

14770

Boreal Acidic Peatland Systems

BpS Model/Description Version: Aug. 2020

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Reviewed by: Brad Slaughter

Vegetation Type

Woody Wetland

Map Zones

40, 41, 50, 51

Model Splits or Lumps

This BpS is lumped with: 1479 (Central Interior and Appalachian Swamp Systems), 1481 (Laurentian-Acadian Alkaline Conifer-Hardwood Swamp)

Geographic Range

This system occurs in MI's Upper Peninsula, northern lower MI, MN and WI. It can also be found in scattered location in southern MI and the central sand plains and Lower Lake Michigan coastal areas of WI. It also occurs in NY and New England in small bogs. Occurs in 212 (all), 222 (R all), 222 (Kb,Kc,Ke), 222 (J all) and 222 (Ud, Ua).

Within Hiawatha National Forest (Section 212R), open bog and muskeg are interpreted to have covered ca. 18,000 ha (44,000 ac) at the time of the General Land Office Surveys (Comer et al. 1995), although this number is a significant underestimate because extensive areas of muskeg were interpreted and mapped as Mixed Conifer Swamp. Mixed Conifer Swamp, which includes both acidic (e.g., poor conifer swamp, muskeg) and minerotrophic (e.g., rich conifer swamp) cover types, historically covered ca. 324,000 ha (800,000 ac) of the HNF (Comer et al. 1995). At present, acid peatlands are especially prevalent in central and western Chippewa County and in north-central Delta County.

Biophysical Site Description

Peatlands develop in humid climates where precipitation exceeds evapotranspiration (Gignac et al. 2000, Halsey and Vitt 2000, Boelter and Verry 1977). 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 (Mitsch and Gosselink 2000, Damman 1990, Boelter and Verry 1977, Gates 1942). Two landscape features are conducive to the development of peat; small ice-block basins and poorly-drained, level terrain such as proglacial outwash plains and glacial lakeplain (Boelter and Verry 1977; Comer et al. 1995; Cohen 2006). Peatlands occurring on former glacial lake beds and drainageways tend to be more extensive than kettle peatlands, which are limited in area by the size of the glacial ice-block that formed the basin (Lindeman 1941). Peatlands range in size from a few thousand square meters to several thousand hectares (Futyma and Miller

1986). The overall topography of peatlands is flat to gently undulating with microtopography characterized by hummocks and hollows (NatureServe 2006, Locky et al. 2005, Bubier 1991, Glaser et al. 1981, Wheeler et al. 1983, Vitt and Slack 1975, Heinselman 1963). The pronounced microtopography in these systems leads to extreme and fine-scale gradients in soil moisture and pH (Bridgham et al. 1996). Climate, topography, near surface geology, soils, and vegetation influence the hydrology of peatlands (Miller and Futyma 1987). The accumulation of peat within these systems alters drainage patterns and raises water tables (Brinson 1993).

Vegetation Description

This system encompasses treed, shrub-dominated, and herb-dominated sphagnum peatlands, generally known as poor conifer swamp, muskeg, and bog and/or poor fen. Poor conifer swamps are characterized by a canopy of coniferous trees, low ericaceous, evergreen shrubs, a sparse, low-diversity herbaceous layer and a hummocky carpet of sphagnum moss (NatureServe 2006, Glaser et al. 1981, Verry 1975, Vitt and Slack 1975, Curtis 1959, Gates 1942). The harsh growing conditions of poor conifer swamps (high acidity, low nutrient availability and saturated peat) results in a unique but depauperate flora; relatively few species have evolved the necessary adaptations to survive ombrotrophic conditions (Mitsch and Gosselink 2000, Glaser 1992, Siegel 1988). Poor conifer swamps are characterized by an exceptionally distinct plant community with similarity throughout its range (Curtis 1959). Sphagnum species form nearly continuous carpets consisting of low hummocks and extensive lawns; other characteristic species include *Maianthemum trifolium* (false mayflower), *Sarracenia purpurea* (pitcher-plant), *Cypripedium acaule* (pink lady-slipper), *Gaultheria hispidula* (creeping snowberry), *Vaccinium oxycoccos* (small cranberry), *Trientalis borealis* (starflower), *Melampyrum lineare* (cow-wheat), *Coptis trifolia* (goldthread), *Carex trisperma* (sedge), *C. magellanica* (sedge), *C. oligosperma* (sedge), *Eriophorum vaginatum* (tawny cotton-grass), *E. vaginatum* (cotton-grass), *Rhododendron groenlandicum* (Labrador-tea), *Chamaedaphne calyculata* (leatherleaf), *Kalmia polifolia* (bog-laurel), *Vaccinium angustifolium* (low sweet blueberry), *V. myrtilloides* (Canada blueberry), *Aronia prunifolia* (chokeberry), *Picea mariana* (black spruce), *Larix laricina* (tamarack), *Pinus banksiana* (jack pine), *P. resinosa* (red pine), and *P. strobus* (white pine) (Epstein et al. 2002; MDNR 2003; Cohen 2006; Cohen et al. 2015). Indicators of groundwater influence include *Thuja occidentalis* (northern white-cedar), *Alnus incana* (tag alder), *Betula pumila* (bog birch), *Ilex verticillata* (Michigan holly), *Viburnum cassinoides* (wild-raisin), *Osmunda regalis* (royal fern), and *Iris versicolor* (wild blue flag) (MNFI 2016).

Muskegs are characterized by low ericaceous, evergreen shrubs, a low-diversity herbaceous layer dominated by sedges and a hummocky carpet of sphagnum moss, and widely scattered or clumped, stunted conifers (NatureServe 2006, Glaser et al. 1991, Verry 1975, Vitt and Slack 1975, Curtis 1959, Gates 1942). Floristically, muskegs are relatively homogenous and of limited plant diversity, exhibiting remarkably uniform structure and composition across their wide range (Riley 1989, Curtis 1959). Minerotrophic indicator species are absent or present locally near upland margins (including margins of sand ridges) and drainages (MNFI 2016). A carpet of sphagnum is usually present, although *Pleurozium schreberi* is often very abundant and forms large mats covering drier mounds in shaded sites. Species composition is very similar to that of poor conifer swamps, but open-site species such as *Andromeda glaucophylla* (bog-rosemary), pitcher-plant, *Drosera* spp. (sundews), *Eriophorum* spp. (cotton-grasses), *Carex pauciflora* (sedge), *Rhynchospora alba* (white beak-rush), and *Oclemena nemoralis* (bog aster) may be more prevalent (MDNR 2003; Cohen et al. 2015).

Open bogs are characterized by a continuous carpet of sphagnum moss, a low-diversity herbaceous layer, low ericaceous, evergreen shrubs and widely scattered and stunted conifer trees (NatureServe 2005a, Glaser et al. 1991, Verry 1975, Vitt and Slack 1975, Curtis 1959, Gates 1942). Floristically, open bogs are often homogenous and of limited diversity, exhibiting remarkably uniform structure and composition across their wide range (Riley 1989, Curtis 1959). However, unlike muskegs, bogs often exhibit concentric zonation, with older portions of the bog mat at the margins of the kettle dominated by trees and shrubs, and younger portions dominated by herbaceous species and sphagnum mosses, sometimes bordering an open water zone or “eye” (MNFI 2016). 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 (Mitsch and Gosselink 2000, Glaser 1992, Siegel 1988). Characteristic species of treed and shrub-dominated zones are the same as those listed above for poor conifer swamp and muskeg. Unlike the latter communities, bogs may also support a floating sphagnum mat with white beak-rush, *Drosera intermedia* (spatulate-leaved sundew), pitcher-plant, *Vaccinium macrocarpon* (large cranberry), *Menyanthes trifoliata* (bog buckbean), *Utricularia cornuta* (horned bladderwort), *Xyris montana* (yellow-eyed-grass), *Calopogon tuberosus* (grass-pink), *Pogonia ophioglossoides* (rose pogonia), *Carex limosa* (bog lantern sedge), and *Lycopodiella inundata* (bog clubmoss) (Cohen et al. 2015; MNFI 2016).

BpS Dominant and Indicator Species

Symbol	Scientific Name	Common Name
PIMA	<i>Picea mariana</i>	Black spruce
LALA	<i>Larix laricina</i>	Tamarack
LEGR	<i>Ledum groenlandicum</i>	Bog labrador tea
ANPOG	<i>Andromeda glaucophylla</i>	Bog rosemary
CHCA2	<i>Chamaedaphne calyculata</i>	Leatherleaf
CATR10	<i>Carex trisperma</i>	Three seeded sedge
CAOL3	<i>Carex oligosperma</i>	Fewseed sedge
SPAF70	<i>Sphagnum affine</i>	Sphagnum

Species names are from the NRCS PLANTS database. Check species codes at <http://plants.usda.gov>.

Disturbance Description

Succession within peatland systems is not unidirectional but stochastic, with rates and pathways of succession determined by a complex array of interacting biotic and abiotic factors (Klinger 1996, Jasieniuk and Johnson 1982). Bogs can succeed to poor conifer swamp or remain as bogs depending on the site’s hydrology (lowered water tables and grounding and compaction of peat will allow for the establishment of trees), disturbance regime (fire and flooding will keep open systems open), and species composition (a seed source of conifer trees in the vicinity is required and some ericaceous species can limit seedling establishment and tree growth). Where poor conifer swamp is invading an open bog, the youngest trees are found closest to the bog while the oldest trees are farthest from the bog (Klinger 1996).

Once established, poor conifer swamp can persist for hundreds of years given stable hydraulic conditions and the absence of fire. Poor conifer swamps and muskegs can be even-aged or uneven-aged depending on the disturbance history and age of a site. Younger stands, regenerated following fire tend to be even-aged with tall dense canopies, while older stands tend to be

uneven-aged with more open canopies and variable heights (Groot 2002, Harper et al. 2002, Groot and Horton 1994, Morin and Gagnon 1991, Taylor et al. 1988, Barnes and Wagner 1981, Curtis 1959). Within even-aged stands, stratification of species into distinct size classes is common. This structural feature occurs because one species (e.g., black spruce) obtains a disproportionate share of the finite resources at the expense of the other species (e.g., tamarack or balsam fir) (Newton and Smith 1988). Within dense, stands of even-aged black spruce, density dependent mortality or self-thinning typically occurs after several decades (Carleton and Wannamaker 1987). As poor conifer swamps and muskegs age, they tend to become more complex structurally but with relatively stable tree species composition. The structural diversity of old-growth poor conifer swamps (200-300yrs old) provides important habitat for regional biodiversity. Small scale disturbance factors, such as windthrow events and insect herbivory (e.g., spruce budworm), generate numerous snags, coarse woody debris, and gaps within the canopy. These canopy gaps are captured primarily by black spruce layering but also by swamp conifer seedlings. Compared to trees established from seed, layers tend to be of shorter stature. As stands age, they become more open with discontinuous canopies. In addition to structural complexity, epiphytic diversity tends to increase with stand age since older trees are available for a longer period of time for epiphytic colonization, vegetative expansion, and sexual reproduction (Harper et al. 2005, Ruel et al. 2004, Harper et al. 2003, Harper et al. 2002, Groot 2002, Groot and Horton 1994, Bergeron and Dubuc 1989). Old-growth, uneven-aged poor conifer swamps are most prevalent in fire resistant landscapes and in extensive areas of peatland forest, which have reduced fire frequencies (Groot 2002).

Fire, which is an infrequent but important disturbance factor within poor conifer swamps and muskegs, controls tree population dynamics by initiating and terminating succession (Cleland et al. 2004, Miller and Futyma 1987, Futyma and Miller 1986, Whitney 1986, Foster 1985, Payette and Gagnon 1979, Curtis 1959). The primary ignition source for fires within poor conifer swamps and muskegs is summer lightning strike (Foster 1985, Rowe 1973), however, historically fires started by Native Americans in surrounding uplands (Chapman 1984, Day 1953) likely spread to some swamp forests. Estimates of fire return intervals for forested peatlands range widely from just over a hundred years (superficial fires) to several hundred years in fire-prone landscapes to several hundred to over a thousand years in swamps in fire-protected landscapes (Cleland et al. 2004, MNDNR 2003; Whitney 1986). Fire rotation period typically increases from south to north and with increasing organic soil moisture (Sirois and Payette 1989). The accumulation of thick organic soils often prolongs the fire cycle within these systems (Foster 1985). In addition, forest floor thickness, which increases with time since fire, is negatively correlated with fire severity (Fenton et al. 2005, Ruel et al. 2004). Fire frequency can also be reduced by fire breaks such as bodies of water and deciduous forests (Rowe 1973). Catastrophic fires can convert shrub- and tree-dominated muskeg to *Carex oligosperma* lawns (MNDNR 2003); such sites are prevalent on sand plains within and adjacent to the HNF (MNFI 2016). *Carex oligosperma* lawns provide a fuel source that may increase fire return intervals in affected systems.

Fire severity and frequency in poor conifer swamps and muskegs is closely related to climatic change and fluctuations in water level. Prolonged periods of drought and lowered water table can allow the surface peat to dry out enough to burn (Schwintzer and Williams 1974, Vogl 1964). When the surface peat burns, the fire releases organic matter from the peat, stimulates decay,

slows peat accumulation and exposes mineral soil (Jean and Bouchard 1991, Damman 1990, Rowe 1973, Vogl 1964). Fires within poor conifer swamps and muskegs are typically stand-replacing crown fires that kill the majority of canopy trees (Harper et al. 2002, Knowles 1991a, Bergeron and Dubuc 1989, Curtis 1959). Depending on its severity, fire can eliminate or reduce the soil organic layer (Fenton et al. 2005, Harper et al. 2005, Ruel et al. 2004). Fires in poor conifer swamps and muskegs generate a flush of growth, first in ground layer taxa and ericaceous shrubs, and then in coniferous trees. Increased growth, seed and fruit production, and flowering results from increases in light availability, soil temperature, decomposition rates and nutrient availability (Ruel et al. 2004, Larsen and MacDonald 1998, Foster 1985, Barnes and Wagner 1981, Rowe 1973).

Exposure of the mineral soil provides a suitable medium for the establishment and germination of swamp conifers (i.e., black spruce, tamarack, jack pine and northern white cedar) (Brown et al. 1988, Barnes and Wagner 1981, Curtis 1959). Species present in abundance before the fire are typically at an advantage for extending their distributions afterward (Rowe 1973). Cone serotiny provides black spruce and jack pine a competitive advantage in terms of seeding onto burned sites in that fire-killed trees can provide seed. Tamarack, white pine, cedar and balsam fir must rely on wind or animal dispersal from seed trees that survived the fire or occur in neighboring, unburned stands (Knowles 1991a). The majority of seedlings typically establish within the first couple of years following the fire (Rajora and Pluhar 2003, St-Piere and Gagnon 1992, Morin and Gagnon 1991) but recruitment at a lessened rate often continues for several decades following the disturbance and initial pulse of seedlings (Larsen and MacDonald 1998, Groot and Horton 1994, Sirois and Payette 1989). The initially established trees often serve as an internal seed source. The rate of reforestation following fire is dependent on the size and severity of the burn; centers of large burns are especially slow to restock (Foster 1985). Swamps in which the organic layer burns evenly tend to support rapid seedling establishment and become even-aged (Foster 1985); these stands can even be monospecific (typically dominated by black spruce or tamarack) if the diversity of seed source is limited (Bergeron and Dubuc 1989). Seed source availability and seedbed availability and quality determine the burned stand's tree density as well as composition (Sirois and Payette 1989). Fires of weak severity leave much of the organic layer intact, which can result in slow and irregular recruitment because of the limited availability of mineral soil seedbed (Fenton et al. 2005, Harper et al. 2005, Foster 1985) and may facilitate the conversion of poor conifer swamp to muskeg (Vogl 1964). In fire prone landscapes, periodic fire can also maintain open peatlands: conversely, fire suppression in these areas can lead to the conversion of open bogs to poor conifer swamps (Vitt and Slack 1975, Curtis 1959).

Fires typically cause change in species abundance but not in species composition. In contrast, water regime and nutrient regime changes result in drastic modification of species composition and abundance (Jasieniuk and Johnson 1982). Beaver, through their dam-building activities, can instigate substantial hydrologic change to peatland systems, either causing flooding or the lowering of the water table of poor conifer swamps and muskegs depending on the location of the forest in relation to the dam (Futyma and Miller 1986, Jeglum 1975, Heinselman 1963, Curtis 1959, Gates 1942). Behind a beaver dam the water table is higher while below it, drier conditions are generated (Jeglum 1975). Short periods of flooding can cause needle chlorosis, necrotic needle tips, and decreased shoot and root growth of swamp conifers due to low oxygen concentration and nutrient availability in the rooting medium from water logging (Islam and

MacDonald 2004, Islam et al. 2003). Prolonged flooding of poor conifer swamps and muskegs can result in the death of canopy trees and the conversion of forested peatlands to bogs or even open systems dominated by marsh and fen vegetation (Asada et al. 2005). Flooding can also cause grounded peat mats to become loosened from the bottom and float (Asada et al. 2005, Gates 1942). Flooding induced tree mortality is greater on grounded peat mats compared to free floating mats: free mats float up with a rising water table while grounded mats become inundated and have shallower aerobic zones (Asada et al. 2005, Schwintzer 1979, Schwintzer 1978a, Schwintzer 1973). 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). Flooding typically causes tree mortality after about a decade but different tree species have different tolerances for flooding (Asada et al. 2005, Janssen 1967). Tamarack, which is often most prevalent on wet sites, exhibits greater flooding tolerance than black spruce. In response to prolonged soil flooding, tamarack produces adventitious roots which increase root hydraulic conductivity or the capacity to regulate water flow (Islam and MacDonald 2004, Islam et al. 2003). However, tamarack can also be more deleteriously affected by flooding than black spruce since it is often restricted to hollows while black spruce is elevated on hummocks (Denyer and Riley 1964).

The lowering of the water table through beaver damming or climatic changes can also dramatically affect the species composition and successional trajectory of poor conifer swamps and muskegs. Lowering of a forested peatland's water table results in increased soil aeration, soil temperature, decomposition, nutrient availability, and consequently tree growth (Pepin et al. 2002, MacDonald and Yin 1999, Liefers and MacDonald 1990, Liefers and Rothwell 1987, Liefers and Rothwell 1986, Jasieniuk and Johnson 1982). Increased tree growth following lowering of the water table is especially prevalent in species such as tamarack, which often establishes in wet microsites (i.e., hollows). Species such as black spruce, which are often more prevalent on hummocks, may be detrimentally impacted by lengthy periods of drying because of water stress. Lowered water tables can dramatically reduce the micro-scale heterogeneity that characterizes peatlands by eliminating the fine-scale gradients in pH, moisture, and nutrient availability associated with hummocks and hollows (MacDonald and Yin 1999). In addition, a low water table for a prolonged period of time can cause the decomposition of the organic layer (Curtis 1959) and the conversion of poor conifer swamp to a more minerotrophic forest type. Lowering of the water table in open peatland systems can lead to the conversion to shrub swamp or poor conifer swamp (Gignac et al. 2000).

The natural disturbance regime in poor conifer swamps and muskegs is also influenced by wind. Trees growing in poor conifer swamp are particularly susceptible to windthrow because saturated sphagnum peat provides a poor substrate for anchoring trees (Harper et al. 2002, Burns 1906). As noted above, the living roots of woody peatland plants occur in a shallow rooting zone, generally restricted to the uppermost 15 cm where there is sufficient oxygen to maintain aerobic respiration (Hamel et al. 2004). The poor drainage of poor conifer swamps and muskegs and the superficial rooting of swamp trees results in numerous windthrows (Harper et al. 2003, Harper et al. 2002, Barnes and Wagner 1981, Curtis 1959, Dansereau and Segadas-Vianna 1952). Most windthrow only partially disturbs a stand, creating small canopy gaps but complete canopy destruction can also occur (Harper et al. 2002, Groot and Horton 1994). Catastrophic, stand-leveling blowdowns are infrequent disturbance factors in poor conifer swamps and muskegs, with return intervals

likely greater than 1000yrs. As noted above, small-scale wind disturbance, along with insect herbivory, contribute to the structural diversity of poor conifer swamps and muskegs. Small-scale wind disturbance, along with insect herbivory contribute to the structural diversity of muskegs by generating moderate pit and mound topography, standing snags, and woody debris, which is quickly enveloped by the sphagnum.

Poor conifer swamps, which often contain dense monospecific stands, are inherently susceptible to epizootic attacks of insects and parasites. The plant parasite *Arceuthobium pusillum* (dwarf mistletoe) can increase the mortality of black spruce (Barnes and Wagner 1981, Gates 1942, Coburn et al. 1933). Two insect defoliators are most prevalent in peatlands, *Pristiphora erichsonii* (larch sawfly), and *Choristoneura fumiferana* (spruce budworm) (Newton and Jolliffe 1998, Barnes and Wagner 1981, Curtis 1959). Spruce budworm defoliates both black spruce and balsam fir but tends to be more detrimental to the latter. The principal effect of spruce budworm outbreaks on black spruce stands is the increase in competitive asymmetry with smaller conspecifics suffering from greater competition-induced mortality post-defoliation (Newton and Jolliffe 1998). Tamarack growing in poor conifer swamps often suffers from repeated defoliation by larch sawfly (Girardin et al. 2005, Tilton 1977). The life of a given tamarack is typically characterized by a series of defoliation episodes, most of which are short in duration and of moderate intensity (Graham 1956). However, prolonged larch sawfly attacks can lead to extensive mortality of tamarack. Larch sawfly outbreaks tend to be more severe on better drained sites; hydric sites have defoliation episodes of lower intensity and duration due to the severe restrictions on sawfly development and survival imposed by a high water table (Girardin et al. 2005). Although a more recent arrival in Michigan, the larch casebearer is beginning to cause heavy defoliation to tamarack, especially in the eastern and central Upper Peninsula.

Native ericaceous shrubs can profoundly limit the establishment and growth of swamp conifer trees through competitive inhibition and also through the production of allelopathic compounds. Many of the ericaceous plants that thrive in poor conifer swamps are fire-adapted and often resprout vigorously and grow densely following fire or clear cuts (Wheeler et al. 1983). Rapid and prolific resurgence of ericads, which resprout or sucker from underground organs, can directly limit tree seedling establishment and growth (Yamasaki et al. 1998, Zhu and Mallik 1994, Foster 1985). Sheep-laurel has been found to produce allelopathic compounds that inhibit the growth and development of black spruce. These water soluble and heat stable substances hinder the primary root development of black spruce and are also believed to negatively impact the ectomycorrhizal fungi associated with black spruce (Yamasaki et al. 1998, Zhu and Mallik 1994, Thompson and Mallik 1989, Peterson 1965). The negative effects of sheep-laurel on black spruce root growth are most pronounced under acidic conditions (Zhu and Mallik 1994).

Poor fens and bogs can succeed to poor conifer swamp or northern shrub thicket. Lowering of the water table of fens and bogs 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 (Gignac et al. 2000, Almendinger and Leete 1998, Riley 1989, Schwintzer 1981, Miller 1981, Schwintzer and Williams 1974). 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 (Glaser et al. 1990, Siegel and Glaser 1987). 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).

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). Option 1 is a permanent to semi-permanent increase in water levels. Option 2 is a permanent to semi-permanent decrease in water levels.

Flooding may also push this BpS to another BpS entirely.

Fire Frequency

Severity	Avg FI	Percent of All Fires	Min FI	Max FI
Replacement	721	15	1	1000
Moderate (Mixed)				
Low (Surface)	124	85	1	1000
All Fires	106	100		

Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is the central tendency modeled. Percent of all fires is the percent of all fires modeled in that severity class. Minimum and Maximum FIs show the relative range of fire intervals as estimated by model contributors, if known.

Scale Description

This BpS can range from thousands of acres to less than five acres in size. The larger delineations typically occur in central to northern MN, the eastern Upper Peninsula of MI, and the smaller and scattered delineations in the western Upper Peninsula, northern Lower Peninsula and northern WI. These areas have a relatively low alpha diversity, but can vary considerably in beta diversity even within the same delineation. They may also contain scattered, better-drained islands with mineral soils and hardwoods in the larger delineations.

Adjacency or Identification Concerns

Reviewer removed descriptions of wet meadow, shrub-carr, and poor fen, which fit better with other alliances. Hydrologic disruption, especially in the form of beaver flooding of isolated depressions, where damming can significantly increase water levels, may result in the conversion of this BpS to a variety of other NVC groups, including Eastern North American Freshwater Marsh Group; Eastern North American Shrub Swamp Group; and Eastern North American Boreal Freshwater Marsh, Wet Meadow, & Shrubland Group, or BpS Laurentian-Acadian Shrub-Herbaceous Wetland Systems.

Within National Vegetation Classification System: Eastern North American Boreal Acidic Bog & Fen Group (Faber-Langendoen & Gawler 2015). The revision of the NVC and development of new hierarchical classes is potentially problematic for the current BpS descriptions that are often based on the old, now replaced Ecological Systems. It would be good to review the BpS types to crosswalk them to the appropriate levels in the NVC.

Other classifications: Michigan Natural Features Inventory (MNFI) Natural Community Classification: Poor Conifer Swamp; Muskeg; Bog (Cohen et al. 2015). Wisconsin Natural

Heritage Inventory: Black Spruce Swamp; Bog Relict; Muskeg; Open Bog (Epstein et al. 2002). Minnesota County Biological Survey, Ecological Land Classification Program, and Natural Heritage and Nongame Research Program: Northern Spruce Bog; Northern Poor Conifer Swamp; Northern Open Bog (Aaseng et al. 2011). International Vegetation Classification (IVC): Alliance: *Picea mariana* - *Larix laricina* / *Sphagnum* spp. Poor - Intermediate Swamp Alliance; *Picea mariana* / *Sphagnum* spp. Eastern Boreal Bog Woodland Alliance; *Chamaedaphne calyculata* / *Carex lasiocarpa* Sub-Boreal Acidic Bog & Fen Group; *Chamaedaphne calyculata* - *Kalmia polifolia* / *Carex oligosperma* Acidic Shrub Bog & Fen Alliance. Associations: *Picea mariana* - (*Larix laricina*) / *Ledum groenlandicum* / *Sphagnum* spp. Forest; *Picea mariana* / *Ledum groenlandicum* / *Carex trisperma* / *Sphagnum* spp. Bog Woodland; *Pinus banksiana* - (*Picea mariana*) - Mixed Hardwoods / *Sphagnum* spp. Forest; *Picea mariana* / *Chamaedaphne calyculata* / *Sphagnum* spp. Open Bog Woodland; *Chamaedaphne calyculata* - *Ledum groenlandicum* - *Kalmia polifolia* Bog Dwarf-shrubland; *Larix laricina* / *Chamaedaphne calyculata* / *Carex lasiocarpa* Shrubland; *Chamaedaphne calyculata* / *Carex oligosperma* - *Eriophorum virginicum* Dwarf-shrubland; *Chamaedaphne calyculata* / *Carex oligosperma* / *Sphagnum* spp. Poor Fen Dwarf-shrubland.

Issues or Problems

Native Uncharacteristic Conditions

Reviewer noted that construction of road crossings, dams and other human disturbances have led to altered beaver distributions and activity, which has implications for bog formation.

Comments

Reviewer also submitted a simplified model that does not include S-classes more typical of other BpS's. Open (muskeg) and closed (poor conifer swamp) conditions can be long-seral and depend on landform/surrounding landscape veg & fire frequency. Modeling water increases or decreases may be too complicated/too regionally specific for broad application. Due to classification implications we were not able to implement suggestions during the 2018 BpS review.

Succession Classes

Mapping Rules

Upper Layer Lifeform	Height (m)	Canopy Cover (%)									
		0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
Herb	0-0.5	E	E	B	B	B	B	UN	UN	UN	UN
Herb	0.5-1.0	E	E	B	B	B	B	UN	UN	UN	UN
Herb	>1.0	E	E	B	B	B	B	UN	UN	UN	UN
Shrub	0-0.5	A	A	A	A	UN	UN	UN	UN	UN	UN
Shrub	0.5-1.0	A	A	A	A	UN	UN	UN	UN	UN	UN
Shrub	1.0-3.0	A	A	A	A	UN	UN	UN	UN	UN	UN
Shrub	>3.0	A	A	A	A	UN	UN	UN	UN	UN	UN
Tree	0-5	UN	UN	C	C	C	D	D	D	UN	UN
Tree	5-10	UN	UN	C	C	C	D	D	D	UN	UN
Tree	10-25	UN	UN	C	C	C	D	D	D	UN	UN

Tree	25-50	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN
Tree	>50	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN

Succession class letters A-E are described in the Succession Class Description section. Some classes use a leafform distinction where a qualifier is added to the class letter: Brdl (broadleaf), Con (conifer), or Mix (mixed conifer and broadleaf). UN refers to uncharacteristic native or a combination of height and cover that would not be expected under the reference condition. NP refers to not possible or a combination of height and cover which is not physiologically possible for the species in the BpS.

Description

Class A 14 Early Development 1 - All Structures

Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
SPIRA	Spiraea	Spirea	Low-Mid
ALNUS	Alnus	Alder	Middle
CALAM	Calamagrostis	Reedgrass	Lower
CALA16	Carex lacustris	Hairy sedge	Lower

Description

Wet meadow/shrub carr are open wetlands dominated by dense cover of broad-leaved graminoids or tall shrubs. Present on mineral to sapric peat soils in basins or along streams. Moss cover is often less than five percent, but can range to >75%. Brown mosses are usually dominant, but sphagnum can be dominant on some sites. Characteristic species include Calamagrostis canadensis, Carex lacustris, Carex stricta, Lysimachia thyrsiflora, Spiraea alba, Alnus incana, American elm and black ash. Sphagnum covers can quickly invade the wet meadow/shrub carr when water levels stabilize. The chemistry of these sites can be quickly converted by sphagnum to poor fen conditions before characteristic wet meadow species have been replaced by plants of poor fens. The process of succession of wet meadow/shrub carr to poor fen can be reversed by return of higher or more variable water level.

Upper Layer Lifeform is not the dominant lifeform. The shrub/herb/moss lifeform may be dominant. Canopy closure is 0%. Min height is 0m, max height is 1.1m. The shrub lifeform may also be dominant. Canopy closure min is 50%, max 100%. Min height is 0.6m, max height is 3.1m.

Maximum Tree Size Class

None

Class B 16 Mid Development 1 - Open

Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
SPHAG2	Sphagnum	Sphagnum	Lower
CALA11	Carex lasiocarpa	Woollyfruit sedge	Lower

CAOL3	Carex oligosperma	Fewseed sedge	Upper
BEP4	Betula pumila	Bog birch	Low-Mid

Description

Poor fens are open sphagnum peatlands with variable development of hummocks and hollows. Dominated either by fine-leaved sedges or low shrubs. Present in small basins, on floating mats near lakes and ponds, and in large peatlands on glacial lake plains. Species diversity is low, but minerotrophic species such as *Betula pumila*, *Carex lasiocarpa*, *Menyanthes trifoliata*, *Potentilla palustris* and *Salix pedicellaris* help distinguish poor fens from bogs. Poor fens occur in peatlands where the peat surface is nearly isolated from mineral-rich runoff and is becoming increasingly acidic (pH is 4.2-5.5). Poor fens can develop through the acidification of wet meadows. This can occur in basins and on floating mats where invasion and accumulation of *Sphagnum* elevates the surface peat, isolating plant roots from underlying minerotrophic water.

Upper Layer Lifeform is not the dominant lifeform. The herb/moss lifeform or the shrub lifeform are the dominant lifeform. Moss cover is nearly always 100%. Herbs are abundant, with graminoids often being the dominant vegetation. Low shrubs are the dominant species on many sites and can have >50% cover.

Maximum Tree Size Class

None

Class C	38	Late Development 1 - Closed
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Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
LARIX	Larix	Larch	Mid-Upper
PIMA	Picea mariana	Black spruce	Mid-Upper
CHAMA5	Chamaedaphne	Leatherleaf	Low-Mid
SPHAG2	Sphagnum	Sphagnum	Lower

Description

Poor conifer swamps are conifer-dominated peatlands with sparse canopy of stunted trees. Understory is depauperate and dominated by ericaceous shrubs, fine-leaved graminoids, and low hummocks of *Sphagnum* moss. Tree canopy cover is usually 25-50%. Surface water pH is usually >4.1. Species diversity is low, but minerotrophic indicators are typical. *Sphagnum* species form nearly continuous carpets consisting of low hummocks and extensive lawns; other characteristic species include *Smilacina trifolia*, *Sarracenia purpurea*, *Carex trisperma*, *Eriophorum vaginatum*, *Ledum groenlandicum*, *Chamaedaphne calyculata*, *Alnus incana*, black spruce and tamarack. In general, poor conifer swamps develop in peatlands where the peat surface is becoming isolated from mineral-rich groundwater because of buildup of peat and invasion by sphagnum. They may also develop from poor fens where the formation of sphagnum hummocks creates sufficiently aerated condition for the establishment and growth of black spruce and tamarack. Catastrophic fires in poor conifer swamps are not common. An analysis of the Public Land Survey (PLS) records in MN indicates that the historic rotation for catastrophic

fires was about 570yrs. Moderate surface fires and light windthrow were somewhat more common disturbances in poor conifer swamps, occurring about every 90yrs. There is little direct evidence that windthrow has a significant impact on poor conifer swamps. The PLS records in MN suggest the historic rotation of catastrophic windthrow was about 500yrs.

Maximum Tree Size Class

None

Class D 23 Late Development 2 - All Structures

Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
PIMA	Picea mariana	Black spruce	Upper
LEGR	Ledum groenlandicum	Bog labrador tea	Low-Mid
CATR10	Carex trisperma	Threeseeded sedge	Lower
SPHAG2	Sphagnum	Sphagnum	Lower

Description

Muskegs are black spruce dominated peatlands on deep peat. Canopy is often sparse (25-75% cover), with stunted trees. Understory is dominated by ericaceous shrubs and fine-leaved graminoids on high sphagnum hummocks. Minerotrophic indicator species are absent or present only as single individuals or single clones. A carpet of sphagnum is usually present, although Pleurozium schreberi is often very abundant and forms large mats covering drier mounds in shaded sites. Other characteristic species include Carex trisperma, Eriophorum vaginatum, Ledum groenlandicum and black spruce. Muskegs occur where buildup of peat causes the peat surface to become isolated from mineral-rich runoff or subsurface flow so that all mineral inputs come from precipitation. Although fires can occur in muskegs, they are not very common. An analysis of the Public Land Survey (PLS) records in MN indicates that the historic rotation of catastrophic fires was in excess of 1000yrs. These fires can result in conversion of a muskeg to an open bog community; if sufficient nutrients are released into surface waters by burning of peat and vegetation, the bog may be converted to a poor fen. Surface fires appear to have been more common, occurring about every 120yrs. There is little direct evidence that windthrow has a significant impact on muskegs. The PLS records in MN suggest the historic rotation of catastrophic windthrow was about 700yrs.

Maximum Tree Size Class

None

Class E 9 Late Development 3 - Open

Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
SPHAG2	Sphagnum	Sphagnum	Lower

Description

Open bogs are sphagnum-dominated peatlands with microtoppgraphy ranging from deep hollows and low sphagnum carpets to well-developed high hummocks. Present in large patterned peatlands and in small basins in nutrient-poor outwash plains and in areas of non-calcareous till deposits in scoured bedrock terrain. Surface water pH is <4.2 and Minerotrophic indicator species are absent. Sphagnum cover is about 90%, other mosses 10%; other characteristic species include *Carex oligosperma*, *Eriophorum vaginatum*, *Sarracenia purpurea*, *Chamaedaphne calyculata*, *Kalmia polifolia*, *Vaccinium oxycoccos*, *Andromeda glaucophylla* and *Ledum groenlandicum*. Open bogs develop where the peat surface becomes elevated, isolating it from mineral-rich runoff or groundwater. The saturated conditions and rapid accumulation of sphagnum peat prevent or inhibit establishment and growth of black spruce and tamarack. Open bog can originate from transformation of muskeg after a wind or fire event that eliminated tree canopy. Loss of the tree canopy results in reduced evapotranspiration and increasingly water-logged conditions, causing a shift toward greater presence of carpet forming sphagnum species and the development of wet hollows. Ericaceous shrubs and other xerophytic bog species are the predominant vegetation on the remaining hummocks. Dominant lifeform is the herb/moss lifeform.

Maximum Tree Size Class

None

Model Parameters

Deterministic Transitions

From Class	Begins at (yr)	Succeeds to	After (years)
Early1:ALL	0	Mid1:OPN	40
Mid1:OPN	41	Late1:CLS	80
Late1:CLS	81	Late2:ALL	250
Late2:ALL	251	Late2:ALL	500
Late3:OPN	251	Late3:OPN	999

Probabilistic Transitions

Disturbance Type	Disturbance occurs In	Moves vegetation to	Disturbance Probability	Return Interval (yrs)	Reset Age to New Class Start Age After Disturbance?	Years Since Last Disturbance
Wind or Weather or Stress	Mid1:OPN	Mid1:OPN	0.01	100	No	0
Surface Fire	Mid1:OPN	Mid1:OPN	0.01	100	No	0
Optional 1	Mid1:OPN	Early1:ALL	0.01	100	Yes	0
Optional 1	Mid1:OPN	Mid1:OPN	0.033	30	No	0
Wind or Weather or Stress	Late1:CLS	Late1:CLS	0.002	500	No	0
Replacement Fire	Late1:CLS	Early1:ALL	0.002	500	Yes	0
Optional 1	Late1:CLS	Early1:ALL	0.003	333	Yes	0
Surface Fire	Late1:CLS	Late1:CLS	0.01	100	No	0
Replacement Fire	Late2:ALL	Mid1:OPN	0.001	1000	Yes	0
Wind or	Late2:ALL	Late3:OPN	0.001	1000	Yes	0

Weather or Stress						
Replacement Fire	Late2:ALL	Late3:OPN	0.001	1000	Yes	0
Wind or Weather or Stress	Late2:ALL	Late2:ALL	0.001	1000	No	0
Optional 1	Late2:ALL	Mid1:OPN	0.003	333	Yes	0
Insects or Disease	Late2:ALL	Late2:ALL	0.007	143	No	0
Surface Fire	Late2:ALL	Late2:ALL	0.008	125	No	0
Replacement Fire	Late3:OPN	Mid1:OPN	0.002	500	Yes	0
Optional 1	Late3:OPN	Mid1:OPN	0.003	333	Yes	0
Surface Fire	Late3:OPN	Late3:OPN	0.01	100	No	0

Optional Disturbances

Optional 1: Flooding

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