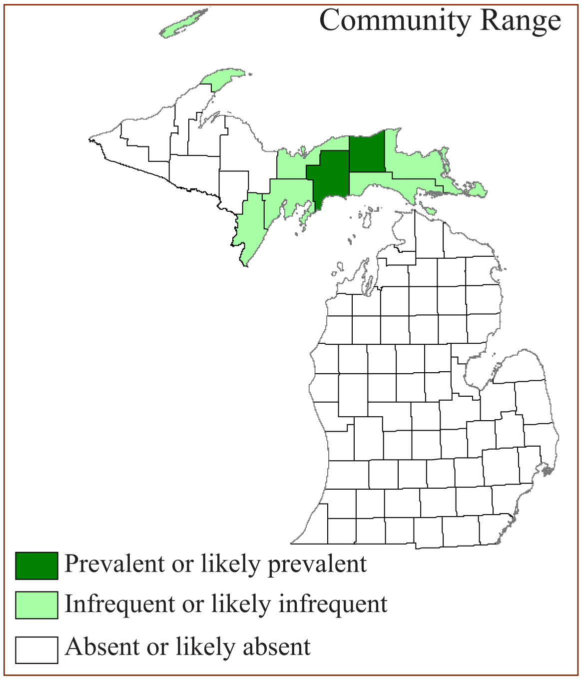
Patterned Fen

Community Abstract

Photo by Joshua G. Cohen



Overview: Patterned fen is a minerotrophic shrub- and herb-dominated peatland mosaic defined by the presence of alternating peat ridges (strings) and hollows (flarks) oriented along the contours of the peatland slope, perpendicular to the flow of groundwater. The strings vary in height, width, and spacing, but are generally less than one meter tall, resulting in a faint wave-like pattern that may be discernable only from aerial photographs. The flarks are saturated to inundated open lawns of sedges, and rushes, while the strings are dominated by sphagnum mosses, sedges, shrubs, and scattered, stunted conifer trees.

Patterned fen occurs on broad, poorly drained glacial lakeplain and poorly drained outwash channels adjacent to lakeplain. The development of patterned fen is driven by peat accumulation, seasonal flooding, surface water and groundwater flow regimes, and periodic wildfire. Patterned fens are also referred to as patterned bogs, patterned peatlands, ribbed fens, string fens, strangmoor, aapa mires, and string bogs. In Michigan, patterned fens occur primarily in the eastern Upper Peninsula, with the highest concentration found in Schoolcraft County.

Global and State Rank: GU/S2

Range: Patterned fen exhibits circumboreal distribution, occurring throughout subarctic North America and Eurasia. The community also occurs locally in the southern hemisphere, where it has been recorded from Tasmania, Patagonia, and New Zealand (Dickinson and Mark 1994, Mark et al. 1995, Dickinson et al. 2002, Rapson et al. 2006). Patterned fen and other peatlands occur where excess moisture is abundant (i.e., where precipitation is greater than evapotranspiration) (Mitsch and Gosselink 2000). In North America, patterned fen is widely distributed from Alaska through most of Canada to the Atlantic coast, and is also found in northern regions of the conterminous United States in Minnesota, Wisconsin, Michigan, New Hampshire, New York, and Maine (Sorenson 1986, Sperduto et al. 2000, NatureServe 2009). Conditions suitable for the development of fens have occurred in the northern Lake States for the past 8,000 years (Heinselman 1963, 1970, Boelter and Verry 1977, Futyma 1982, Foster and King 1984, Riley 1989, Comer et al. 1995b). Expansion of peatlands likely occurred following climatic cooling, approximately 5,000 years ago (Heinselman 1970, Boelter and Verry 1977, Riley 1989). The Michigan range of patterned fen is concentrated in the eastern Upper Peninsula in the Luce Subsection (VIII.2), where 15 element occurrences have been documented from the Seney Sand Lake Plain (VIII.2.1) and the Grand Marais Sandy End Moraine and Outwash (VIII.2.2) Sub-subsections, primarily in Schoolcraft and Luce Counties (Albert 1995, MNFI 2010). Patterned fen occurs less frequently in the Niagaran Escarpment and Lakeplain Subsection (VIII.1) within the St. Ignace (VIII.1.1) and Escanaba/Door Peninsula (VIII.1.3) Sub-subsections (two occurrences), in the Dickinson Subsection (VIII.3)

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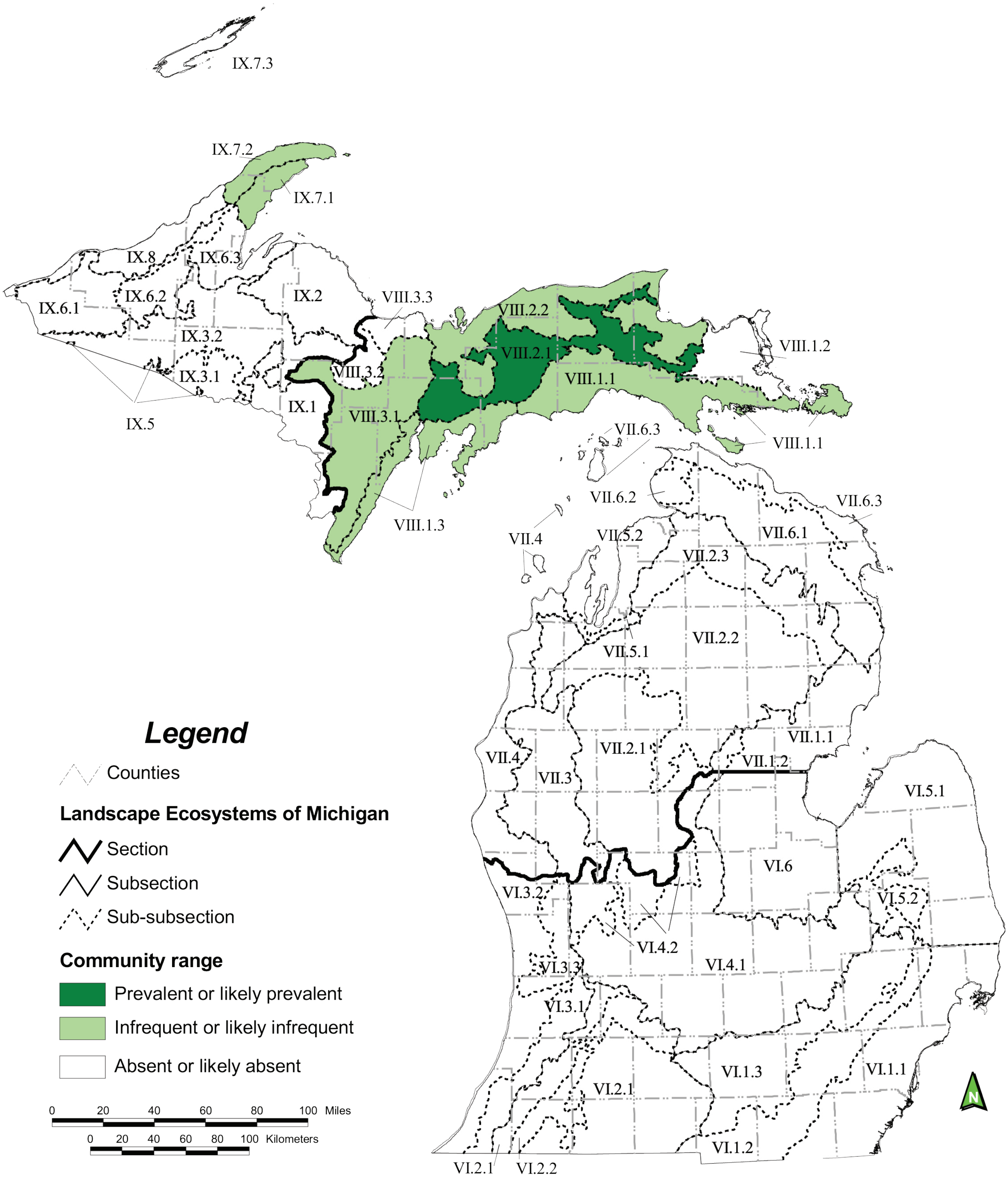

Ecoregional map of Michigan (Albert 1995) depicting distribution of patterned fen (Albert et al. 2008)

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within the Northern Lake Michigan (Hermanville) Till Plain Sub-subsection (VIII.3.1) (no documented occurrences), and in the western Upper Peninsula in the Keweenaw Subsection (IX.7) (one occurrence) (Albert 1995, Kost et al. 2007, Albert et al. 2008, Cohen 2009, MNFI 2010).

Rank Justification: Circa 1800, open peatlands characterized as patterned fen, muskeg, or bog occupied slightly greater than 100,000 ha (approximately 260,000 ac) in Upper Michigan (i.e., the Upper Peninsula) (Comer et al. 1995a), with over 45,000 ha (110,000 ac) interpreted as patterned fen (Comer et al. 1995a). Relatively small, isolated patterned fens also occurred in large areas of mixed conifer swamp (Comer et al. 1995a, MNFI 2010), and were mapped as mixed conifer swamp due to the scattered distribution of conifers within the open wetlands. Mixed conifer swamp covered approximately 850,000 ha (2,100,000 ac) of Upper Michigan circa 1800, including a significant portion of the land surface in Schoolcraft (77,000 ha or 190,000 ac), Luce (67,000 ha or 165,000 ac), Chippewa (130,000 ha or 320,000 ac), and Mackinac (49,000 ha or 120,000 ac) Counties (Comer et al. 1995a). Approximately 10% of extant patterned fen acreage was mapped as mixed conifer swamp circa 1800, suggesting the total acreage of patterned fen in Michigan circa 1800 may have been slightly greater than proposed by Comer et al. (1995a).

In the late 19th and early 20th centuries, significant areas of patterned fen were degraded by logging and drainage projects in Upper Michigan (Comer et al. 1995b). The vast open peatlands of the Seney Lake Plain, concentrated in Schoolcraft County, were altered by logging of conifers in adjacent uplands and dune ridges within the peatlands, slash fires, and attempts at drainage (Heinselman 1965, Comer et al. 1995b). More recent wildlife habitat projects near Seney resulted in the conversion of additional open peatland acreage to floodings and open pools (Comer et al. 1995b). However, vast areas of patterned fen and other open peatlands in Upper Michigan were spared significant disturbance due to their wet peat soils, lack of marketable timber, large size, and difficulty of access (Heinselman 1965). As of the late 1970s, MIRIS data indicate that approximately 97,000 ha (240,000 ac) of emergent wetland and 220,000 ha (540,000 ac) of shrub/scrub wetland, the two wetland types that characterize most open peatland acreage, occurred in Upper Michigan (MDNR 1978). As of 2000, mixed non-forested wetland covered 130,000 ha (320,000 ac), and shrub-dominated wetland covered nearly 210,000 ha (510,000 ac) in Upper Michigan (MDNR 2001). Comparisons of these acreage data between 1978 and 2000 indicate there has been no significant change in coverage of non-forested wetlands in the region since the late 1970s.

To date, peat harvest, agriculture, modern forestry, and biofuel production have not significantly impacted patterned fen in Michigan (MNFI 2010). However, peatlands, including patterned fen, are susceptible to numerous threats. Peat mining and harvest alters surface hydrology and flow patterns. Peat is harvested for use in horticulture, soil modification, and fuel (Miller 1981, Crum 1988). Peat mining alters the quality and quantity of surface water by creating a series of ponds on the peatland surface that alter local flow paths (Meyer 1992, Wassen et al. 1996). Peatlands are also drained for agriculture and forestry, and this disruption of hydrology causes the degradation of peat and homogenization of vegetation (Eurola et al. 1991). Drainage causes consolidation and decomposition of peat, which results in higher bulk density, reduced hydraulic conductivity, and the homogenization of hydraulic properties and vegetation on the peat surface (Whittington and Price 2006). Peatlands have also been proposed for the production of biofuel crops (Keirstead 1992). Research has shown that broad-leaved cat-tail (*Typha latifolia*), narrow-leaf cat-tail (*T. angustifolia*), hybrid cat-tail (*T.* x*glauca*), and reed (*Phragmites australis*) may be suitable for the production of bioenergy. The production of biofuel crops within peatlands can destroy patterned fen directly through outright destruction of soil structure and natural vegetation and indirectly through fragmentation and hydrologic alteration. In addition, narrow-leaf cat-tail, hybrid cat-tail, and common reed are highly invasive plants that can significantly alter community structure and reduce species diversity, especially in minerotrophic wetland systems such as patterned fen (Kost et al. 2007, Cohen et al. 2009).

Vast tracts of open peatland exist at present in Upper Michigan, including 18 documented occurrences of patterned fen, totaling 15,200 ha (37,600 ac) (MNFI 2010). These occurrences range from 2.6 ha (6.3 ac) to 8,150 ha (20,140 ac), and average 840 ha (2,100 ac). Distinctive patterning occurs in a portion of each occurrence, but most occurrences contain areas of unpatterned open fen and other closely associated wetland communities. Patterned fen is ranked S2 (imperiled) in Michigan due to the limited number of occurrences (18), limited acreage of distinctive patterning, and the potential for remaining occurrences to be impacted by hydrologic alteration and other disturbances, including climate change. Despite these potential threats, nearly all remaining patterned fens are considered to be of excellent (A-rank) or good (B-rank) viability.

Physiographic Context: Patterned fen occurs primarily on broad, level, poorly drained lakeplain, including former embayments of Glacial Lake Algonquin (Albert 1995, Comer et al. 1995b). The community also occurs in glacial outwash channels (Kost et al. 2007). The landforms that support patterned fen exhibit a gentle slope, generally from 0.4-2.3 meters per kilometer (2-12 feet per mile), and eventually drain into rivers and occasionally lakes (Heinselman 1965, Madsen 1987, Albert 1995, Comer 1995b). The lakeplain and outwash landforms that support patterned fen are characterized by highly conductive medium-textured lacustrine sands and sandy glacial outwash underlain by calcareous sedimentary bedrock, including sandstone, limestone, and dolomite (Sinclair 1959, Heinselman 1965, Madsen 1987, Albert 1995, Comer 1995b, Cohen et al. 2009, MNFI 2010). The porous sands serve as conduits for the discharge of mineral-rich groundwater from the underlying calcareous bedrock (Glaser 1992c). The thickness of the lacustrine and glacial deposits over bedrock ranges from less than 15 m (50 ft) in Sub-subsection VIII.1.1 and Subsection IX.7 to greater than 60 m (200 ft) in Subsection VIII.2 (Albert 1995).

Patterned fens are associated with other wetland communities in large wetland complexes and often border other peatland types, especially northern fen, poor fen, and muskeg (Cohen 2006, Cohen and Kost 2008a, 2008b). Additional wetland communities associated with patterned fen include northern wet meadow, northern shrub thicket, intermittent wetland, and rich conifer swamp (Kost 2002, Cohen and Kost

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Patterned fen occurs primarily on broad, level, poorly drained lakeplain.

Photo by Joshua G. Cohen

Patterned fens develop on water tracks, which are concave- or flat-surfaced, river-like zones of drainage that channel water across the peatland surface.

2007a, 2007b, 2007c, Kost et al. 2007). Narrow transverse dune ridges that occur within many patterned fens support dry-mesic northern forest and dry northern forest (Comer et al. 1995b, Cohen et al. 2009, MNFI 2010).

Hydrology: Patterned fen hydrology is influenced by the interaction of precipitation, surface water, and groundwater. The community occurs in water tracks, which are zones of preferred flow that channel runoff across the peat surface (Glaser 1992a). During spring, water moves across the surface of peatlands as sheet flow following snow melt on adjacent uplands and the peatland surface (Foster and King 1984, Price and Maloney 1994, Quinton and Roulet 1998). Sheet flow also occurs after significant rain events. Water can also drain from peatlands in narrow channels along the wetland margins, in small rivulets on the peatland surface, and by percolating through the upper, porous peat layer (i.e., the acrotelm). However, the majority of water is lost from peatlands primarily through evapotranspiration, rather than discharge. This is due to the low gradient of the peatland landform and the presence of surface microtopography that inhibits lateral flow, including the presence of pools (i.e., flarks) that create a large depression storage capacity and raised strings that impede surface water flow (Brooks 1992, Price and Maloney 1994, Quinton and Roulet 1998). The amount of water in the flarks varies depending on local hydrology, precipitation, and season.

The loss of water due to evapotranspiration is offset by the discharge of groundwater from porous, highly conductive mineral soils that occur underneath the peatland and along its margins (Brooks 1992, Siegel 1992, Price and Maloney 1996, Quinton and Roulet 1998, Reeve et al. 2001b). This groundwater moves upward and laterally through the peatland, primarily through the acrotelm (Madsen 1987, Glaser et al. 1990, Brooks 1992, Glaser 1992c, Price and Maloney 1994, Reeve et al. 2001a, 2006). Although the water table in patterned fen is typically near the surface, periodic infiltration of water from the peat to the underlying mineral layers occurs within peatlands, especially in areas where the mineral soils are relatively close to the peat surface (Laitinen et al. 2008). Strings are more resistant to hydrologic fluctuations than flarks due to their greater cover of desiccation-resistant mosses (Laitinen et al. 2008) and slightly elevated position.

Relative to ombrotrophic peatlands such as muskegs and bogs, the discharge and lateral flow of groundwater in patterned fens creates minerotrophic conditions characterized by high calcium, magnesium, sodium, and potassium concentrations, high specific conductivity, and high pH (Sjörs 1950, Heinselman 1970, Glaser 1992b, Bridgham et al. 1996, Tahvanainen et al. 2003). However, like muskegs and bogs, patterned fens are low in nitrogen and phosphorus, and are typically dominated by species adapted to low nutrient conditions (Bridgham et al. 1996). The low availability of essential nutrients also results in low primary productivity (Moore 1989, Bridgham et al. 1996, Mäkilä et al. 2001, Cohen 2006). Peatland water chemistry is impacted by precipitation chemistry, internal biotic and abiotic processes, soil chemistry, the conductivity and mineral content of mineral soil strata, and the nature of the underlying bedrock, among other factors (Bridgham et al. 1996).

Soils: Patterned fens occur on peat soils that began to accumulate and spread between 8,000 and 3,000 years before present (B.P.) following a shift to cool, moist climatic conditions (Heinselman 1963, 1970, Boelter and Verry 1977, Futyma 1982, Foster and King 1984, Riley 1989, Comer et al. 1995b). Michigan peatlands appear to have established between 5,000 and 3,000 years B.P. following a rise in lake levels caused by this climatic shift (Futyma 1982, Futyma and Miller 1986, Brugam and Johnson 1997). Radiocarbon dating of basal peats in two Michigan patterned fens indicates basal peats established approximately 3,250 years B.P. at one site and 2,000 years B.P. at another site (Madsen 1987). The individual chronologies of peatland development are related to basin characteristics and autogenic (within-site) processes (Janssens et al. 1992). The characteristic alternating strings and flarks are of more recent origin (Heinselman 1963, 1970, Foster and King 1984, Madsen 1987, Foster et al. 1988, Moore 1989, Quinton and Roulet 1998).

Patterned fens occur on shallow to deep (>1 m) peat soils, most of which are characterized by poorly drained Markey and Carbondale mucks underlain by hydric sands (Heinselman 1963, 1965, 1970, Foster and King 1984, Madsen 1987, Whitney 1992, Charman 1994, Comer et al. 1995b, Cohen et al. 2009, MNFI 2010). Patterned fens may also form on peats of several other series, including the Dawson, Greenwood, Loxley, Lupton, Rifle, and Tawas series (USDA, NRCS 2009a, MNFI 2010). These soils consist of moderately well-decomposed to well-decomposed hemic to sapric peats derived from herbaceous plants (sedges and reeds) and sphagnum mosses, with woody material occasional throughout the soil profiles (Futyma 1982, Foster and King 1984, Madsen 1987, Glaser et al. 1990, Charman 1994, MNFI 2010). Peat soils in patterned fens experience seasonal flooding and water level fluctuation, and are generally saturated or inundated in flarks and moist to dry in strings during the growing season (Siegel 1992, Cohen et al. 2009, Laitinen et al. 2008, MNFI 2010). Nutrient availability and pH can differ greatly both within and among patterned peatland systems (Heinselman 1970, Glaser et al. 1981, Foster and King 1984, McNamara et al. 1992, Sjörs and Gunnarsson 2002, MNFI 2010). In Michigan, the peat soils of patterned fens range from strongly acid (pH= 5.1–5.5) to neutral (pH= 6.6–7.3), allowing these sites to be classified as poor to rich fens (Sjörs 1950, Heinselman 1970, Glaser 1992a, MNDNR 2003, Siegel et al. 2006, MNFI 2010). Strings tend to be more acidic than flarks, and are sometimes capped by sphagnum mosses that create a thin layer of extremely acid (pH< 4.5) or very strongly acid (pH= 4.5–5.0) conditions. Flarks are more alkaline (pH= 5.5–6.0 in poor fen sites to 7.0 in rich fen sites) and wetter than strings, and often contain mats of undecomposed sedge fibers over hemic peat.

Climate: Upper Michigan is characterized by a humid continental climate with severe, long winters, no dry season, and short, moist, cool to warm summers (Peel et al. 2007). Peatlands develop in humid climates where precipitation exceeds evapotranspiration (Boelter and Verry 1977, Gignac et al. 2000, Halsey and Vitt 2000). Across northern Michigan, 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 (1.0 in) or more is between 80 and 140. The normal annual total precipitation ranges from 740 to 900 mm (29 to 35 in) with a mean of 823 mm (32 in). 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, Albert 1995). The growing season in eastern Upper Michigan, where patterned fens are concentrated, generally ranges from 110 to 130 days (Eichenlaub et al. 1990, Comer et al. 1995b), and averages 114 days in the Luce Subsection (Barnes and Wagner 2004). July daily maximum temperature in eastern Upper Michigan ranges from 22° to 27° C (72 to 80 °F), the daily minimum temperature in January ranges from -14 to -12 °C (6 to 10 °F), and the annual average temperature is 5 °C (41 °F). The growing season heat sum (a measure of heat accumulation) in the Seney Sand Lake Plain Sub-subsection is one of the lowest in the state (Albert et al. 1986). Mean annual total precipitation in eastern Upper Michigan ranges from 760 to 860 mm (30 to 34 in), with average seasonal snowfall of 200 cm (80 in) in the southern portions of eastern Upper Michigan to over 450 cm (180 in) in portions of northern Luce, Schoolcraft, and Alger Counties (Eichenlaub et al. 1990, Barnes and Wagner 2004). Average seasonal snowfall exceeds 500 cm (200 in) in portions of the Keweenaw Peninsula.

Natural Processes: Patterned fens and the factors influencing their initiation, development, structure, vegetative composition, succession, and function have received considerable research attention across their global range. Patterned fens are peatland landforms that develop in regions where precipitation is greater than evapotranspiration, resulting in significant groundwater storage and discharge (Dansereau and Segadas-Vianna 1952, Boelter and Verry 1977, Almendinger and Leete 1998, Mitsch and Gosselink 2000). High water tables permit the establishment and accumulation of peat-forming vegetation. Stratigraphic and pollen evidence suggests peat-forming vegetation first developed in areas of impeded drainage, such as the downslope margins of broad, level lakeplains (e.g., where beach ridges or moraines impeded drainage), areas impacted by sluggish water flow due to beaver activity, or in lake or pond basins (Heinselman 1970, Futyma 1982, Foster and King 1984, Madsen 1987, Almendinger and Leete 1998). Low levels of oxygen in saturated soils protect plant matter from microorganisms and chemical actions that cause decay, allowing the rate of organic matter accumulation to exceed the rate of decay (Schwintzer and Williams 1974, Miller 1981, Damman 1990, Mitsch and Gosselink 2000). Peat develops vertically, with estimates of vertical accumulation ranging from 100 to 200 cm (39 to 79 in) per 1,000 years (Boelter and Verry 1977, Mitsch and Gosselink 2000). Peat accumulation causes a rise in the water table, which further impedes drainage and promotes the horizontal spread of peat over mineral soils through a process known as paludification (Foster and King 1984). The level to gently sloping topography of the landforms that support patterned fen are particularly favorable for paludification and expansion of peatlands, which coincided with a shift to cool, moist conditions and rises in lake levels in Upper Michigan 5,000 to 3,000 years B.P. (Boelter and Verry 1977, Futyma 1982, Futyma and Miller 1986, Brugam and Johnson 1997).

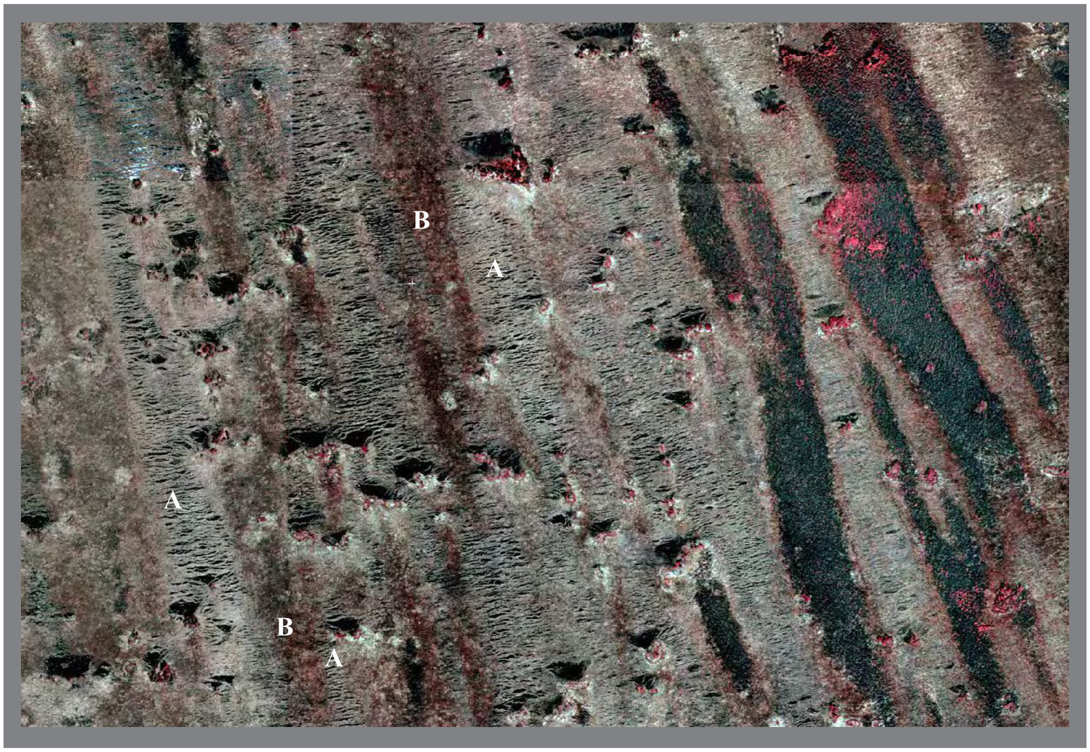
Photo by Joshua G. Cohen

The level to gently sloping topography of the landforms that support patterned fen are favorable for paludification and expansion of peatlands.

Lake and pond basins that support peatlands are often underlain by a layer of amorphous, gelatinous organic material called gyttja that develops from the accumulation of dead algae and invertebrates and minerals from the substrate (Foster and King 1984, Crum 1988, Foster et al. 1988). The initial peats in these basins develop on the lake sediments, and can spread laterally from the basin following sufficient vertical development. Large areas of peatland appear to have developed directly on mineral soils, where shifts in climate led to an increase in the water table that permitted the establishment and growth of peat-forming vegetation (Crum 1988). Throughout their range, patterned peatlands exhibit a relatively consistent stratigraphic sequence beginning with sedge- and shrub-derived peats followed by an increase in mosses and ericaceous shrubs, indicating a transition to more nutrient-poor conditions as peats accumulate, raise the water table, and isolate plant roots from underlying mineral soils and groundwater (Heinselman 1965, 1970, Foster and King 1984, Madsen 1987, Janssens et al. 1992). In some peatlands, layers of woody peat derived from swamp forest occur above the sedge peat layer and below the younger sedge – moss peat layer (Heinselman 1970). These swamp forests may have been replaced by open or shrub-dominated communities following paludification, flooding, or catastrophic fires.

Patterned fens develop on water tracks, which are concave- or flat-surfaced, river-like zones of drainage that channel water across the peatland surface (Glaser 1992a, Price and Maloney 1994). Water tracks begin as narrow channels in swamp forest or other wetland communities at the upslope margins of the peatlands and coalesce and widen downslope (Glaser 1992a). The active flow of mineralized water in water tracks creates conditions favorable for the oxidative degradation of peat, which results in the concave or flat surface characteristic of this peat landform (Heinselman 1963). High water tables and seasonal flooding limits the establishment of trees and tall shrubs in water tracks and favors the development of open sedge lawns (i.e., poor fen, northern fen) (Glaser 1992a). The length of the water tracks varies considerably among sites; water tracks that support patterned fen in Michigan range from less than 150 m to greater than 8 km in length, and from less than 50 m to 2 km in width (MNFI 2010). Several individual water tracks may be aligned in the same direction, separated by bands of trees and shrubs that occur on slightly raised peats (Heinselman 1963). Patterned fen is characterized by the development of ladder-like arrangements of alternating peat ridges (strings) and pools (flarks) oriented perpendicular to the direction of water flow and the orientation of the water track. Fen patterns may begin to develop thousands of years after the initiation of the peatland (Foster and King 1984, Madsen 1987). Several hypotheses have been proposed to explain the factors responsible for the development of strings and flarks (Heinselman 1963, 1970, Glaser et al. 1981, Glaser 1983, 1992a, 1992b, 1992c, Foster and King 1984, Madsen 1987, Charman 1994, Price and Maloney 1994, Quinton and Roulet 1998, Koutaniemi 1999). The most important requirement for the development of fen patterns appears to be a slightly sloped, poorly drained landform that supports directional sheet flow. Peatlands that develop in this setting are known as soligenous mires (Heinselman 1963, Bridgham et al. 1996, Tahvanainen et al. 2003). The process of pattern formation is thought to begin with the development of hummock-hollow microtopography, which creates catchments on the surface of the peatland. Repeated flood events fill the depressions, which widen and eventually merge across the slope by swamping intervening hummocks and impeding growth of vegetation at the pool margins (Foster et al. 1983, Foster and King 1984). This process eventually results in the formation of elongated pools, or flarks. Flarks form along the contours of the slope because the level slope produces a minimum force for downslope drainage (Glaser 1992c). Flarks may drain into adjacent downslope flarks when degradation of intervening peat ridges leads to the development of drainage channels under or across the peat (Foster and King 1984). Over time, flarks expand in length, width, and depth due to the oxidative degradation of surface peats in the flarks and adjacent strings and the increasing resistance to infiltration of the decomposing flark-bottom peats (Foster and King 1984, Glaser 1992c, Price and Maloney 1994, Quinton and Roulet 1998).

The spatial characteristics of the strings and flarks vary considerably among sites. The difference in height between the bottoms of the flarks and the tops of the strings is typically less than 1 m (Madsen 1987, Cohen et al. 2009, MNFI 2010), although this difference in height may appear to be greater due to the growth of shrubs and trees on the strings. Flarks range in length from a few meters to greater than 600 m, and range from one meter to 150 m wide (MNFI 2010). Flarks on gently sloped sites tend to be narrow and arranged in terraces, whereas flarks on imperceptibly sloped or relatively flat sites are often wide (Foster and King 1984). Flarks are often widest at the middle, giving them a distinctive concave edge on the downslope margins. Strings may extend across the entire water track in some patterned fens, but become discontinuous with the development and expansion of flarks. In some sites, strings are represented by isolated hummocks within large flarks (Foster and King 1984). Strings may also branch and rejoin (anastomose), forming web-like patterns with intervening flarks and pools on the peatland surface (Sorenson 1986, MNDNR 2003). Strings range from very narrow to several meters wide (Madsen 1987, MNFI 2010). In addition to changes in size and shape, strings can move both downslope and upslope within the fen (Madsen 1987, Koutaniemi 1999). These



An aerial photograph of a patterned fen exhibiting several patterned water tracks (A) separated by bands of shrubs and trees (B). The elongated, dark features in the water tracks are the flarks. Photo source: MNFI 1998 Digital Orthophoto County Mosaics.

Photo by Joshua G. Cohen

Patterned fens are characterized by ladder-like arrangements of alternating peat ridges (strings) and pools (flarks) oriented perpendicular to the direction of water flow and the orientation of the water track.

Photo by Bradford S. Slaughter

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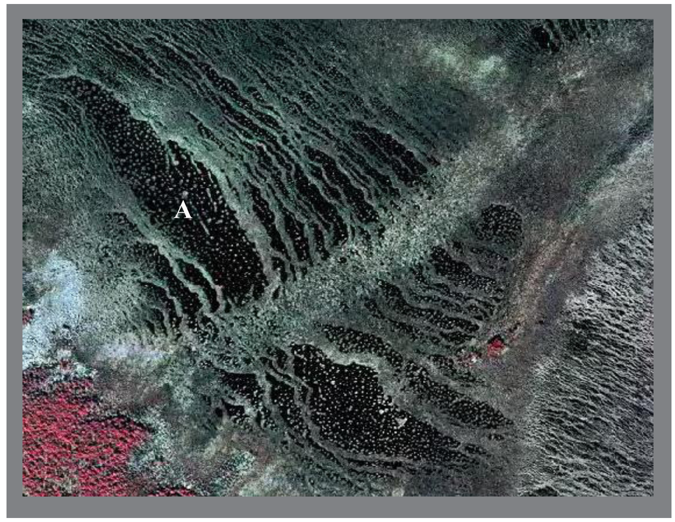
Flark width ranges considerably within Michigan's patterned fens (top to bottom). Gradual erosion of peat along the strings results in flark expansion. Flark expansion can lead to the eventual dissolution of the ribbed patterning (bottom).



This aerial photograph reveals broad flarks (dark) that contain small remnant peat hummocks (gray). These hummocks appear as distinctive circular "islands" within the flark. Photo source: MNFI 1998 Digital Orthophoto County Mosaics.

Photo by Joshua G. Cohen

Strings may extend across the entire water track in some patterned fens.

movements are likely the result of solifluction, or peat slippage, and perhaps also ice/frozen peat push, groundwater pressure, and expansion of the entire peatland (Koutaniemi 1999). Further research is needed to completely understand the complex biotic, chemical, and physical interactions that cause and modify fen patterns.

Within some patterned fen complexes in North America, sphagnum peats accumulate over the sedge-, shrub-, and tree-derived peats, and form ombrotrophic raised bogs that are sharply delimited and separated by narrow water tracks that drain the bog surfaces (Heinselman 1963, 1970, Glaser et al. 1981, 1990, Foster et al. 1988, Glaser 1992a, 1992b, 1992c, Janssen 1992, Janssens et al. 1992, Price and Maloney 1994, Charman 1995, Reeve et al. 2001a, 2001b). These raised bogs appear to have formed approximately 4,000 to 3,000 years B.P. on peatlands that established up to 10,000 years B.P. (Heinselman 1970). Although Upper Michigan is characterized by a climate conducive to peat accumulation (Mitsch and Gosselink 2000) and supports numerous species of acidifying sphagnum mosses (Crum 1988) and acidic peatlands (Cohen 2006a, 2006b, Kost et al. 2007, Cohen and Kost 2008c), raised bogs have not developed in the patterned fens in the state (MNFI 2010). This may be in part due to the relatively young age of these peatlands, the relatively small size of the landforms that support patterned fen in Michigan, the porous, highly conductive mineral soils underlying and surrounding the peat deposits that permit transverse dispersion of solutes to the peat surface, and the lack of water-table divides that can develop following significant peat accumulation and lead to mineral depletion, acidification, and the accumulation of fibric sphagnum peat (Heinselman 1970, Glaser 1992a, 1992c, Janssens et al. 1992, Reeve et al. 2001a, 2001b). Despite the lack of raised, ombrotrophic bogs within Michigan's patterned fens, patterned fens do sometimes grade into flat expanses of weakly minerotrophic to ombrotrophic muskeg, and some of the muskeg areas contain remnant linear patterning that indicates a trend towards acidification (Cohen et al. 2009, MNFI 2010). The conversion of patterned fen to muskeg results from the accumulation of peat, increasing isolation of the plant rooting zone from the influence of mineral-rich groundwater, and colonization and spread of sphagnum mosses, which bind nutrients and produce strong organic acids (Heinselman 1963, Crum 1988, Cohen 2006, Siegel et al. 2006).

Photo by Bradford S. Slaughter

Patterned fens sometimes grade into flat expanses of weakly minerotrophic to ombrotrophic muskeg.

The hydrologic pathways of surface water, regional and local groundwater, and precipitation affect the development and vegetative composition of patterned fen (McNamara et al. 1992). Following snowmelt and significant rain events, sheet flow from adjacent uplands and within the peatland connects the flarks, which discharge water downslope across the peat surface (Price and Maloney 1994, Quinton and Roulet 1998). As the water table recedes, the flarks become isolated. Low-permeability peats in the strings downslope of the disconnected flarks impede the flow of water across the peatland during most of the growing season, which results in the loss of most surface water in the peatland to evapotranspiration (Price and Maloney 1994, Quinton

Photo by Bradford S. Slaughter

Water that collects in flarks during the growing season is generally lost from the peatland to evapotranspiration.

and Roulet 1998). In addition to surface water and precipitation, groundwater is an important contributor to patterned fen hydrology, soil chemistry, and vegetation. Peat soils are very sensitive to inputs of groundwater; the contribution to peat hydrology of as little as 10% groundwater from calcareous bedrock is sufficient to create alkaline conditions (Glaser et al. 1990). Fen vegetation produces weak organic acids that are buffered by alkaline groundwater in the upper peat layers (Siegel et al. 2006). In sites with strong horizontal groundwater movement, transverse dispersion can transport solutes (including nutrients) to the peatland surface, even in the absence of upward groundwater discharge or run-off from adjacent mineral soils (Reeve et al. 2001a). Species assemblages typical of peatlands are strongly correlated with pH, the concentration of calcium and other salts, and specific conductivity, properties that are closely tied to the influence of groundwater (Sjörs 1950, Glaser et al. 1981, 1990, Wheeler et al. 1983, Glaser 1992b, McNamara et al. 1992, Charman 1993, Bubier 1995, Bridgham et al. 1996, Sjörs and Gunnarsson 2002, NatureServe 2009, MNFI 2010). Flow reversals in peatlands have dramatic effects on peatland development, succession, and vegetative composition. Recent research has demonstrated flow reversals in peatlands in which subsurface flow of water can reverse direction in response to climatic and seasonal variations in evapotranspiration and precipitation that alter water table positions (Siegel 1992, Devito et al. 1997, Reeve et al. 2006). For example, the development of a groundwater discharge zone underneath an ombrotrophic raised bog in Minnesota resulted in the development of fen peat, increases in pH, specific conductivity, and calcium concentration, and colonization by rich fen flora (Glaser et al. 1990, Siegel 1992). The discharge of groundwater into the raised bog may have resulted from pressure caused by an increased hydraulic head associated with a rise of the water table in the upland recharge area of this peatland (Glaser et al. 1990).

Evidence of historic wildfires in patterned fens is provided by layers of charcoal and deposits of mineral soils from eroded uplands in peat profiles and synchronous fire scars in tree trunks on isolated dune ridges within the peatlands (Heinselman 1963, 1970, Glaser et al. 1981, Madsen 1987, Foster et al. 1988, Janssen 1992, Charman 1994, Drobyshev et al. 2008). The frequency and severity of historical wildfires in patterned fens is not well understood, but fires were likely most prevalent in sites associated with fire-prone uplands (e.g., dry northern forest, dry-mesic northern forest) (Whitney 1986, MNDNR 2003, Cleland et al. 2004) and drought-prone sites on thin peats with fluctuating water tables (Ruel et al. 2004, Fenton et al. 2005, Laitinen et al. 2008). Peatland fires may originate in adjacent uplands or within the peatland itself (Madsen 1987, Cohen et al. 2009). Wildfires within peatlands, such as patterned fens, typically occur late in the growing season, when periods of drought lower the water table and allow the surface peat to dry out enough to carry fire (Vogl 1964, Schwintzer and Williams 1974, Drobyshev et al. 2008). In the Seney National Wildlife Refuge (NWR) in Schoolcraft County, major fires occurred in the summers of 1754, 1791, 1864, 1891, 1919, and 1976 (Drobyshev et al. 2008). Minor, asynchronous fires originating on dune ridges within the peatlands are more frequent and occur throughout the growing season, but are limited in extent by the wet peat soils, especially early in the growing season following snowmelt (Drobyshev et al. 2008). Madsen (1987) found several layers of charcoal and eroded mineral particles in a patterned fen immediately north of Seney NWR, which supports the finding by Drobyshev et al. (2008) that fires frequently burned the peatlands in this area. However, only eroded mineral particles were noted from another patterned fen west of Seney NWR, which indicates fires on the surrounding uplands did not burn into the peatlands. These strikingly different findings illustrate that fire frequency varies considerably among sites. Peatland fires appear to shift plant composition and community structure. Peaks of charcoal in the peat profile coincide with shifts in peat composition, often from woody peat, representing tree- and shrub-dominated communities, to sedge- and sphagnum-dominated peat, representing sedge meadow and fen communities (Heinselman 1963, 1970, Madsen 1987). Low severity fires in open peatlands can contribute to their maintenance by killing encroaching trees, promoting sprouting of ericaceous shrubs, and minimally impacting moss cover (Curtis 1959, Vitt and Slack 1975).

The impacts of the 1976 Seney fire were still evident in several patterned fens in 2007 (Cohen et al. 2009). This fire was ignited by a lightning strike in August 1976, and subsequently burned over 14,000 ha (35,000 ac) (Dickmann and Leefers 2003). At one impacted fen, the contrast between strings and flarks may have been modified by the fire, which reduced peat depth and dampened the sphagnum hummock and hollow microtopography. The scattered conifers that once occurred in the fen were killed by the fire. Fire may have also imparted a competitive advantage to sprouting ericaceous shrubs (Curtis 1959, Vitt and Slack 1975). At another site, areas of the patterned fen in the vicinity of drainage ditches were species-poor and supported scattered growth of jack pines that dated to the late 1970s, coinciding with the timing of the fire. Peat depths in this area were shallow, reflecting the impacts of ditches in causing local drainage, aeration, and increased combustibility of peat soils (Glaser et al. 1981, Bradof 1992a). Charcoal from the 1976 fire was present just below the peat surface. Conifers that grew on the strings and in the long vegetation "tails" extending downslope from transverse dunes in the Seney peatlands were killed by the 1976 fire and have not yet recolonized portions of the fens (Madsen 1987, Cohen et al. 2009, MNFI 2010).

The Sleeper Lake Fire in Luce County, Michigan of August 2007 burned over 7,000 ha (18,000 ac), including large portions of a peatland complex containing two patterned fens. In 2008, MNFI ecologists visited McMahon Lake and Sleeper Lake patterned fens to assess the ecological impacts of the fire on the peatland and make comparisons to a previous survey conducted in 2006, one year prior to the wildfire. Within the patterned fens, the fire burned evenly through the flarks (the low areas) and burned patchily within the strings (the hummocks). This likely occurred because the flarks tend to be composed of more sapric and decomposed peats, which likely dried out more completely during the drought that preceded the fire (Cohen et al. 2009). The strings or hummocks are composed of fibric peats and dominated by sphagnum mosses, which likely retained moisture even during the drought (Ruel et al. 2004, Fenton et al. 2005, Laitinen et al. 2008, Cohen et al. 2009). Interestingly, where there were coniferous trees and ericaceous shrubs on the strings, the fire consumed the shrubs and trees, often burning the woody stems and incinerating the hummocks. The shrubs and trees provided fuel for the fire and also absorbed the moisture in localized areas. The fire likely spread to these trees and shrubs through two mechanisms: wind blown flames that ignited the tops of the woody stems and/or subsurface peat fires that ignited the root masses. A preliminary examination of the plant species lists from 2006 and 2008 suggests that some species may be more prevalent following the fire, but there was not noticeable loss of native species diversity. All ericaceous species and peatland shrubs were resprouting and graminoids (e.g., sedges, beak-rushes, and cotton-grasses) throughout the peatlands were growing vigorously (Cohen et al. 2009).

In the surrounding uplands and on the upland pine-dominated ridges that occur within the Sleeper Lake peatland, fire behavior was variable, depending on slope, dune height, and the overstory species composition. Mortality of trees ranged from 100% on low dune ridges dominated by jack pine (*Pinus banksiana*) to 0% on steeper ridges with a hardwood component. It appeared as if the fire crowned in areas dominated by jack pine but occurred as surface fires or patchy crown fires in areas with a mixture of red pine (*Pinus resinosa*) and jack pine, typically causing 50-60% mortality. Most trees were scorched on their boles and were subsequently blown over. However, some trees were completely incinerated with nothing but a nub remaining, or, in places, a root footprint (Cohen et al. 2009).

Photo by Bradford S. Slaughter

The 2007 Sleeper Lake Fire caused considerable mortality of trees within the vast peatland.

Photo by Dave Kenyon

An aerial photograph taken after the Sleeper Lake Fire reveals the patchy nature of the fire in the moss-dominated areas.

Photo by Dave Kenyon

Within the patterned fens, the Sleeper Lake Fire burned evenly through the flarks and burned patchily within the strings. This likely occurred because the flarks tend to be composed of more sapric and decomposed peats, which likely dried out more completely during the drought that preceded the fire.

Photo by Bradford S. Slaughter

Photo by Joshua G. Cohen

The 2007 Sleeper Lake Fire burned extensive areas of the Sleeper Lake peatland complex, including open peatland (left) and low dune ridges within the peatland (right).

Photo by Joshua G. Cohen

Photo by Joshua G. Cohen

Photo by Bradford S. Slaughter

Photo by Joshua G. Cohen

Within the patterned fen, the fire burned evenly through the drought-dried flarks (the low areas) and burned patchily within the moister strings (the hummocks).

Vegetation Description: Patterned fen is a peatland mosaic characterized by open, graminoid- and shrub-dominated fen meadow that occurs in narrow to broad water tracks, sometimes separated by bands of lowland shrubs and conifers. Vegetative composition and dominance differs between the alternating peat ridges (strings) and depressions (flarks) that create the ribbed patterning characteristic of the community. The strings are comprised of slightly raised ridges of peat and are dominated by sphagnum mosses, sedges, forbs, and small shrubs. The flarks consist of level areas or hollows between slightly elevated strings and are dominated by sedges and rushes or support open water and submergent vegetation. Species composition in patterned fens is influenced by a variety of factors, including microtopography, hydrologic fluctuation, gradients in soil moisture and water chemistry, and patterns of peat accumulation and decomposition (Sjörs 1950, Wheeler et al. 1983, Glaser 1992b, Charman 1993, Bridgham et al. 1996, Laitinen et al. 2005, NatureServe 2009). Vascular plant species listed below are derived primarily from patterned fens surveyed by MNFI (2010) and Cohen et al. (2009), and are organized by stratum and vegetation zone (e.g., string, flark, wet meadow). Other sources of vegetation data include Heinselman (1965), Glaser et al. (1981), Wheeler et al. (1983), Foster and King (1984), Reinartz (1985, 1986), Glaser (1987, 1992b), Madsen (1987), MNDNR (2003), and NatureServe (2009). The list of characteristic bryophytes is derived from the above-listed sources in addition to Glaser (1983), Sorenson (1986), Crum (1988), and Janssens (1992); common nomenclature for bryophytes follows USDA, NRCS (2009b).

The most characteristic zone of patterned fen is open fen meadow that exhibits "ribbed" patterning of alternating peat ridges (strings) and hollows (flarks). These open fen meadows develop in water tracks, which are areas that receive and transport runoff as sheet flow from surrounding areas of the peatland (Glaser 1992a). Strings or hummocks within this zone may contain scattered or clumped stunted conifers. Trees are concentrated on the crests of strings, where the peat is relatively well-aerated compared to the flarks and is not subject to prolonged inundation, facilitating tree establishment and growth (Glaser et al. 1981, 1990,

Photo by Bradford S. Slaughter

Trees are concentrated on the relatively dry crests of high strings where well-aerated peat permits their establishment and growth. Characteristic species include tamarack (*Larix laricina*), black spruce (*Picea mariana*), and northern white cedar (*Thuja occidentalis*), the latter species occurring in greatest density or as a dominant species in sites with significant influence of mineral-rich groundwater.

Wheeler et al. 1983, Foster and King 1984, Foster et al. 1988). Characteristic tree species include tamarack (*Larix laricina*), black spruce (*Picea mariana*), and northern white cedar (*Thuja occidentalis*), the latter species occurring in greatest density or as a dominant in sites with significant influence of mineral-rich groundwater. White pine (*Pinus strobus*), jack pine (*P. banksiana*), and, rarely, red pine (*P. resinosa*) also occasionally occur on strings, and are most prevalent near the upland margins of the peatlands where seed sources are abundant. Several hardwoods, including red maple (*Acer rubrum*), paper birch (*Betula papyrifera*), bigtooth aspen (*Populus grandidentata*), and quaking aspen (*P. tremuloides*) may occur as seedlings or stunted saplings. Trees are absent or rare on low, poorly defined strings subject to flooding and long periods of saturation (Grittinger 1970, Glaser et al. 1981, 1990, Foster and King 1984, Foster et al. 1988, MNFI 2010).

Shrubs are an important and often dominant component of strings (Heinselman 1965, Glaser et al. 1981, 1990, Glaser 1992b, Cohen et al. 2009, NatureServe 2009, MNFI 2010). Characteristic tall shrubs are tag alder (*Alnus rugosa*), black chokeberry (*Aronia prunifolia*), bog birch (*Betula pumila*), red-osier dogwood (*Cornus stolonifera*), Michigan holly (*Ilex verticillata*), mountain holly (*Nemopanthus mucronatus*), swamp rose (*Rosa palustris*), and wild-raisin (*Viburnum cassinoides*). Low shrubs are represented by a diversity of species, including many ericads (Ericaceae), and typically occur in greater density than the tall shrubs. Characteristic species are bog rosemary (*Andromeda glaucophylla*), leatherleaf (*Chamaedaphne calyculata*), creeping snowberry (*Gaultheria hispidula*), Kalm's St. John's-wort (*Hypericum kalmianum*), swamp-laurel (*Kalmia polifolia*), Labrador-tea (*Ledum groenlandicum*), fly honeysuckle (*Lonicera villosa*), sweet gale (*Myrica gale*), shrubby cinquefoil (*Potentilla fruticosa*; particularly characteristic of mineral-rich sites), alder-leaved buckthorn (*Rhamnus alnifolia*), swamp dewberry (*Rubus hispidus*), dwarf raspberry (*R. pubescens*), bog willow (*Salix pedicellaris*), balsam willow (*S. pyrifolia*), meadowsweet (*Spiraea alba*), low sweet blueberry (*Vaccinium angustifolium*), Canada blueberry (*V. myrtilloides*), and small cranberry (*V. oxycoccos*).

The ground cover of strings is dense with several characteristic graminoids, forbs, and ferns that occur with low shrubs or as the dominant cover (Heinselman 1965, Glaser et al. 1981, 1990, Foster and King 1984, Madsen 1987, Glaser 1992b, Cohen et al. 2009, NatureServe 2009, MNFI 2010). Characteristic species include wood anemone (*Anemone quinquefolia*), dragon's mouth (*Arethusa bulbosa*), northern bog aster (*Aster borealis*), bog aster (*A. nemoralis*), tall flat-top white aster (*A. umbellatus*), bluejoint grass (*Calamagrostis canadensis*), Buxbaum's sedge (*Carex buxbaumii*), star sedge (*C. echinata*), coastal sedge (*C. exilis*), wiregrass sedge (*C. lasiocarpa*), bog sedge (*C. limosa*), few-seed sedge (*C. oligosperma*), dioecious sedge (*C. sterilis*), tussock sedge (*C. stricta*), goldthread (*Coptis trifolia*), round-leaved sundew (*Drosera rotundifolia*), water horsetail (*Equisetum fluviatile*), green-keeled cotton-grass (*Eriophorum viridi-carinatum*), wild blue flag (*Iris versicolor*), swamp candles (*Lysimachia terrestris*), marsh wild-timothy (*Muhlenbergia glomerata*), royal fern (*Osmunda regalis*), pitcher-plant (*Sarracenia purpurea*), false mayflower (*Smilacina trifolia*), bog goldenrod (*Solidago uliginosa*), purple meadow rue (*Thalictrum dasycarpum*), marsh fern (*Thelypteris palustris*), marsh St. John's-wort (*Triadenum fraseri*), Alpine bulrush (*Trichophorum alpinum*), tufted bulrush (*T. cespitosum*), and starflower (*Trientalis borealis*).


Photo by Joshua G. Cohen

The strings are comprised of slightly raised ridges of peat and are dominated by sphagnum mosses, sedges, forbs, and small shrubs.

Several species of bryophytes are characteristic of strings, and often comprise significant cover on these features in addition to a significant proportion of the upper peat layer (Wheeler et al. 1983, Sorenson 1986, Moore 1989, Glaser et al. 1990, Janssens 1992, MNFI 2010). Strings typically display a vertical zonation of bryophyte species (Wheeler et al. 1983). Characteristic species of lower and middle portions of strings include *Sphagnum angustifolium*, *S. capillifolium*, *S. magellanicum*, *S. recurvum*, and occasionally *S. warnstorfii*. The upper portions of strings and hummocks, which can be highly acidic due to isolation from groundwater, may support *S. fuscum* and juniper polytrichum moss (*Polytrichum juniperinum*) (Wheeler et al. 1983, Crum 1988). The ericaceous low shrubs found on strings can promote rapid vertical growth of sphagnum species that can utilize the physical support of shrub branches and adventitious roots as "scaffolding" (Asada et al. 2005, Fenton et al. 2005). Low, wet strings and strings that are impacted by frequent fires or significant hydrologic fluctuation may have lower importance of bryophytes (Madsen 1987, Laitinen et al. 2008).

(*Potentilla palustris*), white beak-rush (*Rhynchospora alba*), beak-rush (*R. fusca*), pitcher-plant, arrow-grass (*Scheuchzeria palustris*), common bog arrow-grass (*Triglochin maritimum*), and large cranberry (*Vaccinium macrocarpon*). Several of these species also occur on strings, but in lower densities. The presence of calciphiles, including twig-rush, Kalm's lobelia (*Lobelia kalmii*), and false asphodel (*Tofieldia glutinosa*) indicates sites significantly influenced by mineral-rich groundwater (MNDNR 2003, MNFI 2010). Inundated flarks support submergent vegetation, such as yellow pond-lily (*Nuphar variegata*), sweet-scented water-lily (*Nymphaea odorata*), bulrush (*Schoenoplectus subterminalis*), horned bladderwort (*Utricularia cornuta*), flat-leaved bladderwort (*U. intermedia*), and great bladderwort (*U. vulgaris*).

Photo by Bradford S. Slaughter

The flarks consist of level areas or hollows between slightly elevated strings and are dominated by sedges and rushes or support open water and submergent vegetation.

Photo by Bradford S. Slaughter

Inundated flarks support submergent vegetation, such as yellow pond-lily (*Nuphar variegata*), sweet-scented water-lily (*Nymphaea odorata*), and bladderworts (*Utricularia* spp.).

In contrast to strings, flarks are characterized by patchy or low vegetative cover and an absence or near-absence of shrubs and trees (Heinselman 1965, Glaser et al. 1981, 1990, Foster and King 1984, Sorenson 1986, Madsen 1987, Glaser 1992b, Cohen et al. 2009, NatureServe 2009, MNFI 2010). Characteristic species include coastal sedge, wiregrass sedge, bog sedge, livid sedge (*Carex livida*), few-seed-sedge, twig-rush (*Cladium mariscoides*), spoon-leaf sundew (*Drosera intermedia*), three-way sedge (*Dulichium arundinaceum*), golden-seeded spike-rush (*Eleocharis elliptica*), wild blue flag, Canadian rush (*Juncus canadensis*), bog buckbean (*Menyanthes trifoliata*), small green wood orchid (*Platanthera clavellata*), rose pogonia (*Pogonia ophioglossoides*), marsh cinquefoil

Bryophytes are typically of low importance in flarks, but are represented by several species, including aulacomnium moss (*Aulacomnium palustre*), calliergon moss (*Calliergon trifarium*), campylium moss (*Campylium polygamum*), star campylium moss (*C. stellatum*), dicranum moss (*Dicranum undulatum*), drepanocladus mosses (*Drepanocladus* spp.), polytrichum moss (*Polytrichum strictum*), scorpidium moss (*Scorpidium scorpioides*), several sphagnum mosses (e.g., *Sphagnum angustifolium*, *S. cuspidatum*, *S. majus*, *S. magellanicum*, *S. papillosum*, *S. recurvum*, *S. subsecundum*, and *S. teres*), and several liverworts (including *Calypogeia* spp., *Cephalozia* spp., *Kurzia setacea*, and *Mylia anomala*) (Wheeler et al. 1983, Madsen 1987, Crum 1988, Janssens 1992). Flarks also support numerous unicellular and multicellular algae, particularly species in the family Desmidiaceae (Madsen 1987).

In addition to supporting well-defined ribbed fen, water tracks support areas of poorly differentiated strings and flarks and "featureless" open fen that lacks ribbed patterning (Heinselman 1963, Foster and King 1984, Sorenson 1986, Glaser 1992a). These areas of modestly patterned and unpatterned fen occur in the upper, younger portions of expanding water tracks, in areas of relatively low relief, and in areas where expansion and coalescence of flarks and pools has degraded peat on adjacent strings, reducing them to isolated hummocks of low relief (Glaser et al. 1981, Foster et al. 1983, 1988, Foster and King 1984, Sorenson 1986, Glaser 1992c). Low, poorly defined strings and unpatterned open fen are characterized by very low shrub cover, an absence or near-absence of trees, and dominance by graminoids, including coastal sedge, wiregrass sedge, and tufted bulrush (Foster and King 1984, Glaser 1992b, MNFI 2010). Strongly acidic fen "lawns" may be dominated by few-seed sedge, which may be associated with coastal sedge in depressions or few-flower sedge (*Carex pauciflora*) on sphagnum peat. Other species characteristic of modestly patterned or unpatterned fen include bog aster, bluejoint grass, twig-rush, bog sedge, white beak-rush, beak-rush, and arrow-grass (Foster and King 1984, Sorenson 1986, Glaser 1992b, Cohen et al. 2009, MNFI 2010).

Shallow seasonal pools often develop where the movement of groundwater is impeded by islands of mineral soil (Heinselman 1965, MNFI 2010). The underlying peats in these areas are typically thin and are subject to significant seasonal fluctuation of the water table, which can result in the desiccation of surface peats (Laitinen et al. 2008). Seasonal pools often exhibit a crescent or horseshoe shape on aerial photographs (Cohen et al. 2009). These intermittent wetlands support patchy growth of a limited number of graminoids and forbs, including ticklegrass (*Agrostis hyemalis*), bog sedge, twig-rush, English sundew (*Drosera anglica*, state special concern), spoon-leaf sundew, three-way sedge, spike-rush (*Eleocharis palustris*, also known as *E. smallii*), Canadian rush, brown-fruited rush (*Juncus pelocarpus*), bog buckbean, yellow pond-lily, white beak-rush, beak-rush, arrow-grass, bur-reeds (*Sparganium* spp.), great bladderwort, and large cranberry (Heinselman 1965, Cohen and Kost 2007c, Kost et al. 2007, Cohen et al. 2009, MNFI 2010). Most sphagnum mosses are absent or stressed in these areas of unstable hydrology (Laitinen et al. 2008).

Photo by Joshua G. Cohen

Northern wet meadow occurs as a zone within some patterned fen complexes, where it is concentrated at the margins of the peatlands adjacent to upland and lowland forests, along streams, and in areas impacted by beaver activity.

Northern wet meadow occurs as a zone within some patterned fen complexes, where it is typically concentrated at the margins of the peatlands adjacent to upland and lowland forests, along streams, and in areas impacted by beaver activity (Cohen and Kost 2007a, Kost et al. 2007, Cohen et al. 2009, MNFI 2010). This zone occurs on deep to shallow sapric peat over medium-textured sands, and is dominated by lake sedge (*Carex lacustris*), tussock sedge, and bluejoint grass. Other characteristic species include tag alder, marsh bellflower (*Campanula aparinoides*), beaked sedge (*Carex utriculata*), marsh pea (*Lathyrus palustris*), tufted loosestrife (*Lysimachia thyrsiflora*), common skullcap (*Scutellaria galericulata*), and, locally, sweet coltsfoot (*Petasites sagittatus*, state threatened). Former beaver floodings, which typically occur in the vicinity of streams, support low diversity wet meadows characterized by few-seed sedge, three-way sedge, Canadian rush, marsh cinquefoil, and northern St. John's-wort (*Hypericum boreale*) (Cohen et al. 2009, MNFI 2010). These areas grade into intermittent wetlands where they occur on shallow peats and experience seasonal soil desiccation.

Dry northern forest and dry-mesic northern forest on acidic sands occur on "fossil" dune ridges in some patterned fens (Heinselman 1965, Cohen 2002a, 2002b, Kost et al. 2007, Cohen et al. 2009, MNFI 2010). These dune ridges are projected 1 to 3 m (3 to 10 ft) above the peat surface, and average 18 by 60 m (60 by 200 ft) in size (Heinselman 1965). Characteristic tree species include red pine, white pine, jack pine, and black spruce, the latter especially on low dunes. The subcanopy is open to patchy, and consists of pine saplings, black spruce, red maple, paper birch, quaking aspen, and bigtooth aspen. Characteristic low shrubs and ground layer species include Pennsylvania sedge (*Carex pensylvanica*), bunchberry (*Cornus canadensis*), wintergreen (*Gaultheria procumbens*), huckleberry (*Gaylussacia baccata*), rough-leaved rice grass (*Oryzopsis asperifolia*), bracken fern (*Pteridium aquilinum*), starflower, low sweet blueberry, and Canada blueberry. For additional species characteristic of dry northern forest and dry-mesic northern forest, see Cohen (2002a, 2002b) and Kost et al. (2007).


Photo by Bradford S. Slaughter

Scattered "fossil" dune ridges within patterned fens support pine-dominated dry-mesic northern forest and dry northern forest.

Water tracks supporting patterned fen are often separated by bands of tall shrubs and trees that are oriented parallel to the direction of water flow and perpendicular to the orientation of the strings and flarks. These bands of vegetation occur either as extensions of shrub-and tree-dominated wetlands upslope of the patterned fen complex or as long, tapered "tails" immediately downslope of isolated dune ridges within the peatland, where they develop in response to impeded water flow and increased nutrient inputs from the adjacent mineral soils (Heinselman 1963, 1965, 1970, Glaser et al. 1981, Crum 1988, Glaser 1992a, 1992b, 1992c, Cohen et al. 2009, MNFI 2010). Tree- and shrub-dominated "tails" range from less than 50 m to greater than 300 m in width, and may be several kilometers in length in the largest peatlands (MNFI 2010). Characteristic tree species of northern shrub thicket and rich conifer swamp that establish in these "tails" include tamarack, northern white-cedar, black spruce, red maple, and quaking aspen. Trees tend to be concentrated in the upslope portions of the tails; increased water flow in the downslope portions of the tails due to the convergence of adjacent water tracks restricts the growth of trees and favors tall shrubs, primarily tag alder, Michigan holly, bog birch, and red-osier dogwood (Glaser et al. 1981, Glaser 1992c, Cohen et al. 2009, MNFI 2010). Periodic wildfires that kill trees also promote dominance of "tails" by tall shrubs (Madsen 1987, MNFI 2010). Other species characteristic of shrub- or tree-dominated zones include bog rosemary, tall flat-top white aster, blue-joint grass, lake sedge, tussock sedge, three-seeded sedge (*Carex trisperma*), leatherleaf, Labrador tea, royal fern, swamp dewberry, rough goldenrod (*Solidago rugosa*), and marsh fern.


Photo by Bradford S. Slaughter

Water tracks supporting patterned fen (foreground) are often separated by bands of tall shrubs and trees (background) that are oriented perpendicular to the orientation of the strings and flarks.

Especially noteworthy is the lack of ombrotrophic raised bogs within Michigan's patterned peatlands. The lack of these bog features limits the development and importance of ombrotrophic vegetation in patterned fen. However, patterned fen is sometimes associated with broad, flat expanses of muskeg that presumably develop following accumulation of acidifying sphagnum mosses on fibric peat soils. These muskegs are dominated overwhelmingly by few-seed sedge, associated with clumps of ericaceous shrubs (e.g., bog rosemary, leatherleaf, and swamp laurel) and scattered tamarack, black spruce, and jack pine (Cohen et al. 2009, MNFI 2010).

Photo by Bradford S. Slaughter

The state endangered dwarf raspberry (*Rubus acaulis*) occurs at the margins of patterned fens, where it is concentrated on low, moist hummocks.

Rare Plants Associated with Patterned Fen (E, Endangered; T, Threatened; SC, species of special concern).

Scientific Name	Common Name	State Status
Amerorchis rotundifolia	round-leaved orchis	E
Bartonia paniculata	panicled screw-stem	T
Carex heleonastes	Hudson Bay sedge	E
Carex novae-angliae	New England sedge	T
Carex wiegandii	Wiegand's sedge	SC
Drosera anglica	English sundew	SC
Gentiana linearis	narrow-leaved gentian	T
Juncus stygius	moor rush	T
Petasites sagittatus	sweet coltsfoot	T
Rubus acaulis	dwarf raspberry	E

Rare Animals Associated with Patterned Fen (E, Endangered; T, Threatened; SC, species of special concern; LE, Federally Endangered).

Scientific Name	Common Name	State Status
Alces americanus	moose	SC
Asio flammeus	short-eared owl	E
Boloria freija	freija fritillary	SC
Boloria frigga	frigga fritillary	SC
Botaurus lentiginosus	American bittern	SC
Canis lupus	gray wolf	T; LE*
Circus cyaneus	northern harrier	SC
Emydoidea blandingii	Blanding's turtle	SC
Erebia discoidalis	red-disked alpine	SC
Falcipennis canadensis	spruce grouse	SC
Falco columbarius	Merlin	T
Somatochlora incurvata	incurvate emerald	SC
Tympanuchus phasianellus	sharp-tailed grouse	SC
Williamsonia fletcheri	ebony boghaunter	SC

* Gray wolf populations in all of Michigan and Wisconsin, the eastern half of North Dakota and South Dakota, the northern half of Iowa, the northern portions of Illinois and Indiana, and the northwestern portion of Ohio are federally listed as endangered (USFWS 2010).

Noteworthy Animal Species: Beaver have contributed to the development of peatlands by blocking and slowing drainage of level landforms and initiating paludification (Heinselman 1963, 1970, Crum 1988). The replacement of swamp forest by sedge meadow and fen evident in the stratigraphy of some peatlands may have been facilitated or caused by beaver flooding (Heinselman 1963). Beaver can build dams on streams and ditches that drain patterned fen, raising water levels and killing trees and other plants not able to tolerate rising water levels or adapted to prolonged flooding (Bradof 1992a). Beaver are prevalent in unditched portions of some Michigan patterned fen complexes, where they alter surface hydrology, chemistry, and vegetation (Cohen et al. 2009, MNFI 2010). The development of drainage ditches and subsequent tree establishment provided beaver new dam sites in areas that previously lacked suitable woody vegetation for their construction (Heinselman 1963, Berg 1992, Bradof 1992a).

Photo by Bradford S. Slaughter

Interconnected pools in this patterned fen are associated with beaver activity.

Insects and parasites in patterned fens can limit tree survival. Outbreaks of larch sawfly (*Pristiphora erichsonii*) and larch casebearer (*Coleophora laricella*) cause heavy mortality of tamarack (Beckwith and Drooz 1956, Graham 1956, Curtis 1959, Tilton 1977, Girardin et al. 2005), while black spruce is attacked by spruce budworm (*Choristoneura fumiferana*) and the plant parasite dwarf mistletoe (*Arceuthobium pusillum*) (Coburn et al. 1933, Gates 1942, Curtis 1959, Newton and Jolliffe 1998). Larch sawfly outbreaks tend to be more severe on better-drained sites due to the restrictions on sawfly development and survival imposed by a high water table (Girardin et al. 2005). Insect outbreaks are most likely to impact patterned fens with relatively high importance of conifers, including sites with pronounced, relatively well-aerated strings.

Patterned fens provide habitat for numerous marsh and grassland birds, including several species listed in Michigan's Wildlife Action Plan as Species of Greatest Conservation Need (SGCN) (Eagle et al. 2005). Declining wetland and grassland birds such as Le Conte's sparrow (*Ammodramus leconteii*), American bittern, northern harrier, sedge wren (*Cistothorus platensis*), bobolink (*Dolichonyx oryzivorus*), savannah sparrow (*Passerculus sandwichensis*), and sharp-tailed grouse nest and forage in the vast, sedge-dominated wetlands in Upper Michigan, including patterned fen (Brewer et al. 1991, Niemi and Hanowski 1992, Eagle et al. 2005, Cohen et al. 2009, MNFI 2010). Spruce grouse nest in the conifer-dominated scattered dune ridges within peatlands, and feed on low sweet blueberry and Canada blueberry, which are prevalent on sandy soils on these ridges and in adjacent uplands (Brewer et al. 1991, Eagle et al. 2005). Dune ridges also support merlins, which nest in tall white and red pines, and hunt small birds in the surrounding peatland (Brewer et al. 1991, Cuthrell 2002, Eagle et al. 2005, Cohen et al. 2009, MNFI 2010). Where patterned fens are near lakes and large rivers, bald eagles and ospreys may nest in tall trees (especially white pine) on dune islands or adjacent uplands (Brewer et al. 1991).

Conservation and Biodiversity Management:
Patterned fen is imperiled in Michigan and its status is unknown globally (Kost et al. 2007, NatureServe 2009). Patterned fens provide habitat for a unique suite of plants, including several rare species that occur primarily in the community, and a wide variety of animal species (Wheeler et al. 1983, Berg 1992, Glaser 1992b, Karns 1992, Niemi and Hanowski 1992, Nordquist 1992, Kost et al. 2007, MNFI 2010). The remains of plants and animals and atmospheric particles stored in fen peats allow for the elucidation of historic climatic patterns and enhance our understanding of the processes that led to the development of current vegetation patterns. Patterned fens also sequester and store atmospheric carbon; boreal and subarctic peatlands are estimated to contain between 270 and 370 Pg of carbon (1 Pg = 10^{15} g) (Turunen et al. 2002, Huttunen et al. 2003). The tremendous amount of carbon stored in peatlands highlights their importance in global geochemical cycles. Given the rarity of patterned fen and the potential threats to this community type, patterned fens are moderate to high priorities for stewardship and monitoring activity, depending on the severity of the threats within individual sites (Cohen et al. 2009).

Protection of groundwater and surface water hydrology is critical to the conservation of patterned fens. Where hydrologic regimes remain intact, patterned fens tend to be resistant to encroachment by woody vegetation. Disturbances that alter natural hydrology, including the construction of ditches, roads, and trails, and incursions onto the peat surface by off-road vehicle traffic, can alter rates of peat accumulation and/or decay and cause shifts in peatland vegetation structure and composition (Glaser et al. 1981, Bradof 1992a, Glaser 1992c, Laitinen et al. 2008). Reduced water tables allow shrubs and trees to colonize areas of open fen, potentially leading to the conversion of patterned fen to swamp forest. Increased growth of shrubs and trees on drain spoils and adjacent ground and along roads is evident in several Michigan occurrences of patterned fen (Cohen et al. 2009, MNFI 2010). For example, one year following the Sleeper Lake fire in Luce County, black chokeberry had established in significant densities on the rolled-up peat adjacent to a burn line plowed into the open peatland (Cohen et al. 2009). Drainage can also cause the drying of flarks, which facilitates a transition from species that require inundated conditions to species less tolerant of inundation (Glaser et al. 1981). Over time, the flarks in ditched water tracks shrink in size while the strings expand and coalesce, eventually obscuring the original patterning (Glaser et al. 1981)[1]. Land

[1] The expansion of strings and contraction of flarks in ditched patterned fens is a key piece of evidence for the role of seasonal flooding and pooling of water in causing the development and expansion of flarks at the expense of strings (Glaser et al. 1981, Glaser 1992c).

managers should consider destroying ditches and other impediments to natural water flow in hydrologically altered peatlands, and should avoid upslope logging or other developments that may result in increased or reduced runoff to the peatland.

Photo by Bradford S. Slaughter

This road has altered the flow of surface water and groundwater, resulting in the drying of peat on one side of the road (right) and the conversion of open fen to rich conifer swamp.

Photo by Joshua G. Cohen

This fire line within the Sleeper Lake peatland was ineffective at preventing the spread of wildfire and has altered the surface hydrology and chemistry of the fen. The rolled-up peat mounds adjacent to the fire line now support dense growth of black chokeberry (*Aronia prunifolia*).

Monitoring and control efforts to detect and remove invasive species before they become widespread are critical to the long-term viability of patterned fen. In addition to narrow-leaf cat-tail, hybrid cat-tail, and reed, invasive species that may threaten diversity and community structure of patterned fen include purple loosestrife (*Lythrum salicaria*), reed canary grass (*Phalaris arundinacea*), glossy buckthorn (*Rhamnus frangula*), and multiflora rose (*Rosa multiflora*) (Kost et al. 2007). Surveys of potential conduits of these species, including roads, logging trails, and ditches, should be conducted to detect initial invasions of these species before they spread to interior portions of the peatland. Hydrologic alteration to patterned fens is likely correlated with the threat of invasive species. Recent surveys of several patterned fen occurrences revealed that invasive species are uncommon to absent at the present time, and, when they do occur, they are confined to the margins and along linear disturbances, such as roads and drainage ditches (Cohen et al. 2009, MNFI 2010).

Wildfires are a significant component of the natural disturbance regime for patterned fens, particularly those associated with fire-adapted upland communities, such as dry northern forest and dry-mesic northern forest. Fires that establish and remain within patterned fens should be allowed to burn unhindered. In addition, plow lines should be established in the surrounding uplands rather than in the peatlands, as they can alter surface hydrology and chemistry, serve as conduits for invasive species, and have failed to function to prevent the spread of fires (Cohen et al. 2009)[2]. Wherever feasible, existing fire lines in the surrounding uplands, roads, and wetlands should be used to limit the spread of fires. Prescribed fires should be considered for patterned fens that are impacted by shrub and tree invasion, and for fens in particularly fire-suppressed landscapes that are unlikely to naturally ignite. The apparent wide variation in fire cycles among sites urges caution in the frequency of use of this management tool (Madsen 1987, Drobyshev et al. 2008). Prescribed fires should be implemented based on local historical fire return intervals and fire cycles (Drobyshev et al. 2008), and the impacts of these fires on vegetative structure and composition should be carefully monitored.

Research Needs: Patterned fen has a broad distribution and exhibits subtle regional, physiographic, hydrologic, and edaphic variants. The lack of a universally accepted

[2] Following the Sleeper Lake Fire, all fire lines surveyed within the peatlands were ineffective at stopping the fire. Along every stretch of fire line, the fire had burned on both sides of the line, either blowing over the top of the line via wind-blown flames or creeping under the line via a deep peat burn (Cohen et al. 2009).

classification of peatlands and the considerable variability across their range demands the continual refinement of regional classifications of patterned fens (Heinselman 1963, 1970, Glaser et al. 1981, Foster and King 1984, Foster et al. 1988, Glaser et al. 1990, Glaser 1992a, 1992b, 1992c, Charman 1993, Sperduto et al. 2000, Davis and Anderson 2001, Laitinen et al. 2008, NatureServe 2009). Patterned fen is associated with several related wetland communities, and research on the abiotic and biotic indicators and factors that help distinguish these community types will improve our understanding of the relationship among peatland communities. Systematic surveys for patterned fen should be conducted to ascertain the full distribution and extent of the community in Michigan. Recent field surveys revealed the presence of patterned fen in the western Upper Peninsula (Cohen 2009); the community was previously thought to be restricted to eastern Upper Michigan (Kost et al. 2007, MNFI 2010). The importance of patterned fens for mammals, birds, amphibians, reptiles, and insects is incompletely understood, emphasizing the importance of comprehensive surveys of all peatland taxa.

The Sleeper Lake Fire offers a unique opportunity to research the impact of fire on a peatland ecosystem. The impacts of the nearby plow lines on peatland hydrology and invasive species populations should be carefully monitored. Continued research of fire return intervals and fire cycles in patterned fens should be conducted to better understand the development and succession of these peatlands, and to inform conservation and biodiversity management. Site-specific fire frequencies can be estimated by investigating fossil pollen and charcoal in peat profiles and by analyzing tree ring data for fire scars on embedded uplands (Heinselman 1963, 1970, Glaser et al. 1981, Madsen 1987, Drobyshev 2008). The use of prescribed fire should be considered, and any implementation of prescribed fire should be followed with monitoring to detect impacts on the peatlands. Research on techniques to restore hydrology in altered peatlands should be conducted to ascertain the best methods for restoring natural flow regimes. The complicated interaction of surface water, groundwater, and precipitation should be explored to improve understanding of the hydrology of Michigan's patterned fens. To date, the only comprehensive

Photo by Bradford S. Slaughter

Recent field surveys revealed the occurrence of patterned fen in the western Upper Peninsula in Keweenaw County.

study of this natural community in Michigan is an unpublished Doctoral dissertation (Madsen 1987). Therefore, any research pertaining to the physiography, natural processes, and vegetation of patterned fen will be a substantial contribution to our understanding of patterned fen, and may elucidate similarities and differences in these attributes between Michigan and other regions that support the community. As noted earlier, further studies are needed across the range of patterned fens to determine how complex biotic, chemical, and physical interactions cause and modify fen patterns.

Of particular interest is research on the importance of Michigan's peatlands in the global biogeochemical cycle. Boreal and subarctic peatlands store a tremendous amount of carbon; carbon is accumulated when sequestration by peatland vegetation exceeds loss through decomposition, leaching, or fire (Huttunen et al. 2003). Temperature increases predicted by climate change models suggest an increase in evapotranspiration relative to precipitation, which may facilitate shifts in carbon exchange between the peatlands and the atmosphere (Hargreaves et al. 2001, Mäkilä et al. 2001, Heikkinen et al. 2002). However, regional variation of the impacts of climate change on precipitation, spatial heterogeneity of peatland surfaces, and the present status of some peatlands as carbon sinks and some as carbon sources limits our ability to predict the overall impacts of climate change on carbon cycling between peatlands and the atmosphere (Moore 1989, Rivers et al. 1998, Waddington and Roulet 2000, Hargreaves et al. 2001, Heikkinen et al. 2002, Rask et al. 2002, Turunen et al. 2002, Benoy et al. 2007). Studies exploring the carbon budgets of Michigan peatlands would improve our ability to predict the impacts of warming on carbon fluxes, and may lead to a better understanding of the potential threats posed to patterned fens and associated peatlands by climate change. Patterned fens and other peatlands are also threatened by the atmospheric

Photo by Joshua G. Cohen

Peatlands such as patterned fen store a tremendous amount of carbon, which highlights the importance of these systems in global biogeochemical cycles. Studies exploring the carbon budgets of Michigan peatlands may lead to a better understanding of the potential threats posed to patterned fens by climate change.

deposition of nutrients and acidifying agents, highlighting the importance of research on the specific effects of anthropogenic air pollution on peat chemistry and vegetation (Heinselman 1970, Bedford et al. 1999, Gunnarsson et al. 2000, Mitsch and Gosselink 2000).

Similar Communities: Patterned fen is one of several peatland types that occur in northern Michigan (see Kost et al. 2007 and Albert et al. 2008). Other fen communities in this region that lack distinctive patterning include *northern fen*, a minerotrophic shrub- or graminoid-dominated peatland (Cohen and Kost 2008a) and *poor fen*, a slightly minerotrophic shrub- or graminoid-dominated peatland (Cohen and Kost 2008b). Both communities occur within flat areas or shallow depressions of glacial outwash and glacial lakeplains and in kettle depressions on pitted outwash and moraines. Within larger peatland complexes, northern fen and poor fen can occur in association with patterned fen, often in featureless water tracks, and are often included within the patterned fen mapping unit, as patterned fen is treated as a broad peatland complex (Kost et al. 2007, MNFI 2010). Ombrotrophic peatland communities in northern Michigan include *muskeg*, which occurs on acidic sphagnum peat in broad, poorly drained outwash plains and lakeplain (Cohen 2006a), *bog*, which occurs in kettle depressions on pitted outwash and moraines and in flat areas and shallow depressions on glacial outwash and glacial lakeplains (Cohen and Kost 2008c), and *poor conifer swamp*, a forested bog community (Cohen 2006b). These communities can be differentiated from patterned fen based on hydrology, substrate, vegetative composition, and other factors (Kost et al. 2007), and may occur at the margins of patterned fen complexes (MNFI 2010).

Several other wetland communities are associated with patterned fen. *Northern wet meadow* is a minerotrophic, graminoid-dominated wetland that occurs on shallow sapric peat or hydric mineral soils that often occurs as a zone within the patterned fen complex (Cohen and Kost 2007a, Cohen et al. 2009, MNFI 2010). *Northern shrub thicket* is a shrub-dominated wetland community that occurs as bands within patterned fen complexes (Cohen and Kost 2007b). *Rich conifer swamp*, a minerotrophic swamp forest, is also associated with tear-drop islands, and often borders patterned fen (Kost 2002, Cohen et al. 2009, MNFI 2010). Groundwater recharge zones within patterned fen complexes may support *intermittent wetland* (Laitinen et al. 2005, Cohen and Kost 2007c, Cohen et al. 2009). Streambanks and beaver-flooded areas may support *emergent marsh* or *submergent marsh* (Kost et al. 2007).

Upland communities associated with patterned fen include *dry northern forest* and *dry-mesic northern forest* on fire-prone "fossil" dune ridges (Cohen 2002a, 2002b, Cohen et al. 2009), and *mesic northern forest* on moraines adjacent to the lakeplain and outwash plain landforms that support open peatlands (Cohen 2000). Broad interdunal swales within *wooded dune and swale complexes* (Albert and Comer 1999) occasionally develop patterning, as at Whitefish Point in Chippewa County (MNFI 2010).

Photo by Bradford S. Slaughter

A broad swale in the sand-spit complex at Whitefish Point supports strings and flarks.

Other Classifications:

Michigan Natural Features Inventory Land Cover Mapping Code: 6124 (Patterned Peatland)

MNFI circa 1800 Vegetation: Bog or muskeg; Mixed conifer swamp

Michigan Resource Information Systems (MIRIS): 612 (Shrub/Scrub Wetland); 62 (non-forested wetland)

Michigan Department of Natural Resources (MDNR): V (Bog or Muskeg); N (Marsh)

MDNR IFMAP (MDNR 2001): Mixed Non-Forest wetland; Lowland Shrub

NatureServe U.S. National Vegetation Classification and International Classification of Ecological Communities (Faber-Langendoen 2001, NatureServe 2009):

CODE; SYSTEM

CES201.585; Laurentian-Acadian Alkaline Fen

CES201.583; Boreal-Laurentian-Acadian Acidic Basin Fen

CODE; ALLIANCE; ASSOCIATION; COMMON NAME

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

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

III.B.2.N.g; *Betula pumila* – (*Salix* spp.) Saturated Shrubland Alliance; *Larix laricina* / *Chamaedaphne calyculata* / *Carex lasiocarpa* Shrubland; Tamarack Scrub Poor Fen

IV.A.1.N.g; *Chamaedaphne calyculata* Saturated Dwarf-shrubland Alliance; *Chamaedaphne calyculata* / *Carex oligosperma* / *Sphagnum* spp. Poor Fen Dwarf-shrubland; Leatherleaf Poor Fen

V.A.5.N.m; *Carex lasiocarpa* Saturated Herbaceous Alliance; *Carex lasiocarpa* – *Trichophorum caespitosum* – *Rhynchospora capillacea* / *Andromeda polifolia* Herbaceous Vegetation; Boreal Extremely Rich Seepage Fen

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

V.A.5.N.m; *Carex oligosperma* – *Carex lasiocarpa* Saturated Herbaceous Alliance; *Carex lasiocarpa* – *Carex oligosperma* / *Sphagnum* spp. Herbaceous Vegetation; Northern Sedge Poor Fen

Other states and Canadian provinces (natural community types with strongest similarity to Michigan patterned fen indicated in *italics*):

MN: *Northern rich fen (water track)*; *Northern extremely rich fen*; Northern poor fen (MNDNR 2003)
WI: *Patterned peatland*; Boreal rich fen; Poor fen (Epstein et al. 2002)
ON: *Open fen ecosite; Shrub fen ecosite* (Lee et al. 1998)
NY: *Patterned peatland*; Rich graminoid fen; Rich shrub fen; Medium fen; Inland poor fen (Edinger et al. 2002)
NH: *Circumneutral – calcareous flark*; *Northern white cedar circumneutral string*; *Liverwort – horned bladderwort mud-bottom* (Sperduto et al. 2000, Sperduto and Nichols 2004)
ME: *Shrubby cinquefoil – sedge circumneutral fen*; Low sedge – buckbean fen lawn; Leatherleaf boggy fen; Sedge – leatherleaf fen lawn (Gawler and Cutko 2004)

Related Abstracts: bog, dry northern forest, dry-mesic northern forest, emergent marsh, intermittent wetland, muskeg, northern fen, northern shrub thicket, northern wet meadow, poor conifer swamp, poor fen, rich conifer swamp, submergent marsh, wooded dune and swale complex, Freija fritillary, northern harrier, Blanding's turtle, red-disked alpine, spruce grouse, merlin, incurvate emerald, sharp-tailed grouse, round-leaved orchis, panicled screw-stem, English sundew, sweet coltsfoot.

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Photo by Bradford S. Slaughter

Dragon's mouth (*Arethusa bulbosa*), one of the characteristic orchids of patterned fens, flowers in June.

Photo by Joshua G. Cohen

Ribbed patterning in this fen is highlighted by late afternoon sunlight.

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