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Boreal Jack Pine-Black Spruce Forest - Pine Barrens

BpS Model/Description Version: Aug. 2020

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Vegetation Type

Forest and Woodland

Map Zones

51

Geographic Range

System occurs in northern lower MI, northern WI, northern MN, and eastern Ontario, north of the climatic tension zone (Curtis 1959) and is concentrated in the High Plains Subsection in northern lower MI and in central WI (Vora 1993). Also occurs in several locations in the Upper Peninsula of MI and is associated with the upper Mississippi and St. Croix Rivers in MN and WI (Comer 1996).

In MZ51, this type occurs in 212 H, R and S (all subsections contained within). Within Hiawatha National Forest (Section 212R), pine barrens are estimated to have covered ca. 17,000 ha (42,000 ac) at the time of the General Land Office (GLO) Surveys (Comer et al. 1995). The system is nearly restricted to the Racine Plains and vicinity in north-central Chippewa County and east of Little Bay de Noc and Whitefish River in southern Delta County, with small outliers in southern Alger and western Schoolcraft Counties. Jack pine-red pine forests are estimated to have covered ca. 17,000 ha (41,000 ac) at the time of the GLO Surveys (Comer et al. 1995). This system is concentrated in central and western Chippewa County, especially in the vicinity of the Racine Plains, and otherwise found mostly in southern Alger, northeastern Delta, and western Schoolcraft Counties.

Biophysical Site Description

The Boreal Jack Pine-Black Spruce Forest - Pine Barrens system is endemic to very dry, nutrient-impooverished landscape ecosystems. These ecosystems occur in landforms deposited by high-energy glacial melt waters, principally outwash plains and glacial lakebeds, underlain by well-sorted, coarse-textured sandy soils with low water retaining capacity. They also occur in bedrock-controlled landforms with shallow soils of limited moisture storage capacity, and on sand ridges within peatland complexes (Cohen et al. 2002; Cleland et al. 2004). They are generally found in cooler climates north of the tension zone. The topography is flat to gently rolling, typically with long expanses capable of carrying wildfires with few natural fire breaks. In rolling topography, pine barrens are found among depressions that collect cold air, forming frost pockets. The soils of this community are sandy, acidic, droughty, and relatively infertile (Comer 1996). Where the system occurs in low-lying areas and low sand ridges in peatland complexes,

the higher water table promotes paludification, which results in accumulation of an organic horizon above the mineral layers. They become established in areas with continental climate, in which summers are typically short and warm to cool, and winters are cold (Pregitzer and Saunders 1999).

Vegetation Description

In jack pine barrens, *Pinus banksiana* (jack pine) typically dominates the scattered overstory canopy. Trees can occur as scattered individuals or in scattered clumps. Several other tree species can be found in this community. Historically, there was commonly a scattered supercanopy of *Pinus resinosa* (red pine). Most of these trees were likely removed during the logging era. *P. resinosa* and *P. strobus* (white pine) were occasionally common sub-dominants in MI pine barrens, especially in Lake County. As noted by Epstein et al. (2002), pines may be infrequent or even absent in some areas of former pine barrens due to historical logging, altered fire frequencies, and absence of a seed source. Deciduous trees such as *Quercus ellipsoidalis* (northern pin oak), *Prunus serotina* (black cherry) and *Populus* spp. (aspens) are capable of resprouting following fire and are often found as stunted or young trees, sometimes dominating stands where pines were eliminated by the aforementioned disturbances. *Quercus macrocarpa* (bur oak) may occur in Minnesota and Wisconsin. *Vaccinium angustifolium* (low sweet blueberry), *Comptonia peregrina* (sweet-fern), *Prunus pumila* (sand cherry), *Salix humilis* (prairie willow), *Amelanchier* spp. (serviceberries), *Rubus flagellaris* (northern dewberry), *Arctostaphylos uva-ursi* (bearberry), and *Corylus* spp. (hazelnuts) make up most of the shrub layer when present (Epstein et al. 2002; Cohen et al. 2015). *Carex pensylvanica* (Pennsylvania sedge), *Danthonia spicata* (poverty grass), and *Schizachyrium scoparium* (little bluestem) are dominant herbaceous species across the range of this community. Other herbs and forbs vary from one location to another, depending on local site conditions. Characteristic grasses include *Andropogon gerardii* (big bluestem), *Avenella flexuosa* (hair grass), *Bromus kalmii* (prairie brome), *Dichanthelium* spp. (panic grasses), *Elymus trachycaulus* (slender wheatgrass), *Koeleria macrantha* (June grass), *Oryzopsis asperifolia* (rough-leaved rice-grass), *Piptatherum pungens* (rice-grass), and *Sorghastrum nutans* (Indian grass). Common forbs include *Antennaria howellii* (small pussytoes), *Artemisia campestris* (wormwood), *Campanula rotundifolia* (harebell), *Cirsium hillii* (Hill's thistle), *Crocanthemum canadense* (common frostweed), *Fragaria virginiana* (wild strawberry), *Helianthus occidentalis* (western sunflower), *Hieracium kalmii* (Canada hawkweed), *H. scabrum* (rough hawkweed), *Houstonia longifolia* (long-leaved bluets), *Liatris aspera* (rough blazing-star), *L. cylindracea* (cylindrical blazing-star), *L. scariosa* (northern blazing-star), *Lithospermum canescens* (hoary puccoon), *L. caroliniense* (hairy puccoon), *Melampyrum lineare* (cow-wheat), *Packera paupercula* (northern ragwort), *Solidago hispida* (hairy goldenrod), *S. speciosa* (showy goldenrod), *Symphyotrichum laeve* (smooth aster), *S. oolentangiense* (prairie heart-leaved aster), and *Viola pedata* (birdfoot violet; Epstein et al. 2002; Minnesota Department of Natural Resources 2003; Reznicek et al. 2011; Cohen et al. 2015). *Pteridium aquilinum* (bracken fern) is nearly ubiquitous, and *Cladina* spp. (reindeer lichens) are often prevalent.

As noted by Epstein et al. (2002) for Wisconsin, diversity and prevalence of prairie species declines from south to north in Michigan. In Upper Michigan, prairie species are primarily found in Menominee County, southwest of the Hiawatha National Forest. In the HNF, pine barrens in the vicinity of Raco lack the "classic" prairie grasses (little bluestem, big bluestem, and Indian grass), and many characteristic prairie forbs, such as puccoons and blazing-stars, are also absent.

Instead, these sites support a more simplified ground flora of generalist graminoids and both shade-tolerant and shade-intolerant forbs and dwarf shrubs characteristic of dry woodlands and boreal forests, including such species as *Cypripedium acaule* (pink lady-slipper), *Epigaea repens* (trailing-arbutus), *Gaultheria procumbens* (wintergreen), *Maianthemum canadense* (Canada mayflower), and *Trientalis borealis* (starflower) (MNFI 2016). The pine barrens of southern Delta County appear to be similarly impoverished in prairie taxa, although rough blazing-star has been documented from that area (Reznicek et al. 2011).

In dry pine forests, *Pinus banksiana* (jack pine) typically dominates the overstory canopy. *Pinus resinosa* (red pine) dominates some stands and may form a scattered super-canopy in stands otherwise dominated by jack pine. Most of these trees were likely removed during the logging era. *Quercus ellipsoidalis* (northern pin oak) is also locally important. Canopy associates include *Acer rubrum* (red maple), *Betula papyrifera* (paper or white birch), *Pinus strobus* (white pine, which occasionally occurs in the super-canopy), *Populus grandidentata* (bigtooth aspen), *Populus tremuloides* (trembling aspen), *Prunus serotina* (black cherry), and *Quercus rubra* (red oak; Cohen 2002). *Picea mariana* (black spruce) may also occur, particularly where the system occurs on dune ridges within peatlands. Many former areas of jack pine and red pine forests succeeded to open “stump prairies” or scrubby forests of *Populus grandidentata* (bigtooth aspen), *P. tremuloides* (quaking aspen), *Betula papyrifera* (paper birch), and *Prunus serotina* (black cherry) following widespread logging and slash fires in the mid-1800s to early 1900s (Cohen 2002; Epstein et al. 2002). *Vaccinium angustifolium* (low sweet blueberry), *V. myrtilloides* (Canada blueberry), and *Gaylussacia baccata* (huckleberry) are common low shrubs; characteristic dwarf shrubs include *Arctostaphylos uva-ursi* (bearberry), *Chimaphila umbellata* (pipsissewa), *Cornus canadensis* (bunchberry), *Epigaea repens* (trailing-arbutus), and *Gaultheria procumbens* (wintergreen; Epstein et al. 2002; MNDNR 2003; Cohen et al. 2015). In openings, *Comptonia peregrina* (sweet-fern), *Prunus pumila* (sand cherry), *Salix humilis* (prairie willow), and *Corylus* spp. (hazelnuts) may be present. On paludified sand ridges, species typical of peatlands, such as *Chamaedaphne calyculata* (leatherleaf) and *Rhododendron groenlandicum* (Labrador-tea) may proliferate. Characteristic herbaceous species include *Pteridium aquilinum* (bracken fern), *Avenella flexuosa* (wiry hair grass), *Danthonia spicata* (poverty grass), *Carex pensylvanica* (Pennsylvania sedge), *Aralia nudicaulis* (sarsaparilla), *Maianthemum canadense* (Canada mayflower), *Trientalis borealis* (starflower), *Mitchella repens* (partridge-berry), *Apocynum androsaemifolium* (spreading dogbane), *Eurybia macrophylla* (large-leaved aster), *Melampyrum lineare* (cow-wheat), *Linnaea borealis* (twinflower), *Oryzopsis asperifolia* (rough-leaved rice-grass), and *Piptatheropsis pungens* (rice-grass; Cohen 2002; Epstein et al. 2002; MNDNR 2003; Cohen et al. 2015). Mosses (e.g., *Dicranum* spp. and *Pleurozium schreberi*) and lichens (e.g., *Cladina* and *Cladonia* spp.) often form a mat on the soil (Cohen 2002).

At Crex Meadows in western WI, Vogl (1970) studied pine barrens as described by original land survey records. He estimated that there were 20 trees greater than 15cm (6in) in diameter per hectare. This translates to an average distance between trees of 24m (65ft). The trees in this community had typical open-grown shapes. They had branches most of the way down their trunks with many needles. Many burned jack pine snags were encountered by land surveyors in MI. Zimmerman (1956) reported that the tallest tree in his 50 study sites was 16m (52ft). The average tree height was only eight meters (26ft). This may be misleading because past logging may have eliminated the largest trees and there has not been enough time to regenerate the tallest

pinus. Vogl (1970), in his analysis of General Land Office surveys conducted in western Wisconsin, found that the average diameter of *Pinus banksiana* was 25 cm (10 in) and of *P. resinosa* was 50 cm (20 in). This indicates that taller trees may have existed before logging and the subsequent slash-fires that swept through most barrens. In northern Lower Michigan, jack pines in the 5 – 30 cm diameter size classes are characteristic of pine barrens at the present time, with trees in the middle of that range aged between 20 and 45 years (MNFI 2016). Jack pine and jack pine-red pine forests are characterized by a more closed, but still interrupted canopy, often from 50-75% (MNDNR 2003; MNFI 2016). Jack pines are typically in the 20 – 40 cm diameter size class; red pines in the 40 – 75 cm class; and white pines often in the 60 – 80 cm size class, with some trees exceeding 100 cm (MNFI 2016). Canopy height can approach 30 m (100 ft) (MNFI 2016).

BpS Dominant and Indicator Species

Symbol	Scientific Name	Common Name
PIBA2	<i>Pinus banksiana</i>	Jack pine
CAPE6	<i>Carex pensylvanica</i>	Pennsylvania sedge
QUEL	<i>Quercus ellipsoidalis</i>	Northern pin oak
SCSC	<i>Schizachyrium scoparium</i>	Little bluestem
VAAN	<i>Vaccinium angustifolium</i>	Lowbush blueberry
ANGE	<i>Andropogon gerardii</i>	Big bluestem
PIRE	<i>Pinus resinosa</i>	Red pine

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

Disturbance Description

Frequent fire and, in some places, frost and drought conditions, maintain open canopy conditions by limiting the development of woody vegetation and thereby allowing the maintenance of a mixture of grasses and sedges. Pine barrens were found in the most fire-prone and driest areas of the landscape, often west of fire breaks. Barrens typically occur within long expanses capable of carrying wildfires with few natural fire breaks. In rolling topography, pine barrens are found in depressions that collect cold air, forming frost pockets (Comer 1996). There are numerous estimates of fire return interval for upland jack pine systems depending on scale, geographic location of study, and habitat characteristics (e.g., tree density). Whitney (1986) estimated average return time for canopy replacement fire in jack pine forests of northern lower MI to be about 80 yrs. Similar return times (50-100 yrs) have been estimated by Heinselman (1981) in MN. Whitney (1986) also estimated that surface fires occurred every 25 yrs, while Heinselman (1981) suggested that on drier sites light to moderate surface fires may have occurred every 20-40 yrs. Simard & Blank (1982) calculated presettlement fire frequency in the Mack Lake area of Oscoda County, Michigan to have averaged in the range of 13-41 yrs. GLO data indicate that fire and windthrow were important in some barrens landscapes (Comer et al. 1995, Comer and Albert 1999). Historical reports document near-annual fires in barrens (Curtis 1959). Radeloff et al. (2004) concluded that three distinct fire regimes characterized jack pine barrens/forest in northwestern Wisconsin, ranging from frequent, non-lethal surface fires on low-relief landscapes characterized by relatively productive soils, prairie grasses, and relatively dry climate, to medium frequency, lethal crown fires on less productive soils with greater topographic relief occurring in a relatively moist climate near Lake Superior. Large, stand-replacing fires, especially those consuming >1,000 ha, produce narrow, remnant strips of unburned trees

(stringers) that contribute to structural heterogeneity and persistence of late-successional species (Kashian et al. 2012). Stand-replacing fires also create numerous snags (Corace et al. 2010). Insect infestations in jack pine are also an important disturbance factor, often followed by canopy fire. This system falls within Fire Regimes I and II.

Pine barrens in the HNF occur on low-relief proglacial outwash on poor soils with little to no prairie grass component, and occur in both relatively moist (i.e., Racoon Plains) and relatively dry (i.e., Rapid River) climates. Loope and Anderton (1998) report a fire return interval of approximately 17 years for the Racoon Plains, less frequent than that reported for barrens supporting prairie grasses in drier climates, but more frequent than that reported for more heavily forested landscapes (Radeloff et al. 2004). No fire data specific to the area of pine barrens in Delta County are available, but fire frequency and severity there was likely affected by the drier climate, narrower configuration of the barrens just east of major fire breaks (Little Bay de Noc and Whitefish River), and presence of Native American villages near what is today Rapid River.

Fire Frequency

Severity	Avg FI	Percent of All Fires	Min FI	Max FI
Replacement	34	15	10	80
Moderate (Mixed)	64	8	10	80
Low (Surface)	7	77	1	40
All Fires	5	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

There is considerable variation in the size of burned areas. In northern lower MI, GLO surveyors frequently reported the occurrence of large wildfires. These fires were among the largest in the state, covering several square miles (Comer and Albert 1999). Mean patch size of fire in xeric areas dominated by jack pine in the eastern Upper Peninsula of MI varied widely (34-3436ha) (Comer et al. 1995).

Adjacency or Identification Concerns

This system was mapped separately from 5114072 (Laurentian-Acadian Jack Pine Barrens and Forest), but there are significant similarities between the two, especially with the textual descriptions. Jack pine barrens often occurred on extensive areas of outwash plain intermixed with dry sand prairie and closed-canopy jack pine systems. Other classifications: Michigan Natural Features Inventory (MNFI) natural community classification: pine barrens. The Nature Conservancy National Classification: CODE: (III.A.4a.SW20.00). IVC Alliance: Pinus banksiana - Pinus spp. - Quercus spp. Wooded Herbaceous Alliance (Great Lakes Pine - Oak Barrens). Associations: Pinus banksiana - Pinus resinosa - (Quercus ellipsoidalis) / Carex pensylvanica Wooded Herbaceous Vegetation; Pinus banksiana - (Quercus ellipsoidalis) / Schizachyrium scoparium - Prairie Forbs Barrens Woodland.

Issues or Problems

Need more research on frequency of historical surface fire. What constitutes pine barrens versus jack pine forest or dry sand prairie depends on temporal and spatial scales.

Native Uncharacteristic Conditions

Comments

Prior to the LANDFIRE Remap this BpS was named Great Lakes Pine Barrens.

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	A	A	A	A	A	A	A	A	A	A
Herb	0.5-1.0	A	A	A	A	A	A	A	A	A	A
Herb	>1.0	A	A	A	A	A	A	A	A	A	A
Shrub	0-0.5	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN
Shrub	0.5-1.0	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN
Shrub	1.0-3.0	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN
Shrub	>3.0	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN
Tree	0-5	B	B	B	B	UN	UN	UN	UN	UN	UN
Tree	5-10	B	B	C	C	C	UN	UN	UN	UN	UN
Tree	10-25	C	C	C	C	D	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 35 Early Development 1 - All Structures

Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
CAPE6	<i>Carex pensylvanica</i>	Pennsylvania sedge	Lower
SCSC	<i>Schizachyrium scoparium</i>	Little bluestem	Lower
PIBA2	<i>Pinus banksiana</i>	Jack pine	Upper
ANGE	<i>Andropogon gerardii</i>	Big bluestem	Lower

Description

Sedges and grasses and/or low shrubs are dominant, with scattered jack pine regeneration and hardwood resprouts (e.g., *Prunus serotina*, *Quercus ellipsoidalis*).

Upper Layer Lifeform is not the dominant lifeform. Grasses and sedges and/or low shrubs <0.5 m are dominant lifeforms, at least in the first few years of this class. Typically, herbaceous species are less than a meter in height; shrubs may exceed 1 m but dominant shrubs (typically

low sweet blueberry) are typically <0.5 m. Minimum cover for herbaceous species is approximately 40% while maximum coverage is 90%. Shrub cover varies from <1% (atypical) to 90%, likely averaging between 10-50% depending on site conditions and land use history. Tree cover starts out very low as jack pine germination may lag stand replacement fire by up to two months and increases throughout the successional stage as trees increase in size.

Maximum Tree Size Class

Sapling >4.5ft; <5"DBH

Class B 15 Mid Development 1 - Open

Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
PIBA2	Pinus banksiana	Jack pine	Upper

Description

Upper layer characterized by jack pine regeneration (seedlings or saplings), with sedges, grasses, and/or low shrubs codominant, although these may remain dominant in this class in sparsely treed barrens.

Would have similar ground cover as class A.

Maximum Tree Size Class

Sapling >4.5ft; <10"DBH

Class C 31 Mid Development 2 - Open

Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
CAPE6	Carex pensylvanica	Pennsylvania sedge	Lower
PIBA2	Pinus banksiana	Jack pine	Upper
ANGE	Andropogon gerardii	Big bluestem	Lower
SCSC	Schizachyrium scoparium	Little bluestem	Lower

Description

Sedges and grasses are frequent, with scattered jack pine trees and low shrubs.

Upper Layer Lifeform is not the dominant lifeform. Upper layer characterized by jack pine. Grasses and sedges are codominant lifeform. Typically, herbaceous species are less than a meter in height. Minimum cover for herbaceous species is approximately 40%, while maximum coverage is 90%. Shrub cover varies from <1% (atypical) to 90%, likely averaging between 10-50% depending on site conditions and land use history.

Maximum Tree Size Class

Sapling >4.5ft; <10"DBH

Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
PIBA2	<i>Pinus banksiana</i>	Jack pine	Upper
QUEL	<i>Quercus ellipsoidalis</i>	Northern pin oak	Upper
ANGE	<i>Andropogon gerardii</i>	Big bluestem	Lower
PIRE	<i>Pinus resinosa</i>	Red pine	Upper

Description

Closed-canopy jack pine forest that results after prolonged periods of fire suppression or microtopography that protects forest from fires (approximately 25yrs). Red pines and oaks come in after a period of no fire.

Maximum Tree Size Class

Medium 9-21"DBH

Model Parameters**Deterministic Transitions**

From Class	Begins at (yr)	Succeeds to	After (years)
Early1:ALL	0	Mid1:OPN	15
Mid1:OPN	16	Mid2:OPN	24
Mid2:OPN	25	Late1:CLS	50
Late1:CLS	51	Late1:CLS	224

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
Surface Fire	Early1:ALL	Early1:ALL	0.02	50	No	0
Replacement Fire	Early1:ALL	Early1:ALL	0.033	30	Yes	0
Replacement Fire	Mid1:OPN	Early1:ALL	0.02	50	Yes	0
Surface Fire	Mid1:OPN	Mid1:OPN	0.2	5	No	0
Replacement Fire	Mid2:OPN	Early1:ALL	0.017	59	Yes	0
Mixed Fire	Mid2:OPN	Mid2:OPN	0.05	20	No	0
Surface Fire	Mid2:OPN	Mid2:OPN	0.33	3	No	0
Surface Fire	Late1:CLS	Late1:CLS	0.033	30	No	0
Replacement Fire	Late1:CLS	Early1:ALL	0.05	20	Yes	0

References

Cleland, D., B. Patterson, G. Nowacki, A. Koonce and J. Merzenich. 2004. Fire Regime Condition Class Model for Jack Pine/Open Lands with frequent (high) fire interval (R6JAPI).

Cohen, J.G., M.A. Kost, B.S. Slaughter, and D.A. Albert. 2015. A field guide to the natural communities of Michigan. Michigan State University Press, East Lansing, MI. 362 pp.

Comer P.J. 1996. Natural community abstract for pine barrens. Michigan Natural Features Inventory, Lansing, MI. 3 pp.

Comer, P.J., D.A. Albert, H.A. Wells, B.L. Hart, J.B. Raab, D.L. Price, D.M. Kashian, R.A. Corner and D.W. Schuen. 1995. Michigan's Presettlement Vegetation, as Interpreted from the General Land Office Surveys 1816-1856. Michigan Natural Features Inventory, Lansing, MI. Digital map.

Corace, R.G. III, N.E. Seefelt, P.C. Goebel, and H.L. Shaw. 2010. Snag longevity and decay class development in a recent jack pine clearcut in Michigan. Northern Journal of Applied Forestry 27: 125-131.

Corner, R.A. and D.A. Albert. 1999. Landtype Associations of The High Plains: Subsection VII.2. Prepared for the Northern Lower Michigan Ecosystem Management Project. Michigan Natural Features Inventory report number 1999-03. 177 pp. + maps.

Curtis, J.T. 1959. Vegetation of Wisconsin: An Ordination of Plant Communities. U. of Wis. Press, Madison, WI. 657 pp.

Epstein, E.J., E.J. Judziewicz, and E.A. Spencer. 2002. Wisconsin natural community abstracts. Department of Natural Resources, Bureau of Natural Resources, Madison, WI.

Heinselman, M.L. 1981. Fire intensity and frequency as factors in the distribution and structure of northern ecosystems. Pp. 7-57 in H. Mooney, J.M. Bonnicksen, N.L. Christensen, J.E. Lotan and W.A. Reiners, eds., Fire regimes and ecosystem properties. General Technical Report WO-26, USDA Forest Service, Washington, D.C.

Kashian, D.M., R.G. Corace III, L.M. Shartell, D.M. Donner, and P.W. Huber. 2012. Variability and persistence of post-fire biological legacies in jack pine-dominated ecosystems of northern Lower Michigan. Forest Ecology and Management 263: 148-158.

Loope, W.L., and J.B. Anderton. 1998. Human vs. lightning ignition of presettlement surface fires in coastal pine forests of the Upper Great Lakes. American Midland Naturalist 140: 206-218.

Menard, S., and D. Faber-Langendoen. 2013. Jack Pine - Northern Pin Oak Barrens Group [Version Date 04Oct2013]. United States National Vegetation Classification. Federal Geographic Data Committee, Washington, D.C.

Michigan Natural Features Inventory (MNFI). 2016. Natural heritage database. Michigan Natural Features Inventory, Lansing, MI.

Minnesota Department of Natural Resources. 2003. Field guide to the native plant communities of Minnesota: The Laurentian Mixed Forest Province. Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program, MNDNR St. Paul, MN.

Pregitzer, K.S. and S.C. Saunders. 1999. Jack pine barrens of the northern Great Lakes region. Pp. 343-361 in R.C. Anderson, J.S. Fralish, and J.M. Baskin (eds.) *Savannas, Barrens, and Rock Outcrop Plant Communities of North America*. Cambridge, United Kingdom.

Radeloff, V.C., D.J. Mladenoff, R.P. Guries, and M.S. Boyce. 2004. Spatial patterns in cone serotiny in *Pinus banksiana* in relation to fire disturbance. *Forest Ecology and Management* 189: 133-141.

Simard, A.J. and R.W. Blank. 1982. Fire history of a Michigan jack pine forest. *Mich. Acad.* 15: 59-71.

Vogl, R.J. 1970. Fire and the northern Wisconsin pine barrens. *Proceedings of the Tall Timbers Fire Ecology Conference* 10: 175-209.

Vora, R.S. 1993. Moquah barrens: Pine barrens restoration experiment initiated in Chequamegon National Forest. *Restor. And Mgmt. Notes* 11(1): 39-44.

Whitney, G.G. 1986. Relation of Michigan's presettlement pine forests to substrate and disturbance history. *Ecology* 67(6): 1548-1559.

Zimmerman, D.A. 1956. The jack pine association in the Lower Peninsula of Michigan: Its structure and composition. PhD. Thesis. U. of Mich., Ann Arbor, MI.