et al. 1975, Wheeler et al. 1983). As noted above, ombrotrophic Sphagnum mosses can occur on the tops of hummocks (Amon et al. 2002).

Cyperaceous graminoids dominate the herbaceous layer of fens. The most dominant plant in northern fens is *Carex lasiocarpa* (wiregrass sedge), which can form extensive lawns (NatureServe 2005a). Sedges that are characteristic of northern fens include *Carex aquatilis*, *C. chordorrhiza* (creeping sedge), *C. leptalea* (bristly-stalked sedge), *C. limosa* (mud sedge), and *C. livida* (livid sedge). Other sedges that often occur in northern fens are *Carex buxbaumii* (Buxbaum's sedge), *C. capillaries* (hair-like sedge), *C. exilis* (coastal sedge), *C. interior* (inland sedge), *C. lacustris* (lake or hairy sedge), *C. rostrata* (beaked sedge), *C. sterilis* (dioecious sedge), *C. stricta* (tussock sedge), and *C. viridula* (little green sedge). *Calamagrostis canadensis* (blue-joint grass), *C. stricta* (reedgrass), *Muhlenbergia glomerata* (marsh wild-timothy), and *Panicum lindheimeri* (panic grass) are typical northern fen grasses. Additional graminoids that thrive in northern fens include *Cladium marisicoides* (twig-rush), *Dulichium arundinaceum* (three-way sedge), *Eleocharis compressa* (flat-stem spike-rush), *Eleocharis elliptica* (elliptic spike-rush), *Eleocharis rostellata* (beaked spike-rush), *Eriophorum angustifolium* (tall cotton-grass), *Eriophorum spissum* (sheathed cotton-grass), *Rhynchospora alba* (white beak-rush), *R. capillacea* (needle beak-rush), *Scirpus cespitosus* (tufted bulrush), *Scirpus hudsonianus* (Hudson's Bay bulrush), and *Typha latifolia* (cattail). Northern fens frequently contain marl flats that are dominated by twig-rush, beak-rushes, spike-rushes, rushes, and bulrushes (i.e., *Eleocharis rostellata*). The following is a list of prevalent northern fen herbs: *Aster borealis* (rush aster), *Campanula aparinoides* (marsh bellflower), *Decodon verticillatus* (whorled loosestrife), *Euthamia graminifolia* (flat-topped goldenrod), *Iris versicolor* (wild blue flag), *Lobelia kalmii* (Kalm's lobelia), *Lycopus uniflorus* (northern bugleweed), *Lysimachia terrestris* (swamp candles), *Menyanthes trifoliata* (bogbean), *Parnassia palustris* (grass-of-Parnassus), *Potentilla anserine* (silverweed), *Solidago uliginosa* (bog goldenrod), *Tofieldia glutinosa* (false asphodel), *Triadenum fraseri* (marsh St. John's-wort), and *Triglochin maritimum* (arrow-grass). Insectivorous plants, *Drosera rotundifolia* (roundleaf sundew), *Drosera intermedia* (spoon-leaf sundew), *Sarracenia purpurea* (pitcher-plant), and *Utricularia intermedia* (flat-leaved bladderwort), are common features of fens. The fern ally *Equisetum fluviatile* (water horsetail) is also typical.

Northern fens contain both a tall shrub layer and a low shrub layer. Typically shrub cover is at least 25%. Some areas of fen can contain dense thickets of shrubs (over 60% cover), particularly along the upland margins and where fire and/or flooding have failed to limit shrub encroachment. The low shrub layer is usually less than three feet high with *Potentilla fruticosa* (shrubby cinquefoil), *Myrica gale* (sweet gale), and *Betula pumila* (bog birch) often being the most prevalent species. Other important associates of the low shrub layer include *Hypericum kalmianum* (Kalm's St. John's-wort), *Potentilla palustris* (marsh cinquefoil), *Rhamnus alnifolia* (alder-leaved buckthorn), and *Spiraea alba* (meadowsweet). Ericaceous shrubs occur within the low shrub layer of northern fens but with far lesser frequency and density than in bogs and poor fens. The following are common heath shrubs of northern fens: *Andromeda glaucophylla* (bog-rosemary), *Chamadaephne calyculata* (leatherleaf), *Ledum groenlandicum* (Labrador-tea), and *Vaccinium oxycoccos* (small cranberry). The tall shrub layer of northern fens, which is three to six feet tall, is less dense than the low shrub layer and is often restricted to the periphery of the fen. Tall shrubs typical of northern fens include *Alnus rugosa* (speckled alder), *Cornus stolonifera* (red-osier dogwood), *Salix pedicellaris* (bog willow), and *Salix petiolaris* (slender willow). Bog birch and meadowsweet can occur in both the tall and low shrub layers

Trees within fens are widely scattered and typically of low stature (ranging from two to ten meters but seldom reaching six meters) (Wheeler et al. 1983, NatureServe 2005). Tree cover is typically below ten percent. The most common dominants of the open canopy are *Larix laricina* (tamarack) and *Thuja occidentalis* (northern white cedar). Infrequent associates include *Picea mariana* (black spruce), *Pinus banksiana* (jack pine), and *P. strobus* (white pine). (Above species lists compiled from Michigan Natural Features Inventory database, Gates 1942, Curtis 1959, Heinselman 1963, Heinselman 1965, Heinselman 1970, Schwintzer and Williams 1974, Vitt and Slack 1975, Schwintzer 1978a, Glaser et al. 1981, Schwintzer 1981, Schwintzer and Tomberlin 1982, Wheeler et al. 1983, Richardson and Marshall 1986, Riley 1989, Glaser et al. 1990, Glaser 1992, Eggers and Reed 1997, Mitsch and Gosselink 2000, Swinehart and Parker 2000, NatureServe 2005a.)

Michigan Indicator Species: bog birch, *Carex chordorrhiza*, *C. lasiocarpa* , *C. limosa*, *C. leptalea*, northern white cedar, shrubby cinquefoil, and tamarack, (Heinselman 1970, Wheeler et al. 1983, Anderson et al. 1996).

Other Noteworthy Species: Northern fens provide habitat for numerous rare insect species including *Appalachia arcana* (secretive locust, state special concern), *Merolonche dollii* (Doll's merolonche moth, state special concern), *Phyciodes batesii* (tawny crescent, state special concern), *Somatochlora hineana* (Hine's emerald, state and federally endangered), and *Somatochlora incurvata* (incurvate emerald, state special concern dragonfly). Numerous butterflies and moths are restricted to bogs and fens because their food plants occur within these peatland systems (Riley 1989). Numerous tiny land snails are associated with calcareous fens (Bedford and Godwin 2003). Snail populations of northern fens includes numerous rare species such as *Catinella exile* (Pleistocene catinella, state special concern), *Euconulus alderi* (land snail, state special concern), *Hendersonia occulta* (cherrystone drop, threatened), *Planogyra asteriscus* (eastern flat-whorl, state special concern), *Vertigo elatior* (tapered vertigo, state special concern), *Vertigo morsei* (six-whorl vertigo, state special concern), and *Vertigo pygmaea* (crested vertigo, state special concern). Rare herptiles that utilize northern fens include *Clemmys guttata* (spotted turtle, state threatened), *Emys blandingii* (Blanding's turtle, state special concern), *Pseudacris triseriata maculata* (boreal chorus frog, state special concern), *Sistrurus catenatus catenatus* (eastern massasauga, state special concern), and *Terrapene carolina carolina* (eastern box turtle, state special concern).

If suitable nesting trees or snags are available, *Falco columbarius* (merlin, state threatened), *Haliaeetus leucocephalus* (bald eagle, state threatened), and *Pandion haliaetus* (osprey, state threatened) can be found nesting in these systems and *Ardea herodias* (great blue heron, protected by the Migratory Bird Treaty Act of 1918) can establish rookeries. Other rare birds that could occur in northern fens are *Asio flammeus* (short-eared owl, state endangered), *Botaurus lentiginosus* (American bittern, state special concern), *Circus cyaneus* (northern harrier, state special concern), *Coturnicops noveboracensis* (yellow rail, state threatened), and *Picoides arcticus* (black-backed woodpecker, state special concern). *Alces alces* (moose, state threatened), *Canis lupus* (gray wolf, state threatened), and *Lynx canadensis* (lynx, state endangered) utilize peatland habitat. Fens provide important habitat for small mammals such as *Blarina brevicauda* (short-tailed shrew), *Castor canadensis* (beaver), *Microtus pennsylvanicus* (meadow vole), *Mustela vison* (mink), *Ondatra zibethicus* (muskrat), and *Sorex cinereus* (masked shrew). Both muskrats and beaver can profoundly influence the hydrology of peatlands. Muskrats create open water channels through the peat and beavers can cause substantial flooding through their dam-building activities (Gates 1942, Heinselman 1963).

Northern fens support a large number of rare plants, including many calciphilic species (Almendinger and Leete 1998, Bedford and Godwin 2003). Compared to other wetland types, fen systems support a disproportionate number of threatened and endangered rare plant species (Eggers and Reed 1997). Rare plants associated with northern fens include *Cacalia plantaginea* (Indian plantain, state special concern), *Carex heleonastes* (Hudson Bay sedge, state endangered), *Carex scirpoidea* (bulrush sedge, state threatened), *Drosera anglica* (English sundew, state special concern), *Empetrum nigrum* (black crowberry, state threatened), *Erigeron hyssopifolius* (hyssop-leaved fleabane, state threatened), *Juncus stygius* (moor rush, state threatened), *Pinguicula vulgaris* (butterwort, state special concern), *Rubus acaulis* (dwarf raspberry, state endangered), and *Solidago houghtonii* (Houghton's goldenrod, state and federally threatened).

Conservation and Biodiversity Management: Northern fen is a widely distributed but uncommon community type in the Great Lakes region that contributes significantly to the overall biodiversity of northern Michigan by providing habitat for a unique suite of plants and wide variety of animal species. Numerous rare species are associated with fens, including many calciphiles which depend on the carbonate precipitate. In addition to their high levels of biodiversity, fens also contribute numerous ecosystem services. Fens modulate water temperature of connecting surface waters, are characterized by high rates of denitrification and Phosphorous sorption, and serve as critical buffers between downstream waters and nutrients and other pollutants from the surrounding uplands. Fens maintain water quality and flows to streams (Bedford et al. 1999, Bedford and Godwin 2003). By storing high levels of sequestered carbon and functioning as carbon sinks, fens and related peatlands play an important role in global geochemical cycles. Fens also preserve paleo-environmental records: a wealth of information is stored in the remains of plants, animals, and atmospheric particles deposited and stored in fen peat profiles (Chapman et al. 2003).

The primary mechanism for preserving fens is to maintain their hydrology. As noted, peatland systems are sensitive to slight changes in water chemistry: modifications in fen hydrology result in changes in peatland vegetation. Perhaps the greatest threat to northern fens comes from off-road-vehicle traffic, which can destroy populations of sensitive species and drastically alter fen hydrology through rutting. Reduction of access to peatland systems will help decrease detrimental impacts. Resource mangers operating in uplands adjacent to fens should take care to minimize the impacts of management to hydrologic regimes, especially increased surface flow and reduction in groundwater recharge. This can be accomplished by establishing a no-cut buffer around fens and avoiding road construction and complete canopy removal in stands immediately adjacent to fens. Where shrub/tree encroachment threatens to convert open wetlands to shrub-dominated systems or forested swamps, prescribed fire or selective cutting can be employed to maintain open conditions (Bowles et al. 1996). Silvicutural management of fens to preserve open canopy should be employed during the winter to minimize damage to the organic soils and impacts to the hydrologic regime.

Research Needs: Northern fen has a broad distribution and exhibits numerous regional, physiographic, hydrologic, and edaphic variants. The diversity of variations throughout its range demands the continual refinement of regional classifications that focus on the inter-relationships between vegetation, physiography, and hydrology (Barnes et al. 1982, Heinselman 1963). Northern fens and related community types (i.e., poor fen, bog, and intermittent wetland) are frequently difficult to differentiate (Heinselman 1963, NatureServe 2005a). Research on abiotic and biotic indicators that help distinguish similar peatlands would be useful for field classification. Systematic surveys for northern fens and related peatlands are needed to help prioritize conservation and management efforts.

Little is known about the fire regimes of northern fens and the interaction of disturbance factors within these systems. As noted by Hammerson (1994), beaver significantly alter the ecosystems they occupy. An important research question to examine is how the wetland ecosystems of the Great Lakes have been and continue to be affected by fluctuations in populations of beaver. Experimentation is needed to determine how best to prevent shrub and tree encroachment of fens that are threatened by conversion to shrub thicket or conifer swamp. A better understanding is needed of the influence of direct and indirect anthropogenic disturbance on peatlands (Amon et al. 2002). Effects of management within fens should be monitored to allow for assessment and refinement. Monitoring should also focus on how fen succession and management influence populations of rare species. Scientific understanding of the microbes and invertebrates that thrive in the organic soils of fens is lacking. More research is needed to elucidate the relationship of chemical factors and nutrients to floristic community structure of peatlands (Amon et al. 2002). Given the sensitivity of peatlands to slight changes in hydrology and nutrient availability, it is important for scientists to predict how peatlands will be affected by global warming and atmospheric deposition of nutrients and acidifying agents (Heinselman 1970, Riley 1989, Bedford et al. 1999, Gignac et al. 2000, Mitsch and Gosselink 2000). Peat deposits are of great scientific interest because they contain historical ecological records in the form of fossils of plants, animals, and organic matter that contributed to the deposit. Stratigraphical analysis of peat cores provides insights into past climatic change and associated vegetation change, floristic distribution, the development of wetland ecosystems, and the successional pathways of peatlands (Heinselman 1963, Glaser et al. 1981, Miller 1981, Glaser and Janssens 1986, Riley 1989, Gignac et al. 2000).

Similar Communities: bog, Great Lakes marsh, intermittent wetland, muskeg, patterned fen, poor conifer swamp, poor fen, prairie fen, rich conifer swamp, and wooded dune and swale complex.

Other Classifications:
Michigan Natural Features Inventory Circa 1800 Vegetation (MNFI): Emergent Marsh (6221), Wet Meadow (6224), and Inland Wet Prairie (6227)

Michigan Department of Natural Resources (MDNR): D-treed bog, V-bog, N-marsh

Michigan Resource Information Systems (MIRIS): 62 (non-forested wetland) and 622 (emergent wetland)

The Nature Conservancy National Classification:
CODE; ALLIANCE; ASSOCIATION; COMMON NAME

III.B.2.N.g; *Betula pumila* – (*Salix* spp.) Saturated Shrubland Alliance; *Alnus incana – Salix* spp. - *Betula pumila / Chamaedaphne calyculata* Shrubland; Speckled Alder – Willow Species – Bog Birch / Leatherleaf Shrubland; Bog Birch-Willow Shore Fen

III.B.2.N.g; *Betula pumila* – (*Salix* spp.) Saturated Shrubland Alliance; *Betula pumila / Chamaedaphne calyculata / Carex lasiocarpa* Shrubland; Bog Birch / Leatherleaf / Wiregrass Sedge Shrubland; Bog Birch – Leatherleaf Rich Fen

III.B.2.N.g; *Betula pumila* – (*Salix* spp.) Saturated Shrubland Alliance; *Betula pumila – Dasiphora fruticosa* spp. *floribunda / Carex lasiocarpa –Trichophorum alpinum* Shrubland; Bog Birch – Shrubby-cinquefoil / Wiregrass Sedge – Alpine Cottongrass Shrubland; Bog Birch – Shrubby-cinquefoil Rich Boreal Fen

IV.A.1.N.g; *Chamaedaphne calyculata* Saturated Dwarf-shrubland Alliance; *Chamaedaphne calyculata – Myrica gale / Carex lasiocarpa* Dwarf-shrubland; Leatherleaf – Sweet Gale / Wiregrass Sedge Dwarf-shrubland; Leatherleaf – Sweet Gale Shore Fen

V.A.5.N.m; *Calamagrostis canadensis – Carex viridula – Cladium marisicoides – Lobelia kalmii* Saturated Herbaceous Alliance; *Calamagrostis canadensis – Carex viridula – Cladium marisicoides – Lobelia kalmii* Herbaceous Vegetation; Bluejoint – Hairy Sedge – Twig-rush – Ontario Lobelia Herbaceous Vegetation; Great Lakes Sedge Rich Shore Fen

V.A.5.N.m; *Carex lasiocarpa* Saturated Herbaceous Alliance; *Carex lasiocarpa – Carex buxbaumii – Trichophorum caespitosum* Boreal Herbaceous Vegetation; Wiregrass Sedge – Brown Bog Sedge – Deerhair Bulrush Boreal Herbaceous Vegetation; Boreal Sedge Rich Fen

V.A.5.N.m; *Carex lasiocarpa* Saturated Herbaceous Alliance; *Carex lasiocarpa* – (*Carex rostrata*) – *Equisetum fluviatile* Herbaceous Vegetation; Wiregrass Sedge – (Swollen-beak Sedge) – Water Horsetail Herbaceous Vegetation; Wiregrass Sedge Shore Fen

Related Abstracts: American bittern, black-backed woodpecker, Blanding's turtle, bog, cherrystone drop, eastern box turtle, eastern massasauga, English sundew, great blue heron rookery, Great Lakes marsh, incurvate emerald, Indian plantain, intermittent wetland, Hine's emerald, Houghton's goldenrod, merlin, northern harrier, poor fen, prairie fen, rich conifer swamp, secretive locust, short-eared owl, spotted turtle, and wooded dune and swale complex, and yellow rail.

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Abstract Citation:

Cohen, J.G. 2005. Natural community abstract for northern fen. Michigan Natural Features Inventory, Lansing, MI. 15 pp.

Appendix 4. Poor Fen

Overview: A sedge dominated wetland on very strongly to strongly acidic, saturated peat moderately influenced by groundwater. Occurs north of the climatic tension zone in kettle depressions and on flat areas or mild depressions of glacial outwash and glacial lakeplain.

Global and State Rank: G3G4/S3

Range: Poor fen is a peatland type of glaciated landscapes of the northern Great Lakes region, ranging from Michigan west to Minnesota and northward into central Canada (Ontario, Manitoba, and Quebec) (Gignac et al. 2000, Faber-Langendoen 2001, Amon et al. 2002, NatureServe 2005a). Poor fens may also occur in parts of the northeastern U.S. (i.e., Maine, New Hampshire, and New York) and range south into northern Illinois and Iowa (NatureServe 2005a). In Michigan, poor fens occur in the northern Lower Peninsula and the Upper Peninsula (within the U.P., poor fen occurrences have been documented by Michigan Natural Feature Inventory in just the eastern portion). Fens and other peatlands occur where excess moisture is abundant (where precipitation is greater than evapotranspiration) (Mitsch and Gosselink 2000). Conditions suitable for the development of fens have occurred in the northern Lake States for the past 8,000 years. Expansion of peatlands likely occurred following climatic cooling, approximately 5,000 years ago (Heinselman 1970, Boelter and Verry 1977, Riley 1989).

Several other natural peatland communities also occur in Michigan and can be distinguished from weakly minerotrophic poor fens, based on careful comparisons of nutrient levels, flora, canopy closure, distribution, and groundwater influence. Additional open wetlands occurring on peat include bog, northern fen, and prairie fen. Bogs, peat-covered wetlands raised above the surrounding groundwater by an accumulation of peat, receive inputs of nutrients and water primarily from precipitation and are classified as ombrotrophic (nutrient-poor) (Gignac et al. 2000). In comparison, the hydrology of fens is influenced by groundwater and as a result, fens have higher nutrient availability, increased alkalinity (less acidity), and greater species richness compared to bogs, with poor fens being most similar to bogs in terms of these factors and species composition (Zoltai and Vitt 1995, Bedford and Godwin 2003). Both poor fens and northern fens are dominated by sedges, rushes, and grasses, with poor fens containing a higher coverage of ericaceous shrubs and sphagnum mosses than northern fens (Mitsch and Gosselink 2000). Like northern fen and poor fen, prairie fens are graminoid dominated and groundwater influenced, however prairie fens are restricted to south of the climatic tension zone. Intermittent wetlands are herb or herb-shrub dominated wetlands that experience fluctuating water levels seasonally and yearly and have soils that range from loamy sand and peaty sand to peaty muck and are very strongly acid to strongly acid. Like bogs, muskegs and poor conifer swamp are nutrient-poor, acidic wetlands. However, these ombrotrophic peatlands exhibit a greater degree of canopy closure than bogs (muskegs having clumped and scattered conifers and poor conifer swamp being a closed canopy system). Closed canopy, minerotrophic peatlands include rich conifer swamp, a *Thuja occidentalis* (northern white cedar) dominated system found north of the tension zone, and relict conifer swamp, which is dominated by *Larix laricina* (tamarack) and occurs primarily south of the tension zone (Kost 2001).

Rank Justification: Poor fens are uncommon features of the northern Great Lakes region, occurring sporadically in Michigan's northern Lower Peninsula and the Upper Peninsula. The northern lake states contain over six million hectares (15 million acres) of peatland (Boelter and Verry 1977). What percentage of that area is poor fen has yet to be determined. Likewise, the current status of fens relative to their historical status is unknown (Bedford and Godwin 2003). Peatland scientists concur that fens have always been localized and not very abundant but have suffered from extensive loss, fragmentation, and degradation (Bedford and Godwin 2003, NatureServe 2005a). Historically, widespread fires following the turn of the century logging drastically altered many peatlands, either converting conifer swamp to open fen systems or destroying the peat and converting peatlands to wetlands without organic soils (mineral soil wetlands) (Dean and Coburn 1927, Gates 1942, Curtis 1959). Logging of cedar and tamarack from peatland systems also favored the conversion of forested peatlands to open peatlands (Gates 1942, Dansereau and Segadas-Vianna 1952, Riley 1989). Beginning in the 1920s, effective fire control by the U.S. Forest Service and state agencies reduced the acreage of fires ignited by man or lightning (Swain 1973). In landscapes where frequent fire was the prevalent disturbance factor, fire suppression has led to the conversion of open fens to closed canopy peatlands or shrub thickets (Curtis 1959, Schwintzer 1981, Riley 1989).

Currently, fens are primarily threatened by peat mining, logging, quarrying, agricultural runoff and enrichment, off-road-vehicle (ORV) activity, draining, flooding, and development (Bedford and Godwin 2003, NatureServe 2005a). Peat mining and cranberry farming have degraded numerous peatlands throughout the region (Gates 1942, Curtis 1959, Eggers and Reed 1997, Chapman et al. 2003). Michigan, along with Florida and Minnesota, are leaders in peat production in the U.S. (Miller 1981). In addition to direct impacts to vegetation, alteration of peatland hydrology from road building, ORVs, quarrying, creation of drainage ditches and dams, and runoff from logging has led to the drastic change of peatland composition and structure (Schwintzer and Williams 1974, Schwintzer 1978b, Riley 1989, Bedford and Godwin 2003, Chapman et al. 2003). Fen vegetation is extremely sensitive to minor changes in water levels and chemistry, ground water flow, and nutrient availability (Siegel 1988, Riley 1989). A reduction in groundwater flow and subsequent decrease in nutrients in poor fens can result in the shift to less minerotrophic wetlands such as bog. Conversion to more eutrophic wetlands has occurred as the result of nutrient enrichment and raised water levels, which cause increased decomposition of peats. Eutrophication from pollution and altered hydrology has detrimentally impacted fens by generating conditions favorable for the invasion of exotic species (Riley 1989, Bedford and Godwin 2003) and dominance by aggressive, common natives such as *Phalaris arundinaceae* (reed canary grass) and *Typha* spp. (cat-tails) (Richardson and Marshall 1986, Almendinger and Leete 1998). Bedford et al. (1999) have noted a widespread decline in wetland species richness associated with the overall eutrophication of the landscape: nutrient enrichment has converted numerous wetlands into monospecific stands of nitrophilic species. Lowering of water tables from drainage has allowed for tree and shrub encroachment into open fens and the eventual succession to closed canopy peatland (Almendinger and Leete 1998). Increased shrub and tree canopy cover typically results in decreased species richness of fen systems (Bowles et al. 1996). The sensitivity of fens to changes in water chemistry makes them especially susceptible to acid rain and air pollution (Siegel 1988, Chapman et al. 2003). Atmospheric deposition can contribute Nitrogen, Sulphur, Calcium and heavy metals to fens (Damman 1990, Chapman et al. 2003). Dust-fall and atmospheric deposition from air pollution are particularly threats to fen systems that are surrounded by cultivated land and close to industrial and urban centers (Damman 1990).

Physiographic Context: Two landscape features are conducive to the development of peat; poorly-drained, level terrain and small ice-block basins (Boelter and Verry 1977). Poor fen occur on flat areas or mild depressions of sandy glacial outwash and glacial lakeplains, and in kettle depressions on pitted outwash and moraines (Gates 1942, Verry 1975, Vitt and Slack 1975, Boelter and Verry 1977, Schwintzer 1978a, Siegel 1988, Michigan Natural Features Inventory 2003, NatureServe 2005a). The overall topography of fens is flat to gently undulating with microtopography characterized by hummocks and hollows (Heinselman 1963, Vitt and Slack 1975, Wheeler et al. 1983, Siegel 1988, NatureServe 2005a). Poor fens found in kettle depressions are associated with active or extinct glacial lakes that are very strongly acidic to strongly acidic (Vitt and Slack 1975). Within kettle depressions, fens can occupy the entire basin or frequently occur as a floating mat on the margin of the remaining glacial lake above the level of seasonal flooding (Vitt and Slack 1975, Schwintzer 1978a, NatureServe 2005a). When fens occur along the edge of large bodies of water, they are found in sheltered bays or coves that are protected from wave and ice action, which can prevent the development of peat or erode existing peat mats (Gates 1942, NatureServe 2005a). Fens occurring on former glacial lake beds and drainageways tend to be more extensive than kettle fens, which are limited in area by the size of the glacial ice-block which formed the basin (Lindeman 1941).

Poor fens occur adjacent to other peatland communities, often grading into bog, poor conifer swamp, and muskeg. More minerotrophic systems such as northern fen, northern shrub thicket, northern wet meadow, and rich conifer swamp can occur along the outer margins of poor fens where groundwater seepage from the adjacent uplands is prevalent. Upland community types which neighbor poor fen include dry-mesic northern forest, dry northern forest, and pine barrens.

Hydrology: Poor fens are weakly minerotrophic peatlands, receiving inputs of water and nutrients from both ion-poor precipitation and low exposure to nutrient-rich groundwater (Heinselman 1970, Boelter and Verry 1977, Siegel and Glaser 1987, Siegel 1988, Bedford et al. 1999, Gignac et al. 2000, Bedford and Godwin 2003, NatureServe 2005a). Low-levels of groundwater discharge and the high water retaining capacity of fibric peat produce continuously saturated conditions in the rooting zone of poor fens. The water table of poor fens is stable, typically at the soil surface with the peat soils saturated but seldom flooded (Heinselman 1970, Schwintzer 1978b, Riley 1989, Amon et al. 2002, Bedford and Godwin 2003, NatureServe 2005a). The surface waters of poor fens are characterized by very strong to strong acidity, low available nutrients, low specific conductivity, cool temperatures, anaerobic conditions, and moderate levels of dissolved organic matter (Verry 1975, Boelter and Verry 1977, Schwintzer 1978b, Glaser et al. 1981, Glaser et al. 1990, Bedford et al. 1999, Bedford and Godwin 2003, NatureServe 2005a). The limited amount of ground water which enters poor fens is telluric, having moved over or percolated through base-rich bedrock, calcareous glacial deposits, or mineral soil (Heinselman 1970, Schwintzer 1978b, Mitsch and Gosselink 2000, Bedford and Godwin 2003). The poorly mineralized or poorly buffered ground water discharge of poor fens typically contains low concentrations of dissolved mineral nutrients (Heinselman 1970, Boelter and Verry 1977, Glaser et al. 1981, Glaser et al. 1990, Bedford and Godwin 2003, NatureServe 2005a). The acidity of poor fens limits the availability and uptake of essential mineral plant nutrients. Poor fens are characterized by low concentrations of available Calcium, Magnesium, Nitrogen, and Phosphorous in the surface water and peat (Heinselman 1970, Glaser et al. 1981, Schwintzer 1981, Glaser et al. 1990, Mitsch and Gosselink 2000). Scientists studying poor fens in the Great Lakes have reported pH values to range between 4.1-5.9 (Heinselman 1970, Boelter and Verry 1977, Glaser et al. 1981, Glaser et al. 1990, Almendinger and Leete 1998, Bedford et al. 1999, NatureServe 2005a). The degree of minerotrophy of a given fen and within a fen depends on the kind and amount of groundwater discharge, degree of dilution from precipitation, the characteristics of the bedrock and/or glacial deposits the groundwater has percolated through (i.e., older glacial sediments have less dissolved minerals due to prior leaching), the distance the water has traveled through the peatland, and the thickness and character of the peat (Heinselman 1963, Heinselman 1970, Boelter and Verry 1977, Siegel and Glaser 1987, Amon et al. 2002, Bedford and Godwin 2003). The ground water entering poor fens typically passes through materials with low solubility or low buffering capacity (Bedford and Godwin 2003). Poor fens often occur in basins with small watersheds which minimize the groundwater input from the surrounding uplands (NatureServe 2005a). It is likely that many poor fens are restricted to areas where the bedrock is buried under thick glacial deposits.

Soils: The organic soils of poor fens are composed of peat which frequently forms a shallow, continuous mat and is typically 1-3 meters deep (Glaser et al. 1981). Peat is a fibrous network of partially decomposed organic material that is formed under anaerobic conditions (Almendinger et al. 1986, Heinselman 1963). The surface peats of poor fens are saturated, fibric peats, and like the surface waters, are very strongly to strongly acidic and characterized by low nutrient availability (NatureServe 2005a). Fibric peat, which is loosely compacted, contains partially decomposed sphagnum moss with fragments of wood and occasionally sedge. Fibric peat has high water retaining capacity and large intercellular pores that permit rapid water movement (Boelter and Verry 1977, Miller 1981, Swanson and Grigal 1989, Amon et al. 2002). Peats of fens tend to have lower water retaining capacity and higher levels of organic decomposition compared to the peats of bogs (Boelter and Verry 1977, Miller 1981). Peats of poor fens tend to be less decomposed with higher water retaining capacity compared to northern fen peats. Peat composition changes with depth and depending on the successional history of a given fen. Generally, fiber content and hydraulic conductivity usually decreases with depth; deeper peats are more decomposed, retain more water, and drain slower than surface peats (Verry 1975, Boelter and Verry 1977).

Climate: Peatlands develop in humid climates where precipitation exceeds evapotranspiration (Boelter and Verry 1977, Gignac et al. 2000, Bedford and Godwin 2003). The northern Lake States are characterized by a humid, continental climate with long cold winters and short summers that are moist and cool to warm (Gates 1942, Boelter and Verry 1977, Damman 1990, Mitsch and Gosselink 2000). The Michigan range of poor fen falls within the area classified by Braun (1950) as the Northern Hardwood-Conifer Region (Hemlock/White Pine/Northern Hardwoods Region) and within the following regions classified by Albert et al. (1986) and Albert (1995): Region II, Northern Lower Michigan; Region III, Eastern Upper Michigan; and Region IV, Western Upper Michigan. The Northern Hardwood-Conifer Region has a cool snow-forest climate with short, warm summers, cold winters and a large number of cloudy days. The mean number of freeze-free days is between 90 and 160, and the average number of days per year with snow cover of 2.5 cm or more is between 80 and 140. The normal annual total precipitation ranges from 740 to 900 mm with a mean of 823 mm. The daily maximum temperature in July ranges from 24 to 29 °C (75 to 85 °F), the daily minimum temperature in January ranges from -21 to -9 °C (-5 to 15 °F) and the mean annual temperature is 7 °C (45 °F) (Albert et al. 1986, Barnes 1991). Temperatures vary less in peatlands compared to the surrounding landscape because of groundwater influence, the insulating effect of fens' saturated peat carpet in the growing season, and snow cover in the winter (Burns 1906, Heinselman 1963, Curtis 1959, Glaser 1992). Fens are characterized by local climates or microclimates that are cooler in the summer and warmer in the winter compared to the regional climate (Heinselman 1963, Bedford and Godwin 2003).

Natural Processes: Peat establishment requires an abundant supply of water: peatlands occur in regions where precipitation is greater than evapotranspiration producing substantial groundwater discharge (Dansereau and Segadas-Vianna 1952, Boelter and Verry 1977, Almendinger and Leete 1998, Mitsch and Gosselink 2000). Saturated and inundated conditions inhibit organic matter decomposition and allow for the accumulation of peat (Almendinger and Leete 1998, Amon et al. 2002). Under cool and anaerobic conditions, the rate of organic matter accumulation exceeds organic decay (Schwintzer and Williams 1974, Damman 1990, Mitsch and Gosselink 2000). Low levels of oxygen protect plants from microorganisms and chemical actions that cause decay (Miller 1981). Fens have greater levels of microbial activity compared to bogs because of the lesser acidity and higher base status of minerotrophic waters. As a result, organic matter decay is greater while peat accumulation is lesser in fens versus bogs (Heinselman 1970). Development and expansion of fens occurs via two different processes in kettle depressions versus glacial lakeplain and outwash. Fens develop in glacial lakeplain and outwash where groundwater influence maintains saturated conditions which inhibit organic matter decomposition and allow peat accumulation (Almendinger and Leete 1998). Peat develops vertically and spreads horizontally (Boelter and Verry 1977). Estimates of vertical accumulation of peat range between 100 to 200cm/1000 years (Mitsch and Gosselink 2000). Lake-filling or terrestrialization occurs in small kettle lakes with minimal wave action where gradual peat accumulation results in the development of a sedge mat that can fill the basin or occur as a floating mat in the lake or as a grounded mat along the water's edge (Gates 1942, Bay 1967, Curtis 1959, Heinselman 1963, Mitsch and Gosselink 2000, Swinehart and Parker 2000). Floating mats of fen sedges (i.e., *Carex lasiocarpa*) pioneer open water or emergent marsh. The interlacing of rhizomes and roots forms a floating mat that is buoyed up in water and accumulates organic matter in the form of sapric peat (Gates 1942). Over time fen mats are often invaded by ericaceous shrubs and acidifying sphagnum mosses (Osvald 1935, Gates 1942, Schwintzer and Williams 1974, Swineheart and Parker 2000).

The invasion of sphagnum moss into fen systems often results in the conversion of fens to more acidic communities such as poor fen or bog. Succession in lake-filled fens typically proceeds from lake to marsh to fen to poor fen or bog (Heinselman 1963, Boelter and Verry 1977, Schwintzer 1981, Swineheart and Parker 2000). Once Sphagnum mosses become established on fen peat, they maintain and enhance saturated and acidic conditions which in turn promote continued sphagnum peat development (Heinselman 1963). The ability of sphagnum to absorb and hold cations increases the acidity and low nutrient availability of peatlands (Osvald 1935, Curtis 1959, Verry 1975, Vitt and Slack 1975, Boelter and Verry 1977, Zoltai and Vitt 1995). In addition, accumulating sphagnum peat can dilute groundwater influence by absorbing large amounts of precipitated water, impeding drainage, and increasing the distance of the rooting zone from telluric water (Dansereau and Segadas-Vianna 1952, Vitt and Slack 1975, Schwintzer 1981, Zoltai and Vitt 1995). Sphagnum moss, which has numerous pores, partitions, and capillary space, has an enormous water-holding capacity (Osvald 1935, Dansereau and Segadas-Vianna 1952, Curtis 1959): sphagnum peat can hold 15 to 30 times its own weight in water (Miller 1981, Mitsch and Gosselink 2000). In addition to sphagnum peat accumulation, beaver dams can also cause blocked drainage in fens and the subsequent succession of fens to bogs (Heinselman 1963, Heinselman 1970).

Poor fens can also succeed to poor conifer swamp or northern shrub thicket. Lowering of the water table of fens results in the increase in decomposition rates of organic matter and the subsequent accumulation of compact peat that is more conducive to shrub and tree growth (Schwintzer and Williams 1974, Miller 1981, Schwintzer 1981, Riley 1989, Almendinger and Leete 1998, Gignac et al. 2000). Conversions of bog to fen can also occur, however with far less frequency (Glaser et al. 1990). A discharge of alkaline groundwater at the peat surface of a bog, caused by a change in hydraulic head, can result in the conversion of bog vegetation to fen vegetation (Siegel and Glaser 1987, Glaser et al. 1990). Mixing of as little as 10% groundwater from underlying calcareous parent material with acid bog water is sufficient to raise the peatland pH from 3.6 to 6.8 (Glaser et al. 1990). Fens and bogs are very sensitive to changes in pH and subsequent availability of nutrients: fen vegetation can replace bog flora when pH increases above 4.5 (Siegel 1988).

Disturbance factors influencing poor fens include fire, flooding, windthrow, and insects. Numerous fens contain charcoal within their peat profile (Curtis 1959, Heinselman 1963) and many researchers have reported fire as a prevalent part of fen's disturbance regime (Gates 1942, Curtis 1959, Vitt and Slack 1975). Surface fire can contribute to the maintenance of fens by killing encroaching trees and shrubs without completely removing the peat, which is normally saturated (Curtis 1959, Vitt and Slack 1975). Graminoid dominance of fen systems can be perpetuated by surface fires (Bowles et al. 1996). In addition, many of the ericaceous plants that thrive in fens are fire adapted and often grow densely following fire (Wheeler et al. 1983). Fire severity and frequency in fens is closely related to fluctuations in water level. Prolonged periods of lowered water table can allow the surface peat to dry out enough to burn (Schwintzer and Williams 1974). When the surface peat of fens and bogs burns, the fire releases organic matter from the peat, kills seeds and latent buds, stimulates decay, and slows peat accumulation (Damman 1990, Jean and Bouchard 1991). Such peat fires can result in the conversion of peatland to mineral soil wetland. Peat fires within bogs can also release enough nutrients to favor succession to more minerotrophic peatlands such as poor fen or intermittent wetland.

As noted above, flooding can result in the conversion of fens to bogs. Flooding can also contribute to fen maintenance. Roots of peatland trees are physiologically active near the surface and are quickly killed when the water table rises following flooding (Glaser and Janssens 1986). Within kettle fens, flooding-induced tree mortality is likely greater on grounded mats compared to free floating mats: free mats float up with rising water table while grounded mats become inundated and have shallower aerobic zones (Schwintzer 1978a, Schwintzer 1978b, Schwintzer 1979). In addition to flooding, kettle fens can be influenced by waves and ice. Wave and ice action can prevent the expansion of fen mats by eroding the shoreline vegetation (Gates 1942).

The natural disturbance regime in fens is also influenced by wind. The Great Lakes region is one of the most active weather zones in the northern hemisphere, with polar jet streams positioned overhead much of the year. More cyclones pass over this area than any other area in the continental U.S. (Frelich and Lorimer 1991). Trees growing in fens are particularly susceptible to windthrow because peat provides a poor substrate for anchoring trees (Burns 1906). The living roots of woody peatland plants occur in a shallow rooting zone, generally restricted to the uppermost few centimeters where there is sufficient oxygen to maintain aerobic respiration (Glaser and Janssens 1986). The superficial rooting of trees results in numerous windthrows (Dansereau and Segadas-Vianna 1952). Tree survival in fens is also limited by insects and parasites. Insect outbreaks of the *Pristiphora erichsonii* (larch sawfly) cause heavy mortality of *Larix laricina* (tamarack) while, the plant parasite *Arceuthobium pusillum* (dwarf mistletoe) kills *Picea mariana* (black spruce) (Coburn et al. 1933, Gates 1942, Heinselman 1963).

Vegetation Description: Poor fens have a unique flora that is intermediate between bog and northern fen. Poor fens are characterized by a continuous carpet of sphagnum mosses, a graminoid-dominated herbaceous layer of low to moderate diversity, low ericaceous, evergreen shrubs, and widely-scattered and stunted conifer trees (Gates 1942, Curtis 1959, Verry 1975, Vitt and Slack 1975, Glaser et al. 1991, Bedford and Godwin 2003, NatureServe 2005a). The harsh growing conditions of poor fens (strong acidity, low nutrient availability, and saturated peat) results in a distinct flora of low to moderate diversity: relatively few species have evolved the necessary adaptations to cope with ombrotrophic and weakly minerotrophic conditions (Siegel 1988, Glaser 1992, Mitsch and Gosselink 2000). Very few introduced, weedy species are able to establish within bogs and fens because of the unique growing conditions and competition from the adapted flora (Riley 1989). Poor fen plants have developed a diversity of adaptations to cope with low nutrient availability including plant carnivory, evergreen leaves, sclerophylly (thick epidermal tissue), and high root biomass (Mitsch and Gosselink 2000). Poor fens are dominated by plants that thrive under moderately ombrotrophic to weakly minerotrophic conditions. Occasionally minerotrophic indicators may be present in poor fen at low cover. Plants found typically in more alkaline habitat such as *Betula pumila* (bog birch), *Carex aquatilis* (water sedge), *Carex rostrata* (beaked sedge), and *Carex stricta* (tussock sedge), can occur sporadically in poor fen when their roots extend beneath the surface mat to minerotrophic peat influenced by groundwater (NatureServe 2005a). The tops of hummocks support sphagnum mosses and a more acidic micro-environment within poor fens where ombrotrophic species can occur isolated from the influence of ground water. Species richness of poor fens is related to geographical location, climatic factors, nutrient availability, and habitat heterogeneity (Glaser et al. 1990, Glaser 1992). Floristic diversity within poor fens is strongly correlated with levels of available nutrients and microtopography (Riley 1989, Glaser et al. 1990). Small scale environmental heterogeneity can result in vegetational zonation (Amon et al. 2002, Bedford and Godwin 2003). Gradients in pH, light, soil moisture, and cation concentrations (nutrient availability) determine floristic composition of poor fens (Heinselman 1970, Vitt and Slack 1975, Schwintzer 1978a, Glaser et al. 1981, Anderson et al. 1986, Siegel 1988, Glaser et al. 1990, Bedford et al. 1999).

The continuous moss layer of poor fens is dominated by sphagnum mosses especially *Sphagnum magellanicum*, *S. angustifolium*, *S.*

capillaceum, *S. capillifolium*, *S. recurvum*, *S. papillosum*, and *S. fuscum* (Schwintzer 1978b, Crum 1983, Riley 1989, NatureServe 2005a). In comparison, the moss layer of northern fens is patchy to continuous and dominated by calcicolous brown mosses of the family *Amblystegiaceae* (Glaser et al. 1990, Zoltai and Vitt 1995, Swinehart and Parker 2000, Amon et al. 2002). The hummock and hollow microtopography of poor fens allows for high levels of bryophyte diversity since individual species of sphagnum occur at specific elevations (Vitt and Slack 1975, Wheeler et al. 1983, Riley 1989,). Hollows support *S. cuspidatum*, *S. magellanicum*, and *S. papillosum* (Vitt and Slack 1975, Vitt et al. 1975, Heinselman 1970, Wheeler et al. 1983, Riley 1989). The lower, moist slopes of hummocks often support *S. magellanicum* and *S. recurvum* while the drier hummock crests are dominated by *S. fuscum*, *S. capillaceum*, and *S. cappillifolium* (Vitt et al. 1975, Wheeler et al. 1983, Riley 1989). The vertical zonation of species corresponds to gradients in pH and moisture with the hollows being wetter and more alkaline than the drier and more acidic tops of the hummocks (Vitt et al. 1975, Wheeler et al. 1983).

Cyperaceous graminoids dominate the species poor herbaceous layer of poor fens. *Carex oligosperma* (few-seed sedge) and *Carex lasiocarpa* (wiregrass sedge) are common dominants. Other sedges that are characteristic of poor fens include *Carex chordorrhiza* (creeping sedge), *C. exilis* (coastal sedge), *C. livida* (livid sedge), *C. pauciflora* (few-flower sedge), and *C. limosa* (mud sedge). Other sedges that often occur in bogs are *Carex paupercula* (bog or poor sedge), *C. rostrata* (beaked sedge), and *C. trisperma* (three-seeded sedge). Additional graminoids that thrive in poor fens include *Cladium marisicoides* (twig-rush), *Dulichium arundinaceum* (three-way sedge), *Eriophorum angustifolium* (tall cotton-grass), *Eriophorum spissum* (sheathed cotton-grass), *Eriophorum virginicum* (tawny cotton-grass), *Lysimachia terrestris* (swamp candles), *Rhynchospora alba* (white beak-rush), *Scheuchzeria palustris* (rannoch-rush), and *Scirpus cespitosus* (tufted bulrush). The following is a list of prevalent bog herbs: *Aster borealis* (rush aster), *Epilobium angustifolium* (fireweed), *E. ciliatum* (fringed willow-herb), *Euthamia graminifolia* (flat-topped goldenrod), *Iris versicolor* (wild blue flag), *Menyanthes trifoliata* (bog bean), *Smilacina trifolia* (false Solomon-seal), *Solidago uliginosa* (bog goldenrod), and *Triglochin maritimum* (arrow-grass). Insectivorous plants, *Drosera rotundifolia* (roundleaf sundew), *Drosera intermedia* (spoon-leaf sundew), *Sarracenia purpurea* (pitcher-plant), and *Utricularia intermedia* (flat-leaved bladderwort), are common features of fens. The fern ally *Equisetum fluviatile* (water horsetail) is often found in poor fens

The shrub layer of poor fens is dominated by low, ericaceous shrubs with *Chamadaephne calyculata* (leatherleaf) often being the most prevalent. In addition to leatherleaf, the following heath shrubs are important: *Andromeda glaucophylla* (bog-rosemary), *Kalmia polifolia* (bog-laurel), *Ledum groenlandicum* (Labrador-tea), *Vaccinium macrocarpon* (large cranberry), and *V. oxycoccos* (small cranberry). The tall shrub layer of poor fens is less dense than the low shrub layer and is often restricted to the periphery. Tall shrubs typical of poor fens include *Salix discolor* (pussy willow), *S. pedicellaris* (bog willow), and *Spirea tomentosa* (steeplebush). As noted, more minerotrophic shrubs, like *Betula pumila* (bog birch), *Hypericum kalmianum* (Kalm's St. John's-wort), *Potentilla fruticosa* (shrubby cinquefoil), and *P. palustris* (marsh cinquefoil), can occur in poor fens when their roots can extend beneath the surface mat to minerotrophic peat.

Trees within poor fens are widely scattered and stunted (seldom reaching six meters) (Wheeler et al. 1983, NatureServe 2005a). Tree cover is typically below ten percent (NatureServe 2005a). The most common canopy dominants are *Picea mariana* (black spruce) and *Larix laricina* (tamarack). Additional associates include *Pinus banksiana* (jack pine) and *Pinus strobus* (white pine). (Above species lists compiled from Michigan Natural Features Inventory database, Gates 1942, Dansereau and Segadas-Vianna 1952, Curtis 1959, Heinselman 1963, Heinselman 1965, Bay 1967, Heinselman 1970, Schwintzer and Williams 1974, Vitt and Slack 1975, Schwintzer 1978, Glaser et al. 1981, Schwintzer 1981, Wheeler et al. 1983, Riley 1989, Glaser et al. 1990, Glaser 1992, Eggers and Reed 1997, Mitsch and Gosselink 2000, Swinehart and Parker 2000, NatureServe 2005a.)

Michigan Indicator Species: bog birch, *Carex chordorrhiza*, *C. lasiocarpa*, *C. limosa*, *C. livida*, northern white cedar, shrubby cinquefoil, and tamarack (Heinselman 1970, Wheeler et al. 1983, Anderson et al. 1996). Wheeler et al. (1983), in a study of peatland flora in northern Minnesota, concluded that *Carex livida* is a poor fen indicator; the presence of this species readily distinguishes sites as weakly minerotrophic.

Other Noteworthy Species: Poor fens provide habitat for numerous rare insect species including *Appalachia arcana* (secretive locust, state special concern), *Atlanticus davisi* (Davis's shield-bearer, state special concern), *Boloria freija* (Freija fritillary, state special concern butterfly), *Boloria frigga* (Frigga fritillary, state special concern butterfly), *Erebia discoidalis* (red-disked alpine, state special concern butterfly), *Merolonche dollii* (Doll's merolonche moth, state special concern), *Phyciodes batesii* (tawny crescent, state special concern), *Somatochlora incurvata* (incurvate emerald, state special concern dragonfly), and *Williamsoni fletcheri* (ebony boghaunter, state special concern dragonfly). Numerous butterflies and moths are restricted to bogs and fens because their food plants occur within these peatland systems (Riley 1989). Rare herptiles that utilize poor fens include *Clemmys guttata* (spotted turtle, state threatened), *Elaphe obsoleta obsolete* (black rat snake, state special concern), *Emys blandingii* (Blanding's turtle, state special concern), *Sistrurus catenatus catenatus* (eastern massasauga, state special concern), and *Terrapene carolina carolina* (eastern box turtle, state special concern). If suitable nesting trees or snags are available, *Falco columbarius* (merlin, state threatened), *Haliaeetus leucocephalus* (bald eagle, state threatened), and *Pandion haliaetus* (osprey, state threatened) can be found nesting in these systems and *Ardea herodias* (great blue heron, protected by the Migratory Bird Treaty Act of 1918) can establish rookeries. Other rare birds that could occur in poor fens are *Asio flammeus* (short-eared owl, state endangered), *Botaurus lentiginosus* (American bittern, state special concern), *Circus cyaneus* (northern harrier, state special concern), *Coturnicops noveboracensis* (yellow rail, state threatened), *Falcipennis canadensis* (spruce grouse, state special concern), and *Picoides arcticus* (black-backed woodpecker, state special concern). *Alces alces* (moose, state threatened), *Canis lupus* (gray wolf, state threatened), and *Lynx canadensis* (lynx, state endangered) utilize peatland habitat. Poor fens provide important habitat for small mammals such as *Blarina brevicauda* (short-tailed shrew), *Castor canadensis* (beaver), *Microtus pennsylvanicus* (meadow vole), *Mustela vison* (mink), *Ondatra zibethicus* (muskrat), and *Sorex cinereus* (masked shrew). Both muskrats and beaver can profoundly influence the hydrology of peatlands. Muskrats create open water channels through the peat and beavers can cause substantial flooding through their dam-building activities (Gates 1942, Heinselman 1963).

Rare plants associated with poor fens include *Carex nigra* (black sedge, state endangered), *Carex wiegandii* (Wiegand's sedge, state threatened), *Eleocharis nitida* (slender spike-rush, state endangered), and *Petasites sagittatus* (sweet coltsfoot state threatened).

Conservation and Biodiversity Management: Poor fen is a widespread community type in the Great Lakes region that contributes significantly to the overall biodiversity of northern Michigan by providing habitat for a unique suite of plants and wide variety of animal species. Numerous rare species are associated with poor fens. By storing high levels of sequestered Carbon and serving as Carbon sinks, poor fens and related peatlands play an important role in global geochemical cycles. Poor fens also preserve paleo-environmental records: a wealth of information is stored in the remains of plants, animals, and atmospheric particles deposited and stored in fen peat profiles. Paleo-ecologists may be able to provide crucial information about restoration of peatland ecosystems (Chapman et al. 2003). The primary mechanism for preserving poor fens is to maintain their hydrology. As noted, peatland systems are sensitive to slight changes in water chemistry. A serious threat to poor fens is posed by off-road-vehicle traffic, which can destroy populations of sensitive species and drastically alter fen hydrology through rutting. Reduction of access to peatland systems will help decrease detrimental impacts. Resource mangers operating in uplands adjacent to poor fens should take care to minimize the impacts of management to hydrologic regimes, especially increased surface flow and alteration of groundwater discharge. This can be accomplished by establishing a no-cut buffer around poor fens and avoiding road construction and complete canopy removal in stands immediately adjacent to poor fens. Where shrub/tree encroachment threatens to convert open wetlands to shrub-dominated systems or forested swamps, prescribed fire or selective cutting can be employed to maintain open conditions. Silvicutural management of poor fens to preserve open canopy should be employed during the winter to minimize damage to the peat and impacts to the hydrologic regime.

Research Needs: Poor fen has a broad distribution and exhibits numerous regional, physiographic, hydrologic, and edaphic variants. The diversity of variations throughout its range demands the continual refinement of regional classifications that focus on the inter-relationships between vegetation, physiography, and hydrology (Heinselman 1963, Fitzgerald and Bailey 1975, Barnes et al. 1982, Amon et al. 2002). Poor fens and related community types (bog, northern fen, and intermittent wetland) are frequently difficult to differentiate (Heinselman 1963, NatureServe 2005a). Research on abiotic and biotic indicators that help distinguish related peatlands would be useful for field classification. Systematic surveys for poor fens and related peatlands are needed to help prioritize conservation and management efforts. More research is needed to elucidate the relationship of chemical factors and nutrients to floristic community structure of peatlands (Amon et al. 2002). Little is known about the fire regimes of poor fens and the interaction of disturbance factors within these systems. As noted by Hammerson (1994), beaver significantly alter the ecosystems they occupy. An important research question to examine is how the wetland ecosystems of the Great Lakes have been and continue to be affected by fluctuations in populations of beaver. Experimentation is needed to determine how best to prevent shrub and tree encroachment of fens that are threatened by conversion to shrub thicket or conifer swamp. A better understanding is needed of the influence of direct and indirect anthropogenic disturbance on peatlands (Amon et al. 2002). Effects of management within fens should be monitored to allow for assessment and refinement. Monitoring should also focus on how fen succession and management influence populations of rare species. Scientific understanding of the microbes and invertebrates that thrive in the organic soils of fens is lacking (Amon et al. 2002). Given the sensitivity of peatlands to slight changes in hydrology and nutrient availability, it is important for scientists to predict how peatlands will be affected by climate change and atmospheric deposition of nutrients and acidifying agents (Heinselman 1970, Riley 1989, Bedford et al. 1999, Gignac et al. 2000, Mitsch and Gosselink 2000, Bedford and Godwin 2003). Peat deposits are of great scientific interest because they contain historical ecological records in the form of fossils of plants, animals, and organic matter that contributed to the deposit. Stratigraphical analysis of peat cores provides insights into past climatic change and associated vegetation change, floristic distribution, the development of wetland ecosystems, and the successional pathways of peatlands (Heinselman 1963, Glaser et al. 1981, Miller 1981, Glaser and Janssens 1986, Riley 1989, Gignac et al. 2000).

Similar Communities: bog, intermittent wetland, muskeg, northern fen, patterned fen, poor conifer swamp, prairie fen, rich conifer swamp.

Other Classifications:
Michigan Natural Features Inventory Circa 1800 Vegetation (MNFI): Emergent Marsh (6221), Wet Meadow (6224), and Inland Wet Prairie (6227)

Michigan Department of Natural Resources (MDNR): D-treed bog, V-bog, N-marsh

Michigan Resource Information Systems (MIRIS): 62 (non-forested wetland) and 622 (emergent wetland).

The Nature Conservancy National Classification: CODE; ALLIANCE; ASSOCIATION; COMMON NAME

III.B.2.N.g; *Betula pumila* – (*Salix* spp.) Saturated Shrubland Alliance; *Alnus incana* –

Salix spp. - *Betula pumila / Chamaedaphne calyculata* Shrubland; Speckled Alder – Willow Species – Bog Birch / Leatherleaf Shrubland; Bog Birch-Willow Shore Fen

III.B.2.N.g; *Betula pumila* – (*Salix* spp.) Saturated Shrubland Alliance; *Betula pumila / Chamaedaphne calyculata / Carex lasiocarpa* Shrubland; Bog Birch / Leatherleaf / Wiregrass Sedge Shrubland; Bog Birch – Leatherleaf Rich Fen

III.B.2.N.g; *Betula pumila* – (*Salix* spp.) Saturated Shrubland Alliance; *Betula pumila – Dasiphora fruticosa* spp. *floribunda / Carex lasiocarpa –Trichophorum alpinum* Shrubland; Bog Birch – Shrubby-cinquefoil / Wiregrass Sedge – Alpine Cottongrass Shrubland; Bog Birch – Shrubby-cinquefoil Rich Boreal Fen

IV.A.1.N.g; *Chamaedaphne calyculata* Saturated Dwarf-shrubland Alliance; *Chamaedaphne calyculata – Myrica gale / Carex lasiocarpa* Dwarf-shrubland; Leatherleaf – Sweet Gale / Wiregrass Sedge Dwarf-shrubland; Leatherleaf – Sweet Gale Shore Fen

V.A.5.N.m; *Calamagrostis canadensis – Carex viridula – Cladium marisicoides – Lobelia kalmii* Saturated Herbaceous Alliance; *Calamagrostis canadensis – Carex viridula – Cladium marisicoides – Lobelia kalmii* Herbaceous Vegetation; Bluejoint – Hairy Sedge – Twig-rush – Ontario Lobelia Herbaceous Vegetation; Great Lakes Sedge Rich Shore Fen

V.A.5.N.m; *Carex lasiocarpa* Saturated Herbaceous Alliance; *Carex lasiocarpa – Carex buxbaumii – Trichophorum caespitosum* Boreal Herbaceous Vegetation; Wiregrass Sedge – Brown Bog Sedge – Deerhair Bulrush Boreal Herbaceous Vegetation; Boreal Sedge Rich Fen

V.A.5.N.m; *Carex lasiocarpa* Saturated Herbaceous Alliance; *Carex lasiocarpa* – (*Carex rostrata*) – *Equisetum fluviatile* Herbaceous Vegetation; Wiregrass Sedge – (Swollen-beak Sedge) – Water Horsetail Herbaceous Vegetation; Wiregrass Sedge Shore Fen

Related Abstracts: American bittern, black-backed woodpecker, Blanding's turtle, eastern box turtle, eastern massasauga, great blue heron rookery, incurvate emerald, intermittent wetland, merlin, northern fen, northern harrier, poor fen, prairie fen, rich conifer swamp, secretive locust, spotted turtle, sweet coltsfoot, and yellow rail.

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Abstract Citation:

Cohen, J.G. 2005. Natural community abstract for poor fen. Michigan Natural Features Inventory, Lansing, MI. 13 pp.

Appendix 5. Bog

Overview: A nutrient-poor peatland characterized by acidic, saturated peat and the prevalence of *Sphagnum* mosses and ericaceous shrubs. Located in depressions in glacial outwash and sandy glacial lakeplains and in kettles on pitted outwash and moraines; frequently occurring as a floating mat on the margins of lakes and ponds. Fire occurs naturally during drought periods and can alter the hydrology, mat surface, and flora.

Global and State Rank: G5/S4

Range: Bogs are a frequent peatland type of glaciated landscapes of the entire northern hemisphere and are characterized by remarkably uniform floristic structure and composition across the circumboreal region (Curtis 1959). In North America, they are found throughout the glaciated Midwest (Michigan, Minnesota, Wisconsin, and northern portions of Illinois, Indiana, and Ohio) and the northeastern United States (New York, New Hampshire, Vermont, and Maine), and range from central Canada (Ontario, Manitoba, and Quebec) to the maritime provinces (Nova Scotia and New Brunswick) (Faber-Langendoen 2001, NatureServe 2005a). Subtle variations in overall species composition and physiognomy occur across its range along north-south and east-west climatic gradients (Glaser 1992). In Michigan, bogs are common throughout the northern Lower Peninsula and the Upper Peninsula and are less common south of the climatic tension zone (Amon et al. 2002). Bogs and other peatlands occur where excess moisture is abundant (where precipitation is greater than evapotranspiration) (Mitsch and Gosselink 2000). Conditions suitable for the development of bogs have occurred in the northern Lake States for the past 3000-5000 years following climatic cooling (Boelter and Verry 1977, Heinselman 1970).

Several other natural peatland communities also occur in Michigan and can be distinguished from ombrotrophic (nutrient-poor) bogs, based on comparisons of nutrient levels, flora, canopy closure, and groundwater influence. Bogs, peat-covered wetlands raised above the surrounding groundwater by an accumulation of peat, receive inputs of nutrients and water primarily from precipitation (Gignac et al. 2000). Additional open wetlands occurring on peat include northern fen and poor fen. Fens are minerotrophic (nutrient-rich) wetlands that are dominated by sedges, rushes, and grasses (Mitsch and Gosselink 2000). The hydrology of fens is influenced by groundwater, and as a result, fens have higher nutrient availability, increased alkalinity (less acidity), and greater species richness compared to bogs, with poor fens being most similar to bogs in terms of these factors and species composition. In addition to a greater importance by graminoids, fens also are less dominated by sphagnum mosses (*Sphagnaceae*) with brown mosses (*Amblystegiaceae*) being more prevalent. Intermittent wetlands are herb or herb-shrub dominated wetlands that experience fluctuating water levels seasonally and yearly and have soils that range from loamy sand and peaty sand to peaty muck and are very strongly acid to strongly acid. Like bogs, muskegs and poor conifer swamp are nutrient-poor, acidic wetlands. However, these ombrotrophic peatlands exhibit a greater degree of canopy closure than bogs (muskegs having clumped and scattered conifers and poor conifer swamp being a closed canopy system). Closed canopy, minerotrophic peatlands include rich conifer swamp, a *Thuja occidentalis* (northern white cedar) dominated system found north of the tension zone, and relict conifer swamp, which is dominated by *Larix laricina* (tamarack) and occurs primarily south of the tension zone (Kost 2001).

Rank Justification: Bogs are frequent features of the northern Great Lakes region, occurring throughout the northern Lower Peninsula and the Upper Peninsula and sporadically south of the climatic tension zone. The northern lake states contain over six million hectares (15 million acres) of peatland (Boelter and Verry 1977). Within the southern portion of their range, bogs typically occur as isolated pockets separated by large expanses of agricultural lands (Amon et al. 2002). Historically, widespread fires following the turn of the century logging drastically altered many peatlands, either converting poor conifer swamp to open bog systems or destroying the peat and converting bogs to wetlands without organic soils (mineral soil wetlands) (Dean and Coburn 1927, Gates 1942, Curtis 1959). Logging of cedar and tamarack from peatland systems also favored the conversion of forested peatlands to open, ombrotrophic bogs (Gates 1942, Dansereau and Segadas-Vianna 1952, Riley 1989). Beginning in the 1920s, effective fire control by the U.S. Forest Service and state agencies reduced the acreage of fires ignited by man or lightning (Swain 1973). In landscapes where frequent fire was the prevalent disturbance factor, fire suppression has led to the conversion of open bogs to closed canopy peatlands (Curtis 1959, Riley 1989). Peat mining and cranberry farming have degraded numerous bogs throughout the region (Gates 1942, Curtis 1959, Eggers and Reed 1997, Chapman et al. 2003). Michigan, along with Florida and Minnesota, are leaders in peat production in the U.S. (Miller 1981). In addition to direct impacts to vegetation, alteration of peatland hydrology from road building, creation of drainage ditches and dams, and runoff from logging has led to the drastic change of bog composition and structure (Schwintzer and Williams 1974, Riley 1989, Chapman et al. 2003). Bog vegetation is extremely sensitive to minor changes in water levels and chemistry (Siegel 1988, Riley 1989). Succession to more minerotrophic wetlands can occur as the result of increased alkalinity and raised water levels, which can cause the increased decomposition of acidic peats. Lowering of water tables from drainage can allow for tree and shrub encroachment into open bogs and the eventual succession to closed canopy peatland. The natural acidity of bogs makes them especially susceptible to acid rain and air pollution (Siegel 1988, Chapman et al. 2003). Atmospheric deposition can contribute Nitrogen, Sulphur, Calcium and heavy metals to bogs (Damman 1990, Chapman et al. 2003). Dust-fall and atmospheric deposition from air pollution are particularly threats to bog systems in the southern portion of their range, where bogs are surrounded by cultivated land and close to industrial and urban centers (Damman 1990). Eutrophication from pollution and altered hydrology can detrimentally impact bogs by generating conditions favorable for the invasion of exotic species (Riley 1989) and dominance by aggressive, common natives such as *Phalaris arundinaceae* (reed canary grass) and *Typha* spp. (cat-tails) (Almendinger and Leete 1998).

Physiographic Context: Two landscape features are conducive to the development of peat; small ice-block basins and poorly-drained, level terrain (Boelter and Verry 1977). Bogs occur in kettle depressions on pitted outwash and moraines and on flat areas or mild depressions of glacial outwash and glacial lakeplains (Lindeman 1941, Gates 1942, Curtis 1959, Bay 1967, Boelter and Verry 1977, Glaser and Janssens 1986, Siegel 1988, Michigan Natural Features Inventory 2003, NatureServe 2005a). The overall topography of bogs is flat to gently undulating with microtopography characterized by hummocks and hollows (Heinselman 1963, Vitt and Slack 1975, Wheeler et al. 1983, Glaser et al. 1990, NatureServe 2005a). Many bogs are oriented northwest to southeast, corresponding to the direction of glacial movement (Schwintzer 1978a). Bogs found in kettle depressions are associated with active or extinct glacial lakes (Curtis 1959). Within kettle depressions, bogs can occupy the entire basin or frequently occur as a mat (floating or grounded) on the margin of the remaining glacial lake (Vitt and Slack 1975, Schwintzer 1978a). When bogs occur along the edge of large bodies of water, they are found in sheltered bays or coves that are protected from wave and ice action, which can prevent the development of peat or erode existing peat mats (Gates 1942). Bogs occurring on former glacial lake beds and drainageways tend to be more extensive than kettle bogs, which are limited in area by the size of the glacial ice-block which formed the basin (Lindeman 1941). The large peatlands of lakeplains and outwash plains are often over 100 acres while bogs found in kettle depressions typically range from 10 to 30 acres.

Bogs within large wetland complexes typically occur adjacent to other peatland communities, often grading into poor conifer swamp, muskeg, or poor fen. More minerotrophic systems such as northern fen, prairie fen, shrub thicket, wet meadow, rich conifer swamp, and relict conifer swamp can occur along the outer margins of bogs where groundwater seepage from the adjacent uplands is prevalent. Bogs within kettle depressions that contain active glacial lakes and ponds often border aquatic communities such as submergent marsh and emergent marsh. Bog mats can also occur as a vegetative zone within intermittent wetlands, coastal plain marsh, and wooded dune and swale complexes. A wide array of upland community types can occur adjacent to bogs; some of the more frequent neighboring upland systems include dry-mesic northern forest, dry northern forest, mesic northern forest, pine barrens, dry-mesic southern forest, and dry southern forest.

Hydrology: No apparent inlets or outlets supply or drain bogs which are isolated from ground water influence as the result of peat accumulation (Dean and Coburn 1927, Schwintzer 1978b, Riley 1989, Swineheart and Parker 2000, Hoffman 2002, NatureServe 2005a). Bogs are ombrotrophic to weakly minerotrophic peatlands, receiving inputs of water and nutrients primarily from ion-poor precipitation (Heinselman 1970, Verry 1975, Boelter and Verry 1977, Schwintzer 1981, Schwintzer and Tomberlin 1982, Siegel 1988, Riley 1989, Damman 1990, Glaser et al. 1990, Mitsch and Gosselink 2000, Bedford and Godwin 2003). The rooting zone is dominated by inputs of atmospheric water and nutrients (Bedford and Godwin 2003). The water retaining capacity of sphagnum peat is tremendous and as a result bogs are saturated, anoxic systems with water tables near the surface (Burns 1906, Dansereau and Segadas-Vianna 1952, Curtis 1959, Heinselman 1970, Schwintzer 1978b, Siegel and Glaser 1987, Glaser 1992, Eggers and Reed 1997). The stagnant surface waters of bogs are characterized by high acidity, low available nutrients, low specific conductivity, cool temperatures, anaerobic conditions, and high levels of dissolved organic matter that imparts a brown color (Gates 1942, Verry 1975, Schwintzer 1978a, Glaser et al. 1981, Wheeler et al. 1983, Riley 1989, Damman 1990, Glaser 1992). Studies of bog water and peat across the northern Great Lakes have found pH measurements to range from 3.2-4.7 (Heinselman 1970, Boelter and Verry 1977, Schwintzer 1981, Schwintzer and Tomberlin 1982, Wheeler et al. 1983, Riley 1989, Glaser et al. 1990). The high acidity of bogs limits the availability and uptake of essential mineral plant nutrients which are inherently scarce in these systems because of the lack of groundwater input (Glaser 1992). Bogs are characterized by low primary productivity which is correlated with the very low concentrations of available Calcium, Magnesium, Nitrogen, Phosphorous, and Potassium in the surface water and peat (Heinselman 1963, Heinselman 1970, Schwintzer 1978a, Schwintzer 1981, Schwintzer and Tomberlin 1982, Wheeler et al. 1983, Richardson and Marshall 1986, Riley 1989, Glaser 1992, Bedford et al. 1999, Mitsch and Gosselin 2000).

Soils: The organic soils of bogs are composed of peat which forms a continuous mat and can range in thickness from 3-30 feet (1-8 meters) but is typically 2-3 meters deep (Heinselman 1965, Bay 1967, Heinselman 1970, Siegel and Glaser 1987). Peat is a fibrous network of partially decomposed organic material that is formed under anaerobic conditions (Heinselman 1963, Almendinger et al. 1986). The surface peats of bogs are dominated by saturated fibric peat which is loosely compacted, contains partially decomposed Sphagnum moss with fragments of wood and occasionally sedge, and like the surface water, is extremely acidic, cool, and characterized by low nutrient availability and oxygen levels (Burns 1906, Curtis 1959, Heinselman 1963, Heinselman 1970, Schwintzer and Williams 1974, Boelter and Verry 1977, Almendinger et al. 1986). Fibric peat has high water retaining capacity and large intercellular pores that permit rapid water movement (Boelter and Verry 1977, Swanson and Grigal 1989). Peat composition changes with depth and depending on the successional history of a given bog. Generally, fiber content and hydraulic conductivity usually decrease with depth; deeper peats are more decomposed, retain more water, and drain slower than surface peats (Verry 1975, Boelter and Verry 1977).

Climate: Peatlands develop in humid climates where precipitation exceeds evapotranspiration (Boelter and Verry 1977, Gignac et al. 2000). The northern Lake States are characterized by a humid, continental climate with long cold winters and short summers that are moist and cool to warm (Gates 1942, Boelter and Verry 1977, Damman 1990, Mitsch and Gosselink 2000). The Michigan range of bog falls within the area classified by Braun (1950) as the Northern Hardwood-Conifer Region (Hemlock/White

Pine/Northern Hardwoods Region) and within the following regions classified by Albert et al. (1986) and Albert (1995): Region I, Southern Lower Michigan; Region II, Northern Lower Michigan; Region III, Eastern Upper Michigan; and Region IV, Western Upper Michigan. The Northern Hardwood-Conifer Region has a cool snow-forest climate with warm summers. The mean number of freeze-free days is between 90 and 220, and the average number of days per year with snow cover of 2.5 cm or more is between 10 and 140. The normal annual total precipitation ranges from 740 to 900 mm with a mean of 823 mm. The daily maximum temperature in July ranges from 24 to 32 °C (75 to 90 °F), the daily minimum temperature in January ranges from –21 to –4 °C (-5 to 25 °F) and the mean annual temperature is 7 °C (45 °F) (Albert et al. 1986, Barnes 1991). Temperatures vary less in bogs compared to the surrounding landscape because of the insulating effect of bogs' saturated peat carpet in the growing season and snow cover in the winter (Burns 1906, Curtis 1959, Heinselman 1963, Glaser 1992). In Wisconsin, Curtis (1959) observed that at root level, temperatures during the growing season rarely exceed 60°F and are usually between 45 and 55 °F. In Minnesota, Heinselman (1963) found that the maximum bog temperature in August was 56 °F and the minimum temperature in late winter was 30 °F. Bogs are characterized by microclimates that are cooler in the summer and warmer in the winter compared to the regional climate.

Natural Processes: Peat establishment requires an abundant supply of water. As noted, ombrotrophic peatlands occur in regions where precipitation is greater than evapotranspiration and on sites with blocked drainage (Dansereau and Segadas-Vianna 1952, Boelter and Verry 1977, Mitsch and Gosselink 2000). Saturated and inundated conditions inhibit organic matter decomposition and allow for the accumulation of peat (Almendinger and Leete 1998). Under cool, anaerobic, and acidic conditions, the rate of organic matter accumulation exceeds organic decay (Schwintzer and Williams 1974, Damman 1990, Mitsch and Gosselink 2000). Low levels of oxygen protect plants from microorganisms and chemical actions that cause decay (Miller 1981). Likewise, high levels of acidity have inhibitory effects on decay organisms (Heinselman 1963, Mitsch and Gosselink 2000). Once Sphagnum mosses become established on the peat mat, they maintain and enhance saturated and acidic conditions, which in turn promote continued peat development. The ability of sphagnum to absorb and hold cations increases the acidity and low nutrient availability of peatlands (Osvald 1935, Curtis 1959, Verry 1975, Vitt and Slack 1975, Boelter and Verry 1977). Sphagnum moss, which has numerous pores, partitions, and capillary space, has an enormous water-holding capacity (Osvald 1935, Dansereau and Segadas-Vianna 1952, Curtis 1959). Sphagnum peat can hold 15 to 30 times its own weight in water (Miller 1981, Mitsch and Gosselink 2000).

Development and expansion of peatlands occurs via two distinct processes: lake-filling and paludification. Lake-filling or terrestrialization occurs in small lakes with minimal wave action, where gradual peat accumulation results in the development of a bog mat that can fill the basin or occur as a floating mat in the lake or as a grounded mat along the water's edge (Burns 1906, Gates 1942, Bay 1967, Curtis 1959, Heinselman 1963, Mitsch and Gosselink 2000). Succession in lake-filled bogs typically proceeds from lake to marsh to fen to bog (Heinselman 1963, Boelter and Verry 1977, Schwintzer 1981, Swineheart and Parker 2000). Floating mats of fen sedges (i.e., *Carex lasiocarpa*) pioneer open water and accumulate organic matter in the form of peat, which is invaded by sphagnum and ericaceous shrubs (Osvald 1935, Gates 1942, Schwintzer and Williams 1974, Swineheart and Parker 2000).

Fallen logs in kettle lakes and ponds can also provide the substrate for bog vegetation establishment and invasion of the water: *Chamaedaphne calyculata* (leatherleaf) is particularly adept at expanding along logs (Dean and Coburn 1927, Gates 1942, Dansereau and Segadas-Vianna 1952). Peatland vegetation has been recorded advancing into kettle lakes at a rate of 2.1cm/year (Schwintzer and Williams 1974). Estimates of vertical accumulation of bog peat range between 100 to 200cm/1000 years (Mitsch and Gosselink 2000). For both lake-filling and paludification, peat accumulates above the water table and the bog becomes isolated from groundwater influence (Heinselman 1970, Boelter and Verry 1977, Glaser and Janssens 1986, Mitsch and Gosselink 2000). Paludification is the blanketing of terrestrial systems (often forests) by the overgrowth of peatland vegetation (Dansereau and Segadas-Vianna 1952, Heinselman 1963, Mitsch and Gosselink 2000). Paludified peatlands develop on flat areas (typically lakeplain) where peat develops vertically and spreads horizontally (Heinselman 1965, Boelter and Verry 1977). Succession in paludified bogs can proceed from fen, marsh, or shrub carr to swamp forest to bog (Heinselman 1970, Schwintzer 1981).

Once established, bogs can persist for hundreds of years given stable hydraulic conditions. A discharge of alkaline groundwater at the peat surface of a bog, caused by a change in hydraulic head, can result in the conversion of bog vegetation to fen vegetation (Siegel and Glaser 1987, Glaser et al. 1990). Mixing of as little as 10% groundwater from underlying calcareous parent material with acid bog water is sufficient to raise the peatland pH from 3.6 to 6.8 (Glaser et al. 1990). Bogs are very sensitive to changes in pH and subsequent availability of nutrients: fen vegetation can replace bog flora when pH increases above 4.5 (Siegel 1988). However, conversions of bog to fen have been seldom reported in the literature (Glaser et al. 1990). More typically, bogs are converted to shrub swamp or swamp forest following the lowering of the water table. Water table lowering results in increased decomposition rates of organic matter and facilitates the invasion of bogs by opportunistic woody species (Almendinger and Leete 1998, Gignac et al. 2000).

Disturbance factors influencing bogs include fire, flooding, windthrow, and insects. Numerous bogs contain charcoal within their peat profile (Curtis 1959, Heinselman 1963) and many researchers have reported fire as a prevalent part of bog's disturbance regime (Dean and Coburn 1927, Gates 1942, Curtis 1959). Surface fire can contribute to the maintenance of bogs by killing encroaching trees without completely removing the sphagnum (Curtis 1959, Vitt and Slack 1975). Many of the ericaceous plants that thrive in bogs are fire-adapted and often grow densely following fire (Wheeler et al.1983). Fire severity and frequency in bogs is closely related to fluctuations in water level. Prolonged periods of lowered water table can allow the surface peat to dry out enough to burn (Schwintzer and Williams 1974). When the surface peat of bogs burns, the fire releases organic matter from the peat, kills seeds and latent buds, stimulates decay, and slows peat accumulation (Damman 1990, Jean and Bouchard 1991). Peat fires can convert bogs to more graminoid dominated peatlands such as intermittent wetlands or poor fens or if the peat is completely destroyed, to mineral soil wetlands such as northern wet meadow (Curtis 1959).

Flooding often contributes to the development, expansion, and maintenance of bogs. Dam-building activities of beaver can result in blocked drainage and flooding which facilitate sphagnum peat development and expansion (Heinselman 1963, Heinselman 1970) and can also cause grounded bog mats to become loosened from the bottom and float (Gates 1942). Roots of peatland trees are physiologically active near the surface and are quickly killed when the water table rises following flooding (Glaser and Janssens 1986). Within kettle bogs, flooding induced tree mortality is greater on grounded bog mats compared to free floating mats: free mats float up with rising water table while grounded mats become inundated and have shallower aerobic zones (Schwintzer 1973, Schwintzer 1978a, Schwintzer 1979). In addition to flooding, kettle bogs can be influenced by waves and ice. Wave and ice action can prevent the expansion of bog mats by eroding the shoreline vegetation (Gates 1942).

The natural disturbance regime in bogs is also influenced by wind. The Great Lakes region is one of the most active weather zones in the northern hemisphere, with polar jet streams positioned overhead much of the year. More cyclones pass over this area than any other area in the continental U.S. (Frelich and Lorimer 1991). Trees growing in bogs are particularly susceptible to windthrow because sphagnum peat provides a poor substrate for anchoring trees (Burns 1906). The living roots of woody peatland plants occur in a shallow rooting zone, generally restricted to the uppermost few centimeters where there is sufficient oxygen to maintain aerobic respiration (Glaser and Janssens 1986). The superficial rooting of trees results in numerous windthrows (Dansereau and Segadas-Vianna 1952, Eggers and Reed 1997). Tree survival in bogs is also limited by insects and parasites. Insect outbreaks of the *Pristiphora erichsonii* (larch sawfly) cause heavy mortality of *Larix laricina* (tamarack) while, the plant parasite *Arceuthobium pusillum* (dwarf mistletoe) kills *Picea mariana* (black spruce) (Coburn et al. 1933, Gates 1942, Heinselman 1963).

Vegetation Description: Bogs are characterized by a continuous carpet of sphagnum moss, a poor herbaceous layer, low ericaceous, evergreen shrubs, and widely scattered and stunted conifer trees (Gates 1942, Curtis 1959, Verry 1975, Vitt and Slack 1975, Glaser et al. 1991, NatureServe 2005a). Floristically bogs are homogenous and of limited diversity, exhibiting remarkably uniform structure and composition across their wide range (Curtis 1959, Riley 1989). Slight variations in composition, especially within the shrub and tree layer, occur in Michigan bogs along a longitudinal gradient. Southerly bogs have more of a deciduous tree and shrub component compared to the northern coniferous bogs. The harsh growing conditions of bogs (high acidity, low nutrient availability, and saturated peat) results in a unique but depauperate flora: relatively few species have evolved the necessary adaptations to cope with ombrotrophic conditions (Siegel 1988, Glaser 1992, Mitsch and Gosselink 2000). Very few introduced, weedy species are able to establish within bogs and fens because of the unique growing conditions and competition from the adapted flora (Riley 1989). In a study of bogs across eastern North America, Glaser (1992) found the native vascular bog flora to be limited to only 81 species and the mean number of species per bog to be below 26. The mean number of species per plot in kettle bogs in the northern Lower Peninsula of Michigan was found to be fifteen by Vitt and Slack (1975) and fourteen by Schwintzer (1981), with a range of 9-20. For bogs within Michigan Natural Features Inventory's database, the mean number of species per bog is approximately 30. Species richness of bogs is related to geographical location, climatic factors, nutrient availability, and habitat heterogeneity (Glaser et al. 1990, Glaser 1992). Species diversity within bogs is strongly correlated to microtopography (Glaser et al. 1990). Within a bog, floristic composition is determined by gradients in pH, light, soil moisture, and cation concentrations (nutrient availability) (Heinselman 1970, Vitt and Slack 1975, Schwintzer 1978a, Glaser et al. 1981).

Bogs are dominated by mosses from the *Sphagnaceae* and shrubs from the *Ericaceae*; other well-represented families include the *Cyperaceae*, *Orchidaceae*, and *Ranunculaceae* (Gates 1942, Curtis 1959, Heinselman 1970). The most important primary producers within bogs are ericaceous shrubs and sedges (Mitsch and Gosselink 2000). Bog flora is predominantly spring flowering and heliophitic (Curtis 1959, Dansereau and Segadas-Vianna 1952). Bog plants have developed a diversity of adaptations to cope with low nutrient availability including plant carnivory, evergreen leaves, sclerophylly (thick epidermal tissue), and high root biomass (Mitsch and Gosselink 2000). While bogs are dominated by plants that thrive under ombrotrophic conditions, occasionally minerotrophic indicators may be present in bogs at low cover. Plants found typically in more alkaline habitat such as *Betula pumila* (bog birch), *Carex aquatilis* (water sedge), and *Carex stricta* (tussock sedge), can occur sporadically in bogs when their roots extend beneath the bog mat to minerotrophic peat influenced by ground water (NatureServe 2005a).

The continuous moss layer of bogs is dominated by sphagnum mosses especially *Sphagnum magellanicum*, *S. angustifolium*, and *S. fuscum* (Vitt and Slack 1975, Schwintzer 1978a, NatureServe 2005a). Additional mosses can include *S. capillaceum*, *S. capillifolium*, *S. compactum*, *S. cuspidatum*, *S. papillosum*, *S. recurvum*, and *Drepanocladus aduncus* (Gates 1942, Vitt and Slack 1975, Crum 1983, Riley 1989, Glaser et al. 1990). The hummock and hollow microtopography of bogs allows for high levels of bryophyte diversity since individual species of sphagnum occur at specific elevations (Vitt and Slack 1975, Wheeler et al. 1983, Riley 1989). Hollows support *S. magellanicum*, *S. cuspidatum*, and *S. papillosum* (Vitt and Slack 1975, Vitt et al. 1975, Heinselman 1970, Wheeler et al. 1983, Riley 1989). The lower, moist slopes of hummocks often support *S. magellanicum* and *S. recurvum* while the drier hummock crests are dominated by *S. fuscum*, *S. capillaceum*, and *S. cappillifolium* (Vitt et al. 1975, Wheeler et al. 1983, Riley 1989). The vertical zonation of species corresponds to gradients in pH and moisture with the hollows being wetter and more alkaline than the drier and more acidic tops of the hummocks (Vitt et al. 1975, Wheeler et al. 1983).

The herbaceous layer of bogs is dominated by cyperaceous plants. Fine-leaved sedges are more prevalent in bogs while broad-leaved sedges dominate minerotrophic sites (Boelter and Verry 1977). Several sedges that are characteristic of bogs include *Carex oligosperma* (few-seed sedge), *Carex pauciflora* (few-flower sedge), and *Carex lasiocarpa* (wiregrass sedge). Other sedges that often occur in bogs are *C. limosa* (mud sedge), *C. paupercula* (bog or poor sedge), *C. rostrata* (beaked sedge), and *C. trisperma* (three-seeded sedge). Additional graminoids that thrive in bogs include *Cladium marisicoides* (twig-rush), *Dulichium arundinaceum* (three-way sedge), *Eriophorum angustifolium* (tall cotton-grass), *E. spissum* (sheathed cotton-grass), *E. vaginatum* (tussock cotton-grass), *E. virginicum* (tawny cotton-grass), *Rhynchospora alba* (white beak-rush), *Scheuchzeria palustris* (rannoch-rush), and *Scirpus* spp. (bulrushes). The following is a list of prevalent bog herbs: *Epilobium angustifolium* (fireweed), *E. ciliatum* (fringed willow-herb), *Iris versicolor* (wild blue flag), *Menyanthes trifoliata* (bogbean), *Smilacina trifolia* (false Solomon-seal), and *Triglochin maritima* (arrow-grass). Insectivorous plants, *Drosera rotundifolia* (roundleaf sundew), *Drosera intermedia* (spoon-leaf sundew), *Sarracenia purpurea* (pitcher-plant), and *Utricularia intermedia* (flat-leaved bladderwort), are common features of fens. *Woodwardia virginica* (chain-fern) is one of few ferns that occur in bogs. Bogs frequently contain open pools of water or are surrounded by moats that contain emergent vegetation such as *Nuphar* spp. (pond-lilies) and *Nymphaea odorata* (sweet-scented water-lily).

The shrub layer of bogs is dominated by low, ericaceous shrubs with *Chamadaephne calyculata* (leatherleaf) being the most prevalent. The dwarf shrub layer is typically less than three feet high and usually covers at least 25% of the bog area (Eggers and Reed 1997, NatureServe 2005a). In addition to leatherleaf, the following heath shrubs are important components of bogs: *Andromeda glaucophylla* (bog-rosemary), *Gaylussacia baccata* (huckleberry), *Kalmia angustifolia* (sheep-laurel), *K. polifolia* (bog-laurel), *Ledum groenlandicum* (Labrador-tea), *Vaccinium angustifolium* (low sweet blueberry), *V. macrocarpon* (large cranberry), *V. myrtilloides* (Canada blueberry), and *V. oxycoccos* (small cranberry). The tall shrub layer of bogs is less dense than the low shrub layer and is often restricted to the periphery of the bog. Tall shrubs typical of bogs include *Aronia prunifolia* (chokeberry), *Nemopanthus mucranta* (mountain holly), *Salix pedicellaris* (bog willow), *Spirea tomentosa* (steeplebush), and *Viburnum cassinoides* (wild-raisin). South of the climatic tension zone, *Cephalanthus occidentalis* (buttonbush), *Toxicodendron vernix* (poison sumac), and *Vaccinium corymbosum* (highbush blueberry) frequently occur along bog margins. As noted, bog birch can occur at low cover when it roots can extend beneath the bog mat to minerotrophic peat.

Trees within bogs are widely scattered and stunted (seldom reaching six meters) (Wheeler et al. 1983, NatureServe 2005a). Tree cover is typically below ten percent (NatureServe 2005a). The most common canopy dominants are *Picea mariana* (black spruce) and *Larix laricina* (tamarack). Additional associates include *Pinus banksiana* (jack pine), *Pinus strobus* (white pine), and *Acer rubrum* (red maple), with red maple being more prevalent south of the climatic tension zone. (Above species lists compiled from Michigan Natural Features Inventory database, Dean and Coburn 1927, Coburn et al. 1933, Osvald 1935, Gates 1942, Dansereau and Segadas-Vianna 1952, Curtis 1959, Heinselman 1963, Heinselman 1965, Bay 1967, Heinselman 1970, Schwintzer and Williams 1974, Vitt and Slack 1975, Schwintzer 1978a, Glaser et al. 1981, Schwintzer 1981, Wheeler et al. 1983, Riley 1989, Glaser et al. 1990, Glaser 1992, Anderson et al. 1996, Eggers and Reed 1997, Mitsch and Gosselink 2000, Swinehart and Parker 2000, NatureServe 2005a.)

Michigan Indicator Species: black spruce, *Carex oligosperma*, leatherleaf, pitcher plant, sphagnum moss, and sundew.

Other Noteworthy Species: Bogs provide habitat for numerous rare insect species including *Appalachia arcana* (secretive locust, state special concern), *Atlanticus davisi* (Davis's shield-bearer, state special concern), *Calephelis mutica* (swamp metalmark, state special concern), *Boloria freija* (Freija fritillary, state special concern butterfly), *Boloria frigga* (Frigga fritillary, state special concern butterfly), *Erebia discoidalis* (red-disked alpine, state special concern butterfly), *Erynnis baptisiae* (wild indigo duskywing, state special concern), *Liodessus cantralli* (Cantrall's bog beetle, state special concern), *Merolonche dollii* (Doll's merolonche moth, state special concern), *Neoconocephalus lyrists* (bog conehead, state special concern), *Oarisma poweshiek* (poweshiek skipperling, state threatened), *Oecanthus laricis* (tamarack tree cricket, state special concern), *Orchelimum concinnum* (red-faced meadow katydid, state special concern), *Paroxya hoosieri* (Hoosier locust, state special concern), *Somatochlora incurvata* (incurvate emerald, state special concern dragonfly), and *Williamsoni fletcheri* (ebony boghaunter, state special concern dragonfly). Numerous butterflies and moths are restricted to bogs and fens because their food plants occur within these peatland systems (Riley 1989). Rare herptiles that utilize bogs include *Acris crepitans blanchardi* (Blanchard's cricket frog, state special concern), *Clemmys guttata* (spotted turtle, state threatened), *Elaphe obsoleta obsolete* (black rat snake, state special concern), *Emys blandingii* (Blanding's turtle, state special concern), *Nerodia erythrogaster neglecta* (copperbelly watersnake, state endangered), *Pseudacris triseriata maculata* (boreal chorus frog, state special concern), *Sistrurus catenatus catenatus* (eastern massasauga, state special concern), and *Terrapene carolina carolina* (eastern box turtle, state special concern). If suitable nesting trees or snags are available, *Haliaeetus leucocephalus* (bald eagle, state threatened), *Falco columbarius* (merlin, state threatened), and *Pandion haliaetus* (osprey, state threatened) can be found nesting in these systems and *Ardea herodias* (great blue heron, protected by the Migratory Bird Treaty Act of 1918) can establish rookeries. Other rare birds that could occur in bogs are *Botaurus lentiginosus* (American bittern, state special concern), *Circus cyaneus* (northern harrier, state special concern), *Coturnicops noveboracensis* (yellow rail, state threatened), *Falcipennis canadensis* (spruce grouse, state special concern), and *Picoides arcticus* (black-backed woodpecker, state special concern). *Gavia immer* (common loon, state threatened) establish nest sites on natural islands and bog-mats. Small mammals associated with bog habitat include *Sorex fumeus* (smoky shrew, state special concern) and *Cryptotis parva* (least shrew, state threatened). *Alces alces* (moose, state threatened), *Canis lupus* (gray wolf, state threatened), and *Lynx canadensis* (lynx, state endangered) utilize peatland habitat (Mitsch and Gosselink 2000).

In general, the population of animals is low in bogs because of the low productivity of bog plants, the unpalatability of bog vegetation, and the high acidity of bog waters (Mitsch and Gosselink 2000). *Melospiza georgiana* (swamp sparrow) and *M. melodia* (song sparrow) are typical bog songbirds. Common herptiles that frequent bogs include *Bufo americanus americanus* (Eastern American toad), *Rana pipiens* (Northern leopard frog), and *Thamnophis sirtalis sirtalis* (garter snake) (Riley 1989). Bogs provide important habitat for small mammals such as *Blarina brevicauda* (short-tailed shrew), *Castor canadensis* (beaver), *Microtus pennsylvanicus* (meadow vole), *Mustela vison* (mink), *Ondatra zibethicus* (muskrat), and *Sorex cinereus* (masked shrew) (Curtis 1959, Mitsch and Gosselink 2000). Both muskrats and beaver can profoundly influence the hydrology of bogs. Muskrats create open water channels through the bog peat and beavers can cause substantial flooding through their dam-building activities (Gates 1942, Heinselman 1963).

Rare plants associated with bogs include *Amerorchis rotundifolia* (round-leaved orchis, state endangered), *Carex wiegandii* (Wiegand's sedge, state threatened), *Empetrum nigrum* (black crowberry, state threatened), *Isotria verticillata* (whorled pogonia, state threatened), *Platanthera ciliaris* (orange or yellow fringed orchid, state threatened), *Platanthera leucophaea* (eastern prairie fringed orchid, state endangered and listed as federally threatened), *Rubus acualis* (dwarf raspberry, state endangered), and *Sarracenia purpurea f. heterophylla* (yellow pitcher-plant, state threatened). *Eleocharis radicans* (spike-rush, extirpated in Michigan) was historically known from floating mat bogs in Washtenaw County.

Conservation and Biodiversity Management: Bog is a widespread community type in the Great Lakes region that contributes significantly to the overall biodiversity of northern Michigan by providing habitat for a unique suite of plants and wide variety of animal species. Numerous rare and unique species are associated with bogs. By storing high levels of sequestered carbon and serving as carbon sinks, bogs and related peatlands play an important role in global geochemical cycles. Bogs also preserve paleo-environmental records: a wealth of information is stored in the remains of plants, animals, and atmospheric particles deposited and stored in bog peat profiles (Chapman et al. 2003). The primary mechanism for preserving bogs is to maintain their hydrology. As noted, peatland systems are sensitive to slight changes in water chemistry. A serious threat to bog hydrology is posed by off-road-vehicle traffic, which can drastically alter bog hydrology through rutting. Reduction of access to peatland systems will help decrease detrimental impacts. Resource mangers operating in uplands adjacent to bogs should take care to minimize the impacts of management to hydrologic regimes, especially increased surface flow. This can be accomplished by establishing a no-cut buffer around bogs and avoiding road construction and complete canopy removal in stands immediately adjacent to bogs. Elevation of a bog's water table and clear-cutting within a bog can result in the expansion of leatherleaf and sphagnum and a subsequent decrease in floristic diversity (Schwintzer 1979). Where shrub/tree encroachment threatens to convert open wetlands to shrub-dominated systems or forested swamps, prescribed fire or selective cutting can be employed to maintain open conditions. Silvicutural management of bogs to preserve open canopy should be employed during the winter to minimize damage to the peat and impacts to the hydrologic regime.

Research Needs: Bog has a broad distribution and exhibits subtle regional, physiographic, hydrologic, and edaphic variants. The diversity of variations throughout its range demands the continual refinement of regional classifications that focus on the inter-relationships between vegetation, physiography, hydrology, and the successional history of the peat (Heinselman 1963, Fitzgerald and Bailey 1975, Barnes et al. 1982). Bogs and related community types (poor fen, muskeg, and intermittent wetland) can be difficult to differentiate (Heinselman 1963, NatureServe 2005a). Research on abiotic and biotic indicators that help distinguish similar peatlands would be useful for field classification. Systematic surveys for bogs and related peatlands are needed to help prioritize conservation and management efforts. Little is known about the fire regimes of bogs and the interaction of disturbance factors within these systems. As noted by Hammerson (1994), beaver significantly alter the ecosystems they occupy. An important research question to examine is how the wetland ecosystems of the Great Lakes have been and continue to be affected by fluctuations in populations of beaver. Experimentation is needed to determine how best to prevent shrub and tree encroachment of bogs that are threatened by conversion to shrub thicket or conifer swamp. A better understanding is needed of the influence of direct and indirect anthropogenic disturbance on peatlands (Amon et al. 2002). Effects of management within bogs should be monitored to allow for assessment and refinement. More research is needed to elucidate the relationship of chemical factors and nutrient levels to floristic community structure of peatlands (Amon et al. 2002). Given the sensitivity of peatlands to slight changes in hydrology and nutrient availability, it is important for scientists to predict how peatlands will be affected by global warming and atmospheric deposition of nutrients and acidifying agents (Heinselman 1970, Riley 1989, Bedford et al. 1999, Gignac et al. 2000, Mitsch and Gosselink 2000). Peat deposits are of great scientific interest because they contain historical ecological records in the form of fossils of plants and animals and organic matter that contributed to the deposit. Fossilized humans have even been found in non-decomposing bog peat: the bog people of Scandinavia where preserved for approximately

2000 years (Mitsch and Gosselink 2000). Stratigraphical analysis of peat cores provides insights into past climatic change and associated vegetation change, floristic distribution, the development of wetland ecosystems, and the successional pathways of peatlands (Heinselman 1963, Glaser et al. 1981, Miller 1981, Glaser and Janssens 1986, Riley 1989, Gignac et al. 2000).

Similar Communities: coastal plain marsh, intermittent wetland, inundated shrub swamp, muskeg, northern fen, patterned fen, poor conifer swamp, poor fen, prairie fen, relict conifer swamp, rich conifer swamp.

Other Classifications:
Michigan Natural Features Inventory Circa 1800 Vegetation (MNFI): Bog (6121)

Michigan Department of Natural Resources (MDNR): D-treed bog, V-bog

Michigan Resource Information Systems (MIRIS): 62 (non-forested wetland) and 622 (emergent wetland)

The Nature Conservancy National Classification:
CODE; ALLIANCE; ASSOCIATION; COMMON NAME

IV.A.1.N.g; *Chamaedaphne calyculata* Saturated Dwarf-Shrubland Alliance; *Chamaedaphne calyculata / Carex oligosperma –Eriophorum virginicum* Dwarf-shrubland; Leatherleaf / Few-seed Sedge – Tawny Cottongrass Dwarf Shrubland; Leatherleaf Kettle Bog

IV.A.1.N.g; *Chamaedaphne calyculata* Saturated Dwarf-Shrubland Alliance; *Chamaedaphne calyculata – Ledum groenlandicum – Kalmia polifolia* Bog Dwarf-shrubland; Leatherleaf – Labrador-tea –Bog Laurel Bog Dwarf-Shrubland; Leatherleaf Bog

V.A.5.N.m; *Carex oligosperma – Carex lasiocarpa* Saturated Herbaceuos Alliance; *Carex oligosperma – Carex pauciflora – Eriophorum vaginatum / Sphagnum* spp. Herbaceous Vegetation; Few-seed Sedge – Few-flower Sedge – Tussock Cottongrass / Peatmoss Species Herbaceous Vegetation; Open Graminoid / Sphagnum Bog

NatureServe Ecological Systems Classification:
CES103.581: Boreal-Laurentian Bog

Related Abstracts: American bittern, black-backed woodpecker, Blanchard's cricket frog, Blanding's turtle, coastal plain marsh, eastern box turtle, eastern massasauga, eastern prairie fringed orchid, English sundew, great blue heron rookery, incurvate emerald, intermittent wetland, merlin, northern fen, northern harrier, poor fen, prairie fen, relict conifer swamp, rich conifer swamp, round-leaved orchis, secretive locust, spotted turtle, yellow pitcher plant, and yellow rail.

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Abstract Citation:

Cohen, J.G. 2005. Natural community abstract for bog. Michigan Natural Features Inventory, Lansing, MI. 13 pp.

Appendix 6. Northern Wet Meadow

Overview: An open, groundwater-influenced, sedge and grass–dominated wetland that occurs in northern Lower Michigan and Upper Michigan and typically borders streams but is also found on pond and lake margins and above beaver dams. Soils are nearly always on muck soil, which is strongly acid to slightly acid. Open conditions maintained by seasonal flooding, beaver-induced flooding, and/or fire.

Global and State Rank: G4G5/S4

Range: Northern wet meadow, which is commonly referred to as sedge meadow, occurs in Michigan, Minnesota, North Dakota, Wisconsin, and Ontario. In Michigan, northern wet meadow is thought to occur in the northern half of the Lower Peninsula above the climatic transition zone and throughout the Upper Peninsula and to differ from sedge meadows in southern Michigan (Kost 2001). However, no detailed study of the differences between northern and southern types has been undertaken in Michigan. Curtis (1959) studied sedge meadows in northern and southern Wisconsin and found them to be floristically similar but concluded that northern meadows had consistently lower soil pH values and were frequently wetter and smaller than many southern wet meadows. Southern wet meadow is dominated primarily by *Carex stricta* (tussock sedge) while northern wet meadows can be dominated or co-dominated by several additional sedges and/or *Calamagrostis canadensis* (blue-joint grass) (Faber-Langendoen 2001, Michigan Natural Features Inventory 2003, NatureServe 2005a). Another sedge-dominated natural community, poor fen, also occurs in Michigan but differs markedly from sedge meadow because of its acidic, organic soils, and the prevalence of *Carex oligosperma* (few-seed sedge) and other open bog species (Michigan Natural Features Inventory 2003).

Rank Justification: Because northern wet meadow often occurs as a zone within large wetland complexes, information on its historical extent and present acreage is not readily available. However, in Wisconsin, where 459,000 ha (1,130,000 acres) of sedge meadow are thought to have existed circa 1800 (Curtis 1959), it is estimated that less than one percent remain intact (Reuter 1986). It is likely northern wet meadow acreage has declined similarly in other Midwest states, such as Michigan, where similar agricultural methods have been practiced. Northern wet meadows have fared slightly better than southern wet meadows because agriculture and development has been less extensive north of the climatic tension zone (Hoffman 2002).

Northern wet meadows have been extensively utilized for agriculture. Prior to the 1950s mowing for marsh hay was widely practiced (Stout 1914, Curtis 1959, Eggers and Reed 1997). Wet meadows were frequently tiled, ditched, drained, and converted to pasture and row crops or mined for peat or muck (Costello 1936, Curtis 1959, Reuter 1986, Eggers and Reed 1997). The hydrology of these systems is threatened by the reduction and diversion of surface runoff, channelization of stream flow, lowering local groundwater discharge, and deterioration of water quality (Reuter 1986). Lowering of the water table has caused the conversion of many sedge meadows to shrub thickets (Curtis 1959, Reuter 1986, Eggers and Reed 1997). In addition, fire suppression has allowed shrub encroachment with many sedge meadows converting to shrub thicket within ten to twenty years since the interruption of fire disturbance (Curtis 1959, White 1965, Davis 1979, Reuter 1986, Jean and Bouchard 1991). This is especially evident where the water table has been lowered through tiling or ditching and where the practice of mowing for marsh hay has been abandoned (White 1965, Eggers and Reed 1997). Alteration of the fire and hydrologic regimes has allowed for the invasion of sedge meadows by pernicious exotic species, especially *Lythrum salicaria* (purple loosestrife), *Rhamnus cathartica* (common buckthorn), and *Rhamnus frangula* (glossy buckthorn) (Reuter 1986).

Landscape and Abiotic Context: Northern wet meadow occurs on glacial lakebeds, in channels of glacial outwash, and in depressions on glacial outwash and moraines (Curtis 1959, Reuter 1986, Faber-Langendoen 2001, Hoffman 2002, NatureServe 2005a, NatureServe 2005b). The community frequently occurs along the margins of lakes, ponds, and streams where seasonal flooding or beaver-induced flooding is common (Curtis 1959, Reuter 1986, Hoffman 2002).

Wet meadow typically occurs on organic soils such as muck and well-decomposed sapric peat (Curtis 1959) but saturated mineral soil may also support the community (Costello 1936, Curtis 1959, Faber-Langendoen 2001, NatureServe 2005a). Because of the calcareous nature of the glacial drift in the regions occupied by wet meadow, its wet soils can contain high levels of dissolved minerals such as calcium and magnesium. Northern wet meadow occurs on more acidic soils compared to southern wet meadow which is found on neutral to strongly alkaline soils (Costello 1939, Curtis 1959, Warners 1993). Northern wet meadow soils range from strongly acid to slightly acid.

Sedge meadows are found adjacent to other wetland communities, often in large wetland complexes. Northern shrub thicket and swamp forest are typically adjacent to northern wet meadows that occur along streams (Curtis 1959). On the edges of inland lakes, northern wet meadow often borders emergent marsh and less frequently northern fen. It may also occur along the Great Lakes shoreline within extensive areas of Great Lakes marsh.

The Michigan range of northern wet meadow falls within the area classified by Braun (1950) as the Northern Hardwood-Conifer Region (Hemlock/White Pine/Northern Hardwoods Region) and within the following regions classified by Albert et al. (1986): Region II, Northern Lower Michigan; Region III, Eastern Upper Michigan; and Region IV, Western Upper Michigan. The Northern Hardwood-Conifer Region has a cool snow-forest climate with short, warm summers, cold winters and a large number of cloudy days. The daily maximum temperature in July ranges from 24 to 29 °C (75 to 85 °F), the daily minimum temperature in January ranges from -21 to -9 °C (-5 to 15 °F) and the mean annual temperature is 7 °C (45 °F). The mean number of freeze-free days is between 90 and 160, and the average number of days per year with snow cover of 2.5 cm or more is between 80 and 140. The normal annual total precipitation ranges from 740 to 900 mm with a mean of 823 mm (Albert et al. 1986, Barnes 1991, Albert 1995). Northern wet meadows are characterized by local climates with lower temperatures and evaporation rates and shorter growing seasons than the surrounding uplands (Curtis 1959).

Natural Processes: Northern wet meadow is a groundwater-dependent, graminoid-dominated, wetland community. Water levels in northern wet meadow fluctuate seasonally, reaching their peak in spring and lows in late summer (Costello 1936, Warners 1993). However, water levels typically remain at or near the soil's surface throughout the year (Costello 1936, Curtis 1959, Warners 1993, Eggers and Reed 1997). The community's structure may depend on maintaining a consistently high water table. Costello (1936) states that the *Carex stricta* tussocks disappeared within 10 years from a meadow where the water levels were reduced to two to four feet below the surface as a result of tiling. In addition to seasonal flooding, beaver-induced flooding may also play an important role in maintaining the community by occasionally raising water levels and killing encroaching trees and shrubs. Beaver may also help create new northern wet meadows by flooding swamp forests and northern shrub thickets and thus creating suitable habitat for the growth of shade-intolerant wet meadow species.

Evidence from wetland peat cores and circa 1800 vegetation maps indicate that wet meadow is a fire-dependent natural community (Curtis 1959, Davis 1979). Analysis of wetland peat cores shows that charcoal fragments are consistently associated with sedge and grass pollen (Davis 1979). Conversely, charcoal fragments are lacking from sections of peat cores dominated by shrub pollen. Fires typically occur in sedge meadows during dry conditions of early spring or late fall (White 1965). By reducing leaf litter and allowing light to reach the soil surface and stimulate seed germination, fire can play an important role in maintaining wet meadow seed banks (Warners 1997, Kost and De Steven 2000). Fire also plays a critical role in preventing declines in species richness in many community types by creating micro-niches for small species (Leach and Givnish 1996). Another critically important attribute of fire for maintaining open sedge meadow is its ability to temporarily reduce shrub cover (White 1965, Reuter 1986, Hoffman 2002). In the absence of fire or flooding, all but the wettest sedge meadows typically convert to shrub thicket and eventually swamp forest (Curtis 1959). Because many of the species that inhabit wet meadow are shade-intolerant, species richness usually declines following shrub and tree invasion (Curtis 1959, White 1965, Reuter 1986).

Vegetation Description: Northern wet meadow is a sedge dominated system that typically has 100% vegetative cover in the ground layer (Curtis 1959, Eggers and Reed 1997). Sedge meadow is often dominated by *Carex stricta* (tussock sedge) (Stout 1914, Costello 1936, Curtis 1959, Warners 1997, Kost and De Steven 2000). Because the roots of *Carex stricta* form large hummocks or tussocks, the species is often responsible for the community's hummock and hollow structure. Individual culms of *Carex stricta* grow from the tussocks, which may reach more than one meter in height and half a meter in diameter and live for more than 50 years (Costello 1936). The *Carex stricta* tussocks can occur at very high densities (1 to 4 per m^2) and occupy more than 40% of a meadow's area (Costello 1936). Because the shaded areas between tussocks are often covered with standing water and leaf litter, many of the shorter species inhabiting sedge meadows grow almost exclusively from the sides or tops of *Carex stricta* tussocks.

Other sedges that commonly occur in northern wet meadow include: *Carex aquatilis* (water sedge), C. *bebbii* (Bebb's sedge), *C. buxbaumii* (Buxbaum's sedge), *C. comosa* (long-hair sedge), *C. hystericina* (bottlebrush sedge), *C. lacustris* (lake or hairy sedge), *C. lanuginose* (woolly sedge), *C. lasiocarpa* (wiregrass sedge), *C. rostrata* (beaked sedge), *C. stipata* (saw-beak sedge), *C. vesicaria* (blister sedge), and *C. vulpinoidea* (fox sedge). Although most of the associated sedge species tend to be randomly interspersed, *Carex lacustris*, *C. lasiocarpa*, *C. rostrata*, and *C. vesicaria* can often occur as dominants or co-dominants.

The most dominant grass species in northern wet meadow is *Calamagrostis canadensis* (blue-joint grass) (Stout 1914, Kost and De Steven 2000). Other common grasses include: *Bromus ciliatus* (fringed brome), *Glyceria canadensis* (manna grass), *G. striata* (fowl manna grass), *Muhlenbergia glomerata* (marsh wild timothy), *Muhlenbergia mexicana* (leafy satin grass), and *Poa palustris* (fowl meadow grass). Spike-rushes (i.e., *Eleocharis erythropoda*), cat-tails (*Typha latifolia* and *Typha angustifolia*), *Cladium marisicoides* (twig-rush), and *Scirpus atrovirens* (green bulrush) are also common graminoids. Sedge meadows disturbed by agricultural use, grazing, drainage, and/or filling are frequently dominated by *Phalaris arundinaceae* (reed canary grass) and extremely aggressive grass which forms persistent, monotypic stands (Eggers and Reed 1997).

A wide variety of wetland forbs occur scattered in northern wet meadow. Due to the high moisture conditions during the spring, many of the forbs bloom in the summer and fall (Curtis 1959, Hoffman 2002). The following are some of the more common species: *Anemone canadensis* (Canada anemone), *Asclepias incarnata* (swamp milkweed), *Aster lanceolatus* (panicled aster), *A. lateriflorus* (calico aster), *A. puniceus* (swamp aster), *A. umbellatus* (flat-topped aster), *Campanula aparinoides* (marsh bellflower), *Cicuta bulbifera* (water-hemlock), *C. maculata* (water-hemlock), *Cirsium muticum* (swamp thistle), *Epilobium strictum* (downy willowherb), *Eupatorium maculatum* (Joe-pye-weed), *Eupatorium perfoliatum* (boneset), *Euthamia graminifolia* (flat-topped goldenrod), *Galium asprellum* (rough bedstraw), *G. trifidum* (threepetal bedstraw), *Impatiens capensis* (spotted touch-me-not), *Iris versicolor* (wild blue flag), *Lathyrus palustris* (marsh pea), *Lycopus americanus* (American water-horehound), *L. uniflorus* (northern bugleweed), *Lysimachia thyrsifolia* (tufted loosestrife), *Mentha arvensis* (wild mint), *Polygonum amphibium* (water smartweed), *Rumex orbiculatus* (greater water dock), *Sagittaria latifolia* (duck-potato or common arrowhead), *Scutellaria galericulata* (marsh skullcap), *Solidago canadensis* (Canada goldenrod), *S. gigantea* (late goldenrod), *S. patula* (rough-leaved goldenrod or swamp goldenrod), *Thalictrum dasycarpum* (purple meadow-rue), *Triadenum fraseri* (marsh St. John's-wort), *Verbena hastata* (blue vervain), and *Viola cucullata* (marsh violet). Characteristic fern or fern allies include *Dryopteris cristata* (crested woodfern), *Equisetum arvense* (field horsetail), *E. fluviatile* (water horsetail), *Onoclea sensibilis* (sensitive fern), and *Thelypteris palustris* (marsh fern).

Northern wet meadow can also contain numerous, scattered shrub and tree species. Shrub and tree encroachment is especially pronounced in sites that have altered flooding or fire regimes. Prevalent shrubs include *Alnus rugosa* (speckled alder), *Betula pumila* (bog birch), *Cornus stolonifera* (red-osier dogwood), *Potentilla fruticosa* (shrubby cinquefoil), *P. palustris* (marsh cinquefoil), *Salix* spp. (willows), *Spirea alba* (meadowsweet), and *S tomentosa* (hardhack). Scattered trees and tree saplings are often found invading northern wet meadow. Typical tree species include *Acer rubrum* (red maple), *Fraxinus nigra* (black ash), *Larix laricina* (tamarack), *Populus balsamifera* (balsam poplar), *Populus tremuloides* (quaking aspen), and *Thuja occidentalis* (northern white cedar). (Above species lists compiled from Michigan Natural Features Inventory database, Curtis 1959, Reuter 1986, Eggers and Reed 1997, Hoffman 2002, Faber-Langendoen 2001, NatureServe 2005a)

Michigan Indicator Species: blue-joint grass, *Carex lacustris*, *Carex stricta*, common boneset, greater water dock, Joe-pye-weed, marsh bellflower, northern bugleweed, swamp aster, and tufted loosestrife.

Other Noteworthy Species: Several rare plants can be found in northern wet meadow and associated open wetlands including *Cacalia plantaginea* (Indian plantain, state special concern), *Carex wiegandii* (Wiegand's sedge, state threatened), *Gentiana linearis* (linear-leaved gentian, state threatened), *Parnassia palustris* (marsh-grass-of-Parnassus, state threatened), and *Vaccinium cespitosum* (dwarf bilberry, state threatened), which is the host plant for *Lycaeides idas nabokovi* (northern blue butterfly, state threatened).

Northern wet meadow provide habitat for numerous herptiles such as *Clemmys guttata* (spotted turtle, state threatened), *Emys blandingii* (Blanding's turtle, state special concern), *Glyptemys insculpta* (wood turtle, state special concern), *Pseudacris triseriata maculata* (boreal chorus frog, state special concern), and *Sistrurus catenatus catenatus* (eastern massasauga, state special concern, federal candidate species). The late blooming composites found in sedge meadows provide an important food source for songbirds while the hummock provide excellent nesting habitat for wetlands birds (Eggers and Reed 1997). Rare birds that utilize these wetlands include *Asio flammeus* (short-eared owl, state endangered), *Botaurus lentiginosus* (American bittern, state special concern), *Chlidonias niger* (black tern, state special concern), *Circus cyaneus* (northern harrier, state special concern), *Cistothorus palustris* (marsh wren, state special concern), *Coturnicops noveboracensis* (yellow rail, state threatened), *Gallinula chloropus* (common moorhen, state special concern), *Ixobrychus exilis* (least bittern, state threatened), *Phalaropus tricolor* (Wilson's phalarope, state special concern), *Rallus elegans* (king rail, state endangered), and *Sterna forsteri* (Forster's tern, state special concern). *Alces alces* (moose, state threatened), *Canis lupus* (gray wolf, state threatened), and *Lynx canadensis* (lynx, state endangered) utilize sedge meadow habitat.

Conservation and Biodiversity Management: Northern wet meadows contribute significantly to the overall biodiversity of northern Michigan by providing habitat to a wide variety of plant and animal species including numerous rare species. In addition, sedge meadows provide ecosystem services, protecting water quality by assimilating nutrients, trapping sediment, and retaining stormwater and floodwater (Eggers and Reed 1997). Protecting the hydrology of northern wet meadow is imperative for the community's continued existence. This may include avoiding surface water inputs to meadows from drainage ditches, agricultural fields, road construction, and logging in the adjacent uplands, and protecting groundwater recharge areas by maintaining native vegetation types in the uplands around the community. Resource mangers operating in uplands adjacent to sedge meadows should take care to minimize the impacts of management to hydrologic regimes, especially increased surface flow. This can be accomplished by establishing a no-cut buffer around wet meadows and avoiding road construction and complete canopy removal in stands immediately adjacent to wetlands.

Management for wet meadow should include the use of prescribed fire (Curtis 1959, White 1965). Prescribed fire can help reduce litter, stimulate seed germination, promote seedling establishment, and bolster grass, sedge, and perennial and annual forb cover (Bowles et al. 1996, Warners 1997, Kost and De Steven 2000). While prescribed fire can be an important tool for rejuvenating wet meadow seed banks, it can also help ensure that the community remains in an open condition by temporarily setting back invading woody species (Reuter 1986). Using prescribed fire to control shrub invasion in sedge meadows has also been shown to be 85% less expensive to implement than manual cutting (Reuter 1986). The use of prescribed fire should be avoided during periods of drought to avoid igniting the community's organic soils (Curtis 1959, Vogl 1969). Burning in the early spring while the soil moisture is high reduces the chances of destroying the organic soils (Reuter 1986), however, growing season burns can be more effective at reducing aggressive woody vegetation (Bowles et al. 1996). If prescribed burning is not feasible, mowing can be used to simulate fire disturbance but should be restricted to the winter, when ground frost will reduce disturbance to soils, plants, and hydrology, or late summer and fall when the meadows are dry (White 1965, Reuter 1986). In situations where shrub encroachment is severe, resource managers may need to cut invading shrubs and herbicide the cut stumps, especially if the shrubs are stump sprouters, like *Alnus rugosa* (speckled alder) or *Rhamnus frangula* (glossy buckthorn) (Heidorn 1991).

Invasive species that can occur in northern wet meadow include glossy buckthorn, common buckthorn, purple loosestrife, reed canary grass, and *Phragmites australis* (reed). Each of these species is capable of significantly altering community structure and dramatically reducing species richness. Management should strive to prevent the further spread of these invasive species and implement control measures when possible. Establishment of invasive species can be prevented by maintaining the hydrologic and fire disturbance regimes and avoiding grazing (Reuter 1986).

Restoration of degraded northern wet meadows depends on the occurrence of water-saturated peat and muck soils, maintaining waters levels very near the soil surface throughout the year, providing protection from shrub encroachment and invasive species, and the availability of appropriate seed stock (Reuter 1986). Finding viable seed for sedges, the plant group responsible for the overall structure of wet meadow, may be a difficult task. Costello (1936) reports that in more than six years of studying *Carex stricta*-dominated sedge meadows he did not find a single seedling of the species. Because of the difficulty of restoring wet meadow in the absence of favorable hydrology and intact organic soils, conservation efforts should focus on protecting the remaining community occurrences (Reuter 1986).

Research Needs: Further work on community classification is needed to elucidate differences among sedge meadow types both within and among ecoregions (Reuter 1986). More studies need to focus on the flooding and fire regimes of northern wet meadow and the interaction of disturbance factors. As noted by Hammerson (1994), beaver significantly alter the ecosystems they occupy. An important research question to examine is how the wetland ecosystems of the Great Lakes have been and continue to be affected by the fluctuating beaver population. Experimentation is needed to determine how best to prevent shrub encroachment of open wetlands that are threatened by conversion to northern shrub thicket (Reuter 1986). In addition, scientists should gain an understanding of plant and animal community responses to the frequency and seasonal timing of prescribed burning and anthropogenic flooding. Effects of management within northern wet meadow need to be monitored to allow for assessment and refinement. Research is needed on plant and animal community responses to the frequency and seasonal timing of prescribed burning and flooding. Conservation and management of northern wet meadow will be stimulated by research on the importance of the community for maintaining rare species and regional biodiversity.

Similar Communities: emergent marsh, Great Lakes marsh, intermittent wetland, southern wet meadow, northern fen, northern shrub thicket, northern wet-mesic prairie, poor fen, and wet prairie.

Other Classifications:
Michigan Natural Feature Inventory Circa 1800 Vegetation (MNFI): wet meadow (6224)

Michigan Department of Natural Resources (MDNR): L-lowland brush, N-marsh, V-bog

Michigan Resource Information Systems (MIRIS): 622 (emergent wetland)

The Nature Conservancy National Classification: CODE; ALLIANCE; ASSOCIATION; COMMON NAME

V.A.5.N.k; *Calamagrostis canadensis* Seasonally Flooded Herbaceous Alliance; *Calamagrostis canadensis – Phalaris arundinacea* Herbaceous Vegetation; Bluejoint – Reed Canary Grass Herbaceous Vegetation; Bluejoint Wet Meadow.

V.A.5.N.k; *Carex aquatilis* Seasonally Flooded Herbaceous Alliance; *Carex aquatilis – Carex* spp. Herbaceous Vegetation; Aquatic Sedge – Sedge Species Herbaceous Vegetation; Water Sedge Wet Meadow.

V.A.5.N.k; *Carex lacustris* Seasonally Flooded Herbaceous Alliance; *Carex lacustris* Herbaceous Vegetation; Lake Sedge Herbaceous Vegetation; Lake Sedge Wet Meadow.

V.A.5.N.k; *Carex* (*rostrata, urticulata*) Seasonally Flooded Herbaceous Alliance; *Carex rostrata – Carex lacustris –* (*Carex vesicaria*) Herbaceous Vegetation; Swollen-Beak Sedge – Lake Sedge – (Inflated Sedge) Herbaceous Vegetation; Northern Sedge Wet Meadow.

V.A.5.N.k; *Carex stricta* Seasonally Flooded Herbaceous Alliance; *Carex stricta – Carex* spp. Herbaceous Vegetation; Tussock Sedge – Sedge Species Herbaceous Vegetation; Tussock Sedge Wet Meadow.

NatureServe Ecological Systems Classification: CES201.582: Laurentian-Acadian Wet Meadow-Shrub Swamp

CES202.701: North-Central Interior Wet Meadow-Shrub Swamp

Related Abstracts: American bittern, black tern, Blanding’s turtle, dwarf bilberry, eastern massasauga, floodplain forest, Forster’s tern, Great Lakes marsh, Indian plantain, intermittent wetland, king rail, least bittern, marsh-grass-of-Parnassus, northern blue butterfly, northern fen, northern harrier, northern shrub thicket, poor fen, short-eared owl, southern wet meadow, spotted turtle, wood turtle, and yellow rail.

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Abstract Citation:
Cohen, J.G., and M.A. Kost. 2005. Natural community abstract for northern wet meadow. Michigan Natural Features Inventory, Lansing, MI. 8 pp.

Appendix 7. Northern Shrub Thicket

Overview: A fairly persistent, shrub-dominated wetland located north of the transition zone, typically occurring along streams, but also adjacent to lakes and beaver floodings. Muck or peat soil is medium acid to neutral and nutrient rich. Fluctuating water table, beaver, and windthrow limit succession to closed canopy swamp. Northern shrub thickets are overwhelmingly dominated by *Alnus rugosa* (speckled alder).

Global and State Rank: G5?/S5

Range: Alder swamp community types are widespread in the Midwestern and northeastern United States and southern Canada, ranging from Maine west to Manitoba, south to Iowa, and east to New Jersey, mostly north of the glacial boundary (Van Deelen 1991, Faber-Langendoen 2001, NatureServe 2005a, NatureServe 2005b). Within Michigan, northern shrub thicket is found in the northern half of the Lower Peninsula above the climatic transition zone and throughout the Upper Peninsula (Barnes and Wagner 1981).

Rank Justification: In the Great Lakes region, northern shrub thicket is a widespread community type that has dramatically increased in acreage from its historical extent due to anthropogenic disturbance (Daly 1966). Interpretation of the notes of the original land surveyors of Michigan reveal that in the 1800s, alder/willow-dominated shrub wetland covered approximately 50,490 ha (124,761 ac) or just over 0.32% of the state (Comer et al. 1995). Based on 2000 remote sensing imagery interpretation (MDNR 2003), 385,105 ha (951,600 ac) of lowland shrub type occurs in the northern Lower Peninsula and the Upper Peninsula, just under 2.5% of the state, which constitutes close to an eight-fold increase in extent. The drastic increase in northern shrub thicket is the result of ubiquitous logging of swamp forests, alteration of hydrologic regimes, and fire suppression. Widespread logging of conifer swamp at the end of the 19th century and the beginning of the 20th century (Karamanski 1989) resulted in the conversion of many forested swamps to northern shrub thicket in the Great Lakes region (Curtis 1959, Heinselman 1963). As noted by Vincent (1964), shade-intolerant alder develops rapidly following the removal of the softwood overstory. In addition, alder can become established in multiple treefall gaps. Extensive mortality of *Ulmus americana* (American elm) caused by Dutch elm disease not only eliminated elm as a dominant overstory tree in swamp ecosystems but also allowed the expansion of shrub-dominated communities (Huenneke 1983). The capacity of alder to form dense, impenetrable thickets can retard or prevent tree establishment and regeneration (Huenneke 1983, Huenneke 1987). The extensive logging at the turn of the century and the gradual recovery of beaver following the fur trapping era have likely caused a rise in the water table in many sites, which have caused the expansion of shrub-dominated systems at the expense of forest. In other areas, historically dominated by open, herbaceous wetlands (i.e., northern wet meadow, northern fen, emergent marsh), tiling or ditching caused the lowering of the water table which resulted in the conversion of these open systems to shrub-dominated wetlands (Curtis 1959, White 1965, Reuter 1986, Eggers and Reed 1997, Hoffman 2002). Beginning in the 1920s, effective fire control by the U.S. Forest Service and state agencies reduced the acreage of fires ignited by man or lightning (Swain 1973). As the result of fire suppression and subsequent shrub encroachment, many open wetlands have converted to shrub-dominated wetlands (Curtis 1959, Davis 1979, Reuter 1986, Jean and Bouchard 1991, Eggers and Reed 1997, Hoffman 2002). This is especially evident where the water table has been lowered through tiling or ditching and where the practice of mowing for marsh hay has been abandoned (White 1965, Eggers and Reed 1997). Northern shrub thicket has been maintained and expanded by wildlife management geared toward providing favorable habitat for game species of early successional habitat (particularly white tailed deer, American woodcock, and ruffed grouse).

Physiographic Context: Northern shrub thickets occur principally along streams, beaver floodings, lakeshores, and rivers primarily within glacial outwash channels and less frequently within ice-contact topography and coarse-textured end moraines (Curtis 1959, Schwintzer and Tomberlin 1982, Hoffman 1989, Faber-Langendoen 2001, Hoffman 2002, Michigan Natural Features Inventory 2003, NatureServe 2005a). Sites are characterized by little to no slope, can range from small pockets to extensive acreages, and are often a narrow band or zone of 20-30 meters within a larger wetland complex (Curtis 1959, White 1965, Faber-Langendoen 2001, NatureServe 2005a, NatureServe 2005b). Northern shrub thicket typically occurs adjacent to other wetland communities such as emergent marsh, northern wet meadow, northern swamp, poor conifer swamp, and rich conifer swamp. Northern shrub thicket can also be one of many zones within matrix communities such as Great Lakes marsh, northern fen, and wooded dune and swale complex. Within the Great Lakes, this shrub wetland is found on Precambrian Shield bedrock that is overlaid with sandy loam soils that are typically moderately well drained and deep (Faber-Langendoen 2001). The soils overlaying the glacial till are wet to moist, nutrient-rich, well-decomposed muck, peat, or mineral soil (Curtis 1959, Van Deelen 1991, Faber-Langendoen 2001, Michigan Natural Features Inventory 2003, NatureServe 2005a). The pH ranges widely from alkaline to acidic (Curtis 1959) with medium acidity being the most prevalent condition (Michigan Natural Features Inventory 2003). Northern shrub thickets are non-stagnant wetlands with high levels of dissolved oxygen and soil nitrogen that are seasonally flooded and range from poorly-drained to well-drained with most sites remaining saturated throughout the growing season (Curtis 1959, Daly 1966, Parker and Schneider 1974, Van Deelen 1991, Eggers and Reed 1997, NatureServe 2005a). Researchers have documented a strong correlation between soil moisture content and nitrogen concentration (Voigt and Steucek 1969).

The Michigan range of northern shrub thicket falls within the area classified by Braun (1950) as the Northern Hardwood-Conifer Region (Hemlock/White Pine/Northern Hardwoods Region) and within the following regions classified by Albert et al. (1986) and Albert (1995): Region II, Northern Lower Michigan; Region III, Eastern Upper Michigan; and Region IV, Western Upper Michigan. The Northern Hardwood-Conifer Region has a cool snow-forest climate with short, warm summers, cold winters and a large number of cloudy days. The daily maximum temperature in July ranges from 24 to 29 °C (75 to 85 °F), the daily minimum temperature in January ranges from -21 to -9 °C (-5 to 15 °F) and the mean annual temperature is 7 °C (45 °F). The mean number of freeze-free days is between 90 and 160, and the average number of days per year with snow cover of 2.5 cm or more is between 80 and 140. The normal annual total precipitation ranges from 740 to 900 mm with a mean of 823 mm (Albert et al. 1986, Barnes 1991, Albert 1995).

Natural Processes: The dominant species of northern shrub thicket is speckled alder. Alder contains symbiotic nitrogen-fixing bacteria (*Frankia*) in its root nodules that fix atmospheric nitrogen (Daly 1966, Van Deelen 1991, NatureServe 2005a). Soil nitrogen may accumulate at rates in excess of 85kg/ha (Daly 1966, Voigt and Steucek 1969). In addition to atmospheric fixation of nitrogen, the rapid decomposition of alder leaves contributes to the enrichment of the soil (Barnes and Wagner 1981). Organic matter accumulates very slowly in these systems since litter fall is broken down extremely rapidly (Daly 1966). Leaf litter beneath the shrub canopy is usually thin (often less than one centimeter) (Voigt and Steucek 1969). In addition to increasing the nitrogen supply of wetland soils, northern shrub thickets input nutrient rich detritus into aquatic ecosystems (NatureServe 2005a). Northern shrub thickets are most frequently found along streams subject to periodic, seasonal flooding. The soils are typically saturated and well-aerated (Curtis 1959). Northern shrub thickets are typically areas of high primary productivity because of the high nutrient supply in addition to normally favorable oxygen and soil moisture levels (Tilton and Bernard 1975). In sites subject to periodic flooding, alder stems can slow flood waters and trap sediment. Over time, fine-textured sediments accumulate over coarser alluvial material and the land surface may eventually rises above the flood levels (NatureServe 2005a).

Historically, alder was one of the first woody species to colonize recently deglaciated landscapes as an early successional species (Sears 1948). Currently, northern shrub thickets can become established following severe disturbance of swamp forested systems or by invading open wetlands. Alder is shade intolerant (Barnes and Wagner 1981, Huenneke and Marks 1987), tolerant of seasonal flooding (Knighton 1981, Ohmann et al. 1990), and moderately tolerant of fire (Van Deelen 1991). Alder often persists in swamp forests in light gaps. Flooding (i.e. from beaver or fluvial processes), fire, disease, and windthrow can result in sufficient mortality of the swamp forest overstory to allow for the complete opening of the canopy and the expansion of alder through establishment of seedlings or stump sprouting. Following canopy release, alder can form dense, impenetrable thickets that retard or prevent tree establishment (Huenneke 1983, Huenneke 1987). Within open wetlands, alder and associated shrubs can become established following alteration in the fire or hydrologic regime. Prolonged periods without fire or the lowering of the water table allows for shrub encroachment and conversion to northern shrub thicket (Curtis 1959, White 1965, Jean and Bouchard 1991, Eggers and Reed 1997, Hoffman 2002).

Once established northern shrub thicket can persist if disturbance factors maintain the open canopy conditions. Windthrow, beaver herbivory, beaver flooding, seasonal flooding, and fire can limit tree establishment and survival (Michigan Natural Features Inventory 2003). Alders capacity to stump sprout following flooding, fire, and herbivory allow it to persist after these disturbances (Ohmann et al. 1990, Huenneke and Marks 1987). Basal sprout production is critical for maintenance of alder thickets (Huenneke 1987, Huennek and Marks 1987). Northern shrub thickets can recover from moderate flooding and fire disturbance within five years (White 1965). In instances where flooding or fire is severe (prolonged flooding above the root crown or burning of the mineral soil and root crown), alder fails to stump sprout and the shrub thicket may be replaced by an open wetland, such as northern wet meadow or northern fen (Knighton 1981, Ohmann et al. 1990, Van Deelen 1991). Alder and willow are adapted to periodic flooding but intolerant of prolonged and severe flooding (Knighton 1981, Ohmann et al. 1990).

In the absence of disturbance factors that prevent tree establishment and survival or conversion to more open conditions, northern shrub thicket typically succeed to closed canopy swamp forest (Curtis 1959). The capacity of alder to condition the soil by increasing the available nitrogen and contribute to the accumulation of top soil through sediment trapping creates a suitable soil substrate for tree establishment and growth. Saplings of tree species grow through the shrub layer and once a tree canopy becomes established, alder are shaded out, unable to continue sprout production, experience a diminished capacity to fix nitrogen, and decline (Daly 1966, Barnes and Wagner 1981, Huenneke and Marks 1987). Tree species that typically invade northern shrub thickets include *Abies balsamea* (balsam fir), *Acer rubrum* (red maple), *Fraxinus nigra* (black ash), *Larix laricina* (tamarack), *Picea mariana* (black spruce), *Populus balsamifera* (balsam poplar), *Populus tremuloides* (quaking aspen), and *Thuja occidentalis* (northern white cedar) (Parker and Schneider 1974, Van Deelen 1991, Faber-Langendoen 2001, Michigan Natural Feature Inventory 2003, NatureServe 2005a). Northern shrub thickets can be replaced by hardwood swamp, hardwood-conifer swamp, and conifer swamp. Succession from shrub swamp to swamp forest can occur within ten years but may take longer. Curtis (1959) postulated that the minimum life expectancy of shrub-carr (in southern Wisconsin) is fifty years.

Vegetation Description: Northern shrub thicket is characterized by an overwhelming dominance of speckled alder which forms dense (often monotypic) thickets with canopy coverage ranging between 40-95% and stand height ranging from one to eight meters but typically between one and three meters (Curtis 1959, Vincent 1964, White 1965, Parker and Schneider 1974, Tilton and Bernard 1975, Mattson and Winsauer 1986, Huenneke 1987, Hoffman 1989, Van Deelen 1991, Hoffman 2002, Michigan Natural Features Inventory 2003, Faber-Langendoen 2001, NatureServe 2005a). Estimates of stem density range widely from 5,000 to 30,000 stems per acre

(Vincent 1964, Mattson and Winsauer 1986, Tilton and Bernard 1975). In a study in Upper Michigan and northern Wisconsin, Mattson and Winsauer (1986) estimated that on average, alder thickets produce close to 30 tons of green biomass per acre. Stem diameter of alder is typically between one to five inches (Parker and Schneider 1974, Tilton and Bernard 1975, Barnes and Wagner 1981, Mattson and Winsauer 1986). Alder are monoecious and wind-pollinated with germination usually requiring exposed mineral soil (Huenneke 1985, Van Deelen 1991). Within established stands of alder, vegetation reproduction through stump sprouting provides most of the new stems (Huenneke 1985, Huenneke 1987, Van Deelen 1991). Alder forms clonal clumps where few to many stems arise at the root collar (Barnes and Wagner 1981). A fast-growing, shade intolerant shrub, alder is usually short-lived; alder stems typically live 10-30 years (Tilton and Bernard 1975, Barnes and Wagner 1981, Huenneke 1987, Huenneke and Marks 1987).

Northern shrub thicket exhibits a high degree of floristic homogeneity due to the dominance of alder (Tilton and Bernard 1975). Floristic diversity is usually correlated with the degree of shrub canopy closure with more diversity being found in the more open sites (Eggers and Reed 1997). The understory, intermediate between meadow and forest (Curtis 1959), is dominated by an array of short shrubs, forbs, grasses, sedges, and ferns. The density of the understory varies inversely with the density of the tall-shrub canopy.

Prevalent herbs of the northern shrub thicket include: *Asclepias incarnata* (swamp milkweed), *Aster lanceolatus* (panicled aster), *A. puniceus* (swamp aster), *A. umbellatus* (flat-topped aster), *Caltha palustris* (marsh marigold), *Campanula aparinoides* (marsh bellflower), *Chelone glabra* (turtlehead), *Clematis virginiana* (woodbine), *Epilobium coloratum* (purple-leaf willow-herb), *Eupatorium maculatum* (Joe-pye-weed), *Eupatorium perfoliatum* (boneset), *Galium asprellum* (rough bedstraw), *Impatiens capensis* (spotted touch-me-not), *Iris versicolor* (wild blue flag), *Lycopus uniflorus* (northern bugleweed or water-horehound), *Mentha arvensis* (wild mint), *Mimulus ringens* (monkey-flower), *Polygonum sagittatum* (tear-thumb or smartweed), *Rumex orbiculatus* (greater water dock), *Scutellaria galericulata* (marsh skullcap), *Scutellaria lateriflora* (mad-dog skullcap), *Senecio aureus* (golden ragwort), *Smilacina trifolia* (false Solomon-seal), *Solidago canadensis* (Canada goldenrod), *S. gigantea* (late goldenrod), *S. rugosa* (rough-leaved goldenrod), *Symplocarpus foetidus* (skunk cabbage), and *Thalictrum dasycarpum* (purple meadow-rue). Where the tall shrub canopy is open, graminoids can become dense. The most dominant grass species in northern shrub thicket is *Calamagrostis canadensis* (blue-joint grass). Other common grasses include *Bromus ciliatus* (fringed brome), *Glyceria striata* (fowl manna grass), *Leersia oryzoides* (cut grass), and *Poa palustris* (fowl meadow grass). A diversity of sedges is found in these systems including *Carex stricta* (tussock sedge), *Carex flava* (yellow sedge), *Carex lacustris* (lake or hairy sedge), and *Carex leptalea* (bristly-stalked sedge). Bulrushes such as *Scirpus atrovirens* (green bulrush) are also common. Numerous *Sphagnum* species and ferns thrive in these moist, saturated systems. Characteristic ferns and fern allies include *Dryopteris cristata* (crested woodfern), *Equisetum arvense* (field horsetail), *Onoclea sensibilis* (sensitive fern), *Osmunda cinnamomea* (cinnamon fern), *Osmunda regalis* (royal fern), and *Thelypteris palustris* (marsh fern).

The understory layer also contains numerous short shrubs including *Chamaedaphne calyculata* (leatherleaf), *Ledum groenlandicum* (Labrador-tea), *Myrica gale* (wax-myrtle or bayberry), *Potentilla palustris* (marsh cinquefoil), *Ribes americanum* (wild black currant), *Rubus hispidus* (swamp dewberry), *R. pubescens* (dwarf raspberry), *R. strigosus* (wild red raspberry), and *Spirea alba* (meadowsweet). Where alder does not form a monospecific shrub layer, associates of the tall shrub layer can include *Aronia prunifolia* (chokeberry), *Betula pumila* (bog birch), *Cornus amomum* (silky dogwood), *C. stolonifera* (red-osier dogwood), *Ilex verticilata* (winterberry), *Salix bebbiana* (Bebb’s willow), *S. discolor* (pussy willow), *S. exigua* (sandbar willow), *S. petiolaris* (slender willow), *Viburnum cassinoides* (wild-raisin), and *Viburnum opulus* (highbush-cranberry). Scattered trees and tree saplings are often found invading northern shrub thickets. Typical tree species include balsam fir, red maple, black ash, tamarack, black spruce, balsam poplar, quaking aspen, and northern white cedar. (Above species lists compiled from Michigan Natural Features Inventory database, Curtis 1959, White 1965, Parker and Schneider 1974, Hoffman 1989, Van Deelen 1991, Eggers and Reed 1997, Faber-Langendoen 2001, Hoffman 2002, NatureServe 2005a.)

Michigan Indicator Species: blue-joint grass, Joe-pye-weed, marsh fern, marsh marigold, northern bugleweed, sensitive fern, speckled alder, and spotted touch-me-not.

Other Noteworthy Species: Northern shrub thicket provide habitat for numerous herptiles including *Emys blandingii* (Blanding's turtle, state special concern), *Glyptemys insculpta* (wood turtle, state special concern), *Pseudacris triseriata maculata* (boreal chorus frog, state special concern), and *Sistrurus catenatus catenatus* (eastern massasauga, state special concern, federal candidate species). If suitable nesting trees or snags are available, *Haliaeetus leucocephalus* (bald eagle, state threatened) and *Pandion haliaetus* (osprey, state threatened) can be found nesting in these systems and *Ardea herodias* (great blue heron, protected by the Migratory Bird Treaty Act of 1918) can establish rookeries (Hoffman 1989).

Rare plants associated with northern shrub thicket include *Listera auriculata* (auricled twayblade, state special concern), *Lonicera involucrata* (black twinberry, state threatened), *Mimulus guttatus* (western monkey-flower, state special concern), *Stellaria crassifolia* (fleshy stitchwort, state threatened), and *Thalictrum venulosum* var. *confine* (veiny meadow-rue, state special concern). The single collection of *Equisetum telmateia* (giant horsetail, state extirpated) in Michigan was from a "damp alder thicket".

The leaves and twigs of alder provide important browse for a wide array of mammals including *Alces alces* (moose, state threatened), *Ondatra zibethicus* (muskrat), *Castor canadensis* (beaver), *Sylvilagus floridanus* (cottontail rabbit), and *Lepus americanus* (snowshoe hare). Beaver build dams and lodges with speckled alder. The buds and seeds of alder are eaten by a diversity of birds. Songbirds feed on the seeds and *Philohela minor* (American woodcock) and *Bonasa umbellus* (ruffed grouse) eat the buds and catkins. Thickets of alder provide important hiding cover for species such as *Odocoileus virginianus* (white-tailed deer), *Lutra canadensis* (river otter), and *Mustela vison* (mink) (Barnes and Wagner 1981, Van Deelen 1991). *Canis lupus* (gray wolf, state threatened) and *Lynx canadensis* (lynx, state endangered) utilize shrub thicket habitat.

Conservation and Biodiversity Management: Northern shrub thicket is a widespread community type in the Great Lakes region and has dramatically increased from its historical extent due to anthropogenic disturbance. Alder swamps contribute significantly to the overall biodiversity of northern Michigan by providing habitat to a wide variety of plant and animal species including several rare species. However, northern shrub thickets have replaced many rare and declining wetland communities such as rich conifer swamp and northern fen. Where shrub encroachment threatens to convert open wetlands to shrub-dominated systems, repeated prescribed fires, mowing, or herbicide application to cut shrub stumps can be employed to maintain open conditions (White 1965, Heidorn 1991). On sites in which northern shrub thicket is succeeding to swamp forest, allowing succession to proceed unhindered will result in the increase of less common swamp systems. In situations where the management objective is to prevent succession, northern shrub thicket can be maintained by cutting the overstory (Vincent 1964). Following canopy removal with scarification of the soil and mild intensity burning encourages alder regeneration (Van Deelen 1991). Northern shrub thickets provide ecosystem services, protecting water quality by assimilating nutrients, trapping sediment, and retaining stormwater and floodwater.

Research Needs: Northern shrub thicket has a broad distribution and exhibits numerous regional, physiographic, hydrologic, and edaphic variants. The diversity of variations throughout its range demands the continual refinement of regional classifications that focus on the inter-relationships between vegetation, physiography, hydrology, and soils (White 1965, Barnes et al. 1982, Hoffman 1989, Faber-Langendoen 2001, NatureServe 2005a). Little is known about the flooding and fire regimes of northern shrub thickets and the interaction of disturbance factors within these systems. As noted by Hammerson (1994), beaver significantly alter the ecosystems they occupy. An important research question to examine is how the wetland ecosystems of the Great Lakes have been and continue to be affected by fluctuations in populations of beaver. Experimentation is needed to determine how best to prevent shrub encroachment of open wetlands that are threatened by conversion to northern shrub thicket. Effects of management within northern shrub thickets need to be monitored to allow for assessment and refinement.

Similar Communities: floodplain forest, Great Lakes marsh, hardwood-conifer swamp, northern fen, northern swamp, northern wet meadow, poor conifer swamp, rich conifer swamp, southern shrub-carr, and wooded dune and swale complex.

Other Classifications:
Michigan Natural Features Inventory Circa 1800 Vegetation (MNFI): Alder, Willow, Bog Birch Thicket (6122)

Michigan Department of Natural Resources (MDNR): L-lowland brush

Michigan Resource Information Systems (MIRIS): 612 (shrub/scrub wetland)

The Nature Conservancy National Classification: CODE; ALLIANCE; ASSOCIATION; COMMON NAME

III.B.2.N.e; *Alnus incana* Seasonally Flooded Shrubland Alliance; *Alnus incana* Swamp Shrubland; Speckled Alder Swamp Shrubland; Speckled Alder Swamp

NatureServe Ecological Systems Classification: CES201.582: Laurentian-Acadian Wet Meadow-Shrub Swamp

Related Abstracts: Blanding's turtle, eastern massasauga, floodplain forest, great blue heron rookery, Great Lakes marsh, northern fen, northern wet meadow, rich conifer swamp, wooded dune and swale complex, and wood turtle.

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Abstract Citation:

Cohen, J.G. 2005. Natural community abstract for northern shrub thicket. Michigan Natural Features Inventory, Lansing, MI. 8 pp.