

National Park Service Voyageurs National Park Fire Monitoring Plan

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1.0 PURPOSE

The purpose of this Fire Effects Monitoring Plan (FEMP) is to meet the requirements of Reference Manual 18 (RM-18), Chapter 8 – Fire Ecology and Monitoring (USDI National Park Service 2008) and the Fire Management Plan by describing the extent of the monitoring program, the type of plots, protocols being used, and schedules for monitoring.

Prescribed and wildland fire for resource benefit (fire use fire) will be used to maintain and restore fire-adapted ecosystems at Voyageurs National Park. National Park Service RM-18 states: “NPS units using prescribed fire or wildland fire use, or altering the arrangement of wildland fuels to modify fire behavior, must prepare a fire monitoring plan or plans.” Monitoring of all fires is also regarded as essential. Reference Manual 18 states that “Monitoring of wildland fires and non-fire fuels treatments is the primary way of assessing whether the fire program is meeting management goals and objectives...” and “...monitoring must be based on and designed to assess both short- and long-term objectives.”

2.0 INTRODUCTION

2.1 SITE DESCRIPTION

Voyageurs National Park is located in northeastern Minnesota, in the forested lake region on the Minnesota-Ontario border. The park encompasses 218,055 ac. (88,247 ha), of which 84,000 ac. (34,000 ha, 38%) are water in the form of lakes and ponds, and 134,000 ac. (54,000 ha, 62%) are burnable vegetation (Hop et al. 2001). The park is on the western extent of the Canadian Shield; soils are thin and overlie bedrock. The climate is continental with approximately 100 frost free days a year and 24 inches of annual precipitation. The forests are considered sub-boreal and major tree species include red pine (*Pinus resinosa*), white pine (*Pinus strobus*), jack pine (*Pinus banksiana*), black spruce (*Picea mariana*), white spruce (*Picea glauca*), balsam fir (*Abies balsamia*), red maple (*Acer rubrum*), paper birch (*Betula papyrifera*), northern white cedar (*Thuja occidentalis*), and aspen (*Populus tremuloides* and *P. grandidentata*).

2.2 SURROUNDING LANDS

The park is surrounded by public and private lands. Other large protected areas occur within 10 miles east of the park in Canada and the U.S. They include the 1.2 million ac. (486,000 ha) Boundary Water Canoe Area Wilderness (BWCAW), and the 1.1 million ac. (445,000 ha) Quetico Provincial Park. Southeast of the park, the US Forest Service manages the Superior National Forest, including the BWCAW. South and west of the park, is a mosaic of lands belonging to the State of Minnesota, St. Louis and Koochiching Counties, Boise Cascade Corporation and private landholders. There are also numerous inholdings within the park, all of which will eventually be turned over to the park when the leases expire.

2.3 VEGETATION

Pre-settlement and current vegetation coverages were estimated for Voyageurs National Park by Kurmis (1986) and Hop et al. (2001), respectively (Table F-1). The differences in pre and post-

settlement vegetation coverage for the five main cover types shown are attributed to fire and logging. Approximately 75% of the park's forests were logged prior to park establishment in 1975, and large fires in 1917, 1918, 1923, and 1936 collectively burned more than 44,000 ac. (18000 ha) (Coffman et al. 1980).

From the estimated current vegetation coverage of the park, 35,000 ac. (15,000 ha, 28%) would not burn except under extreme drought. These vegetation types include bogs, fens, and northern conifer, hardwood and shrub swamps. The remaining 99,000 ac. (40,000 ha, 72%) would be considered burnable during a normal fire year.

Table F-1. Estimated pre-settlement and current vegetation cover.

Vegetation Type	Pre-settlement* area, %	Pre-settlement area, ac	Current** area, %	Current area, ac
Jack Pine Forests, Barrens and Openings	40	53,708	15	20,653
White and Red Pine	30	40,280	12	15,906
Aspen-Birch	20	26,853	38	51,061
Conifer / Hardwood Swamp	5	6,711	12	15,587
Un-treed Marsh/Wet Meadow/Shrub Swamp	5	6,714	15	19,463
Other Forest	NA	NA	8	11,330

* Kurmis (1986)

** Hop et al. (2001)

2.4 FIRE REGIME

Prior to European settlement, large and small-scale disturbances determined the vegetation composition and patch size distribution at Voyageurs. These disturbances included insect attacks, disease epidemics, windthrow, extended drought, and fire. Heinzelman (1973) conducted an intense fire history study of the nearby BWCA estimating the average return intervals for various communities. This currently is the most applicable data available for fire regimes at Voyageurs though not all forest communities were included in his research (Table F-2). The estimated interval for stand replacement fires in jack pine and upland black spruce is 50 to 75 years, 70 to 110 years for spruce/fir/aspen (mixedwood) forests, and 150 to 250 years for white and red pine forests. Low intensity surface fires typically occurred every 20 to 40 years in white and red pine forests. This fire type is not common in the other aforementioned forest communities. Under the natural regime, some stands escaped fire for as long as 350 years while others had intervals as short as 5 years (Heinzelman 1973, 1981). Fires were started primarily by lightning, although Native Americans also ignited fires by accident or to promote ungulate browse, improve berry crops, or reduce brush. Fire return intervals for other forest communities common to Voyageurs NP are also listed in Table F-2.

Past fire suppression has reduced the impact of fire on Voyageurs' forests. The overall average pre-settlement fire return interval of approximately 75 years has now been changed to 1000 years or more. Barring the occurrence of an extreme drought this change will cause forests to succeed to some mixture of spruce, fir, birch, and cedar, with minor amounts of white and red pine. With

drought, large portions of the park may burn in catastrophic fires, resulting in a uniform, even-aged forest comprised mainly of birch and aspen (Jakala 1994).

Prescribed fire, fire use, and fire effects monitoring were initiated at Voyageurs in 1989. Since that time ~4000 acres were burned via prescribed fire, ~1000 acres by wildfire, and 1400 acres by fire use fire. To maintain the natural fire regime approximately 1400 acres will need to be burned every year. Since 1989, the average has been around 400 acres giving a return interval of ~300 years.

Table F-2. Fire return intervals for select forest types occurring at Voyageurs NP.

Community Type	Light Surface Fires	Severe surface fire or crown fire
Red Pine	10 – 40 years ³	150 – 250 years ¹
White pine	20 – 40 years ¹	150 – 250 years ¹
Jack pine	> 100 years ²	50 – 75 years ¹
Mixedwood	> 100 years ²	70 – 110 years ¹
Upland Black Spruce	> 100 years ²	50 – 75 years ¹
Jack Pine/Oak Barrens	< 25 years ²	25 – 100 years ²
Oak savanna/woodland	5 – 10 years	> 1000 years ²

¹ Heinselman (1996)

² Frelich (2002)

³ Frissel (1973)

2.5 DESIRED FUTURE CONDITIONS

There has been much debate and indecisiveness in the Park Service surrounding the establishment of desired future conditions for terrestrial landscapes. Stephenson (1999) compares two widely used approaches to address desired future condition: structural restoration and process restoration. Structural restoration focuses on restoring forests to a particular time period while process oriented restoration restores natural processes, namely fire, with the idea that restoring the process will restore the system. While neither approach is perfect, our knowledge of fire regimes is far more accurate than our knowledge of forest conditions during the past 100 to 300 years, the common time period chosen for restoration. Suffice to say, neither approach will turn back time and managers will need to be content with the fact that landscapes can only be restored to a relatively broad range of conditions considered as “natural”. This broad condition, known as the natural range of variability (NRV), is established based on what we know of plant communities, how they function, and what we know past conditions when human influences were relatively minimal. This serves as the basis for setting goals for the protection and maintenance of ecosystems (Landers et al. 1999). This approach is recommended for use at Voyageurs and is outlined in greater detail in Section 4.2 of this document.

2.6 CLIMATE CHANGE

Given the numerous factors involved in determining the Earth’s climate, CO₂ levels, ice and vegetation coverage (albedo), variations in solar radiation, oceanic circulations, the Earth’s tilt, etc., it is highly unlikely that the exact climate of a particular era will ever repeat itself. It thus follows that the spatial orientation and composition of vegetation on a landscape is also

unrepeatable. Therefore developing goals in the face of climate change may best be focused on establishing ecosystems which are in union with current climate conditions, rather than trying to reestablish some past vegetation condition or perpetuate the current one which was established during a different climate.

It is important to point out that ecosystems are dynamic, not static as often perceived. Paleoecological studies show that the Earth's climate has undergone significant changes in the past 10,000 years causing dramatic shifts in vegetation composition. Many of the large shifts at Voyageurs, and likely elsewhere, were associated with a high incidence of charcoal just prior to the shift (Winkler and Sanford 1998). Vegetation communities tend to lag behind changes in climate until a disturbance, such as fire, facilitates a change in species composition.

Maintenance of an array appropriate community types and their associated species composition, successional stages and spatial distribution, provides the maximum suite of species across the landscape (Heinselman 1973) and ensures that state shifts that do arise will be followed by the establishment of a community composed of native species, not exotics or monocultures (Kennedy et al. 2002). Additionally, systems and landscapes which are more diverse in composition of species and successional stages tend to be more resistant to state shifts caused by drought, fire, and other disturbances (Tilman and Haddi 1992). Fire is considered to be a keystone element in achieving these conditions (Heinselman 1973, Stephenson 1999) and should be utilized on the face of climate change. Most of the plants which may shape the future landscape at Voyageurs are already present however, the dominance of select community types will likely change as has been the case for millennia (Winkler and Sanford 1998).

Temperature predictions for the future clearly point toward increases, however it is not known whether precipitation will increase or decrease, or how consistent precipitation events will be. There are two probable scenarios for the future composition of Voyageur's forests. On a general basis, increased moisture will lead to more closed forests and an increase in hardwood species while decreased or inconsistent precipitation will lead to more open savanna-like forests. Expert opinion suggests the following. The presence of oaks will increase while spruce and fir decrease (Winkler and Sanford 1998, L. Frelich 2007 pers. comm.), and pine coverage may remain more or less as is depending greatly on the future occurrence of catastrophic wind and fire events. Catastrophic fire events can be mitigated now with judicious use of fire.

3.0 DESCRIPTION OF THE ECOLOGICAL MODEL

Four main forest communities are monitored at Voyageurs National Park, jack pine, red pine, white pine and mixedwood. Oak barrens and wet meadows are currently only being monitored within the Section 33 fire use fire perimeter as these types have not been burned via prescribed fire. Successional patterns as influenced by the natural disturbance regime will be described for each community/monitoring type. Important plant species within each type are described as well as the silvical characteristics of the dominant species.

The three plant communities being monitored for short- and long-term effects were chosen based on management objectives and which types were likely to be affected by natural and prescribed fire. Prescribed fire is taking place for ecological and fuel reduction purposes.

3.1 JACK PINE FOREST COMMUNITY

Approximately 20,500 ac (8,300 ha) of the park's forests and woodlands are classified as jack pine. This is only about half of what the historic coverage was (Table F-1), which is cause for concern. Managers hope to use fire to increase jack pine coverage in the park. Currently, many of the park's jack pine stands are beginning to degrade due to windthrow and various pathogens. The once dominate jack pine are thus replaced by spruce, fir, aspen, birch, and cedar; and without a seed source, jack pine cannot be reestablished naturally, even in the presence of fire. Therefore action must be taken prior to stand breakup.

3.1.1 Description

Most jack pines stands in the park originated from the 1936 fire and stands throughout the region originated from severe fires in 1863-4, 1875, 1894, 1910 and 1936. At Voyageurs this type is common on dry to very dry, nutrient poor sites, particularly on ridges having shallow soils. Jack pine is a pioneer species and typically grows in monotypic, even-aged stands. It is considered a short-lived species typically living as intact stands for 100 – 200 years. It regenerates by seed only and can store viable seeds in its serotinous cones for approximately 20 years. Being very shade intolerant, exposed mineral soil and a high light environment are necessary for seed germination and seedling survival (Ahlgren 1960, Chrosiewicz 1974, Carroll and Bliss 1982, Carey 2007). Fire provides these conditions by opening serotinous cones, removing litter and duff, and eliminating the overstory.

Jack pine typically grows as a monotype however Ohmann and Ream (1971) describe 4 sub-communities where jack pine is dominant in the overstory along with oak, balsam fir, and black spruce. The four types are described in detail below.

3.1.1.1 Jack Pine – Oak Community

The jack pine - oak community occurs on xeric sites characterized by shallow soils (< 6") over bedrock and low species diversity. Common woody species include bush honeysuckle (*Diervilla lonicera*), beaked hazel (*Corylus cornuta*), blueberry (*Vaccinium angustifolium*, *V. myrtilloides*), and wintergreen (*Gaultheria procumbens*). Non-woody species include bracken fern (*Pteridium*

aquilinum), Canada mayflower (*Maianthemum canadense*), large-leaved aster (*Eurybia macrophylla*), broom mosses (*Dicranum polysetum*, *D. montanum*), Schreber's moss (*Pleurozium schreberi*), and reindeer lichens (*Cladina randiferina*, *C. stellaris*) (Ohmann and Ream 1971).

3.1.1.2 Jack Pine – Fir Community

The jack pine - fir community differs from the previous in that it occurs on deeper soils having greater available moisture. The presence of jack pine on such sites is indicative of a fire regime which allows it to dominate. These sites are highly diverse and contain several species of ferns, buckwheat, and horsetails not found on other jack pine sites (*Osmundaceae*, *Polygonaceae*, and *Equisetaceae* respectively). Along with balsam fir, aspen, paper birch, and black spruce are also common. In order of decreasing importance the following shrubs are present: bush honeysuckle, beaked hazel, mountain maple (*Acer spicatum*), green alder (*Alnus crispa*), juneberry (*Amelanchier* spp.), and willow (*Salix* spp.). Low shrubs, though not abundant, include blueberry, dewberry, (*Rubus flagellaris*), wintergreen, prickly rose (*Rosa acicularis*), pipsissewa (*Chimaphilla umbellata*), and creeping snowberry (*Gaultheria hispidula*). The well developed herb layer includes large-leaved aster, Canada mayflower, bunchberry (*Cornus canadensis*), twinflower (*Linnaea borealis*), and blue-bead lily (*Clintonia borealis*) (Ohmann and Ream 1971).

3.1.1.3 Jack Pine – Black Spruce Community

The third community type includes black spruce as a co-dominant overstory species. Black spruce actually outnumber jack pine and are more consistent through the stand, however the jack pine dominate in terms of basal area. Soils are between 2 and 3 feet deep over bedrock with large boulders often present. It is similar to the fir community in terms of understory species composition however, the low shrub layer is more developed dominated by blueberry and the herb layer is dominated by bunchberry. In some stands red and/or white pine may be more important than jack pine (Ohmann and Ream 1971).

3.1.1.4 Black Spruce – Jack Pine Community

The last community black spruce – jack pine is characterized by a thick carpet of moss and a poorly developed shrub and herb component. Again black spruce out-number jack pine however jack pine are much larger and account for more than 50% of the overstory basal area. Soils are 18 – 24 inches deep and boulders are a major feature. Common mosses are Schreber's and plume feather mosses (*Ptilium crista-castrensis*) and Dicranium moss. The understory shrub and herb composition is similar to the other types however none are particularly abundant (Ohmann and Ream 1971).

3.1.2 The Fire Regime and Succession (Figure F-1)

The common fire return interval for jack pine types in this region is 50 to 75 years. After fire, jack pine grows rapidly and often forms dog-hair stands of seedlings which can burn again in as little as 10 years (Fig. F-1). It readily replaces itself if burned at intervals of 20 to 120 years,

however shorter intervals often cause a community type shift to one dominated by sprouters such as aspen, birch, maple, and oak. In stands older than 100 years, invasion of spruce and fir is well advanced in the understory. Mortality of overstory jack pine increases due to windthrow and insect attacks, however scattered individuals will remain for 200 – 250 years (Heinselman 1973). The absence of fire for more than 200 years will lead to a spruce/fir/birch/cedar community or a black spruce – feather moss community (Ohmann and Ream 1971). These systems can theoretically perpetuate themselves indefinitely however attacks by spruce budworm and periodic drought will inevitably allow fire back into the system. The site will then regenerate to aspen/birch or black spruce with a small component of jack pine.

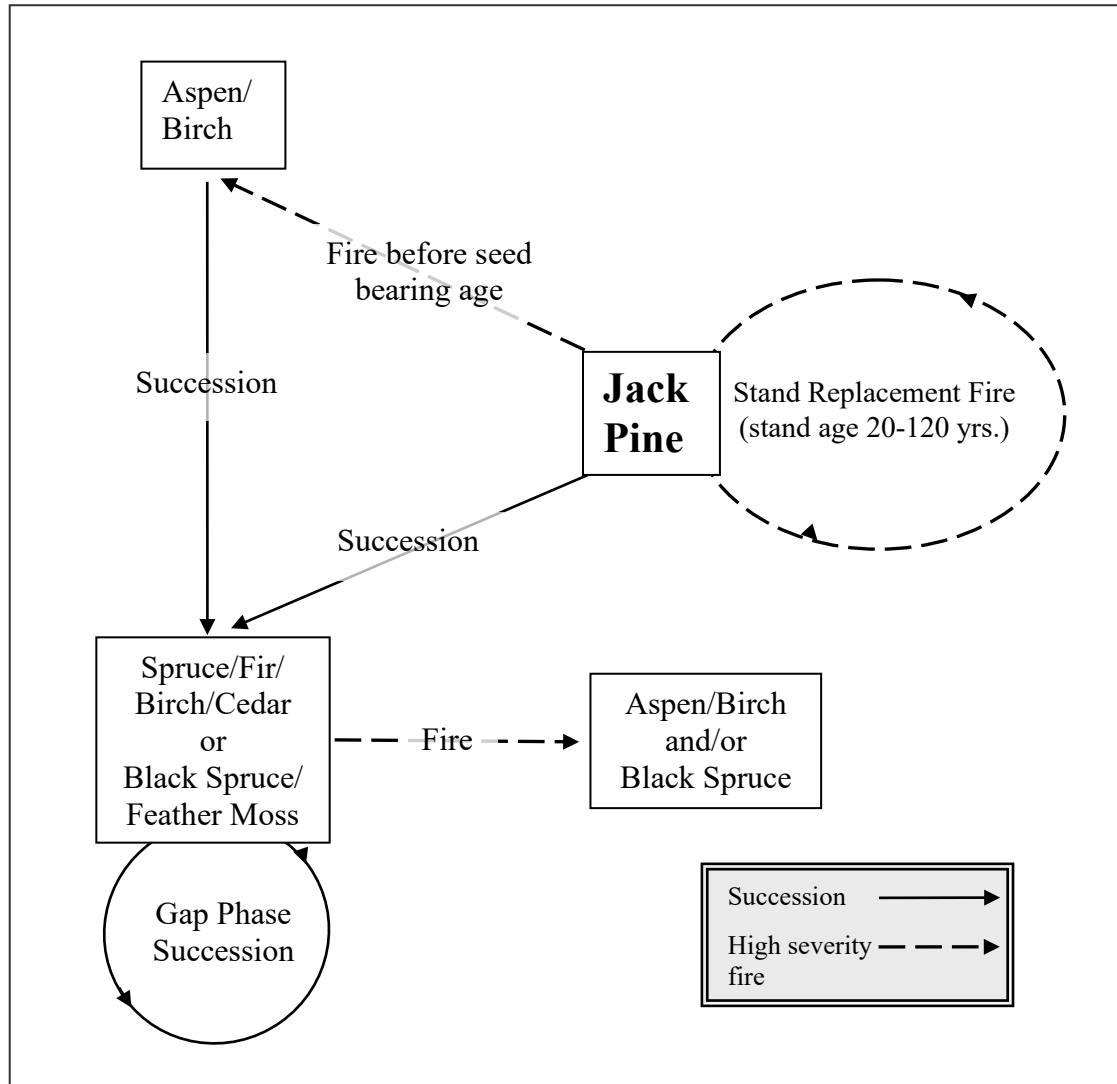


Figure F-1. Ecological model for the Jack Pine Forest Community.

Adapted from Frelich (2002) and Heinselman (1973).

3.1.3 Restoration with Prescribed Fire

Past prescribed burns in the park have been unsuccessful at regenerating jack pine. Burn objectives for this type must include opening serotinous cones, removing the overstory, and exposing mineral soil. The serotinous cones must be exposed to temperatures of at least 200°F

before the resin melts and cones are opened (Beaufait 1960). Stands that are underburned without successfully opening the cones, but kill and/or cause trees to tip over should be re-burned as soon as possible before the seed rots. However cones contained in slash piles may not produce viable seed due to long exposure of seeds to high temperatures (Beaufait 1960). Fire-Use fires will be the most efficient means to regenerate this type, as they are allowed to burn under much broader prescriptions. Prescribed fire may accomplish regeneration if much of the overstory has already fallen allowing for single tree and group torching without the risk of crown fire. Spring fires in jack pine have proven to be ineffective at regenerating this species at Voyageurs. Springs fires may be intense enough to torch overstory jack pine but they rarely remove the duff layer which is needed to expose the mineral soil. The Hoist Bay prescribed burn is good example of this (visit the VOYA 30 monitoring plot).

3.2 RED AND WHITE PINE FOREST COMMUNITIES

The red and white pine type covers approximately 15,902 ac. (6,440 ha) at Voyageurs. Within the park, red and white pines often occur together and pure stands of these species are uncommon. They are often found on islands and along the north, east, and southeast shores of lakes, streams, and wetlands where they are protected from severe fires commonly approaching from the southwest (Heinselman 1973, Swain 1973). Generally, this stand type is more common in the south and east portions of the park where soils are shallower.

Resource managers are concerned that in the absence of fire these types will succeed to hardwood mixes. The coverage of red and white pine was reduced significantly in the region by widespread logging of these species prior to 1930. The removal of pine seed sources subsequently led to the conversion of many stands to hardwoods (Heinselman 1981, Heinselman 1996).

3.2.1 Description

Red and white pine, differ somewhat in their ecology, so their descriptions will be discussed separately.

3.2.1.1 Red Pine

Red pine stands usually occur on dry nutrient poor to nutrient medium sites. Red pine often shares dominance with white pine in the overstory. Common understory tree species include red maple, red oak, paper birch, and jack pine. Balsam fir, white and black spruce, and white cedar may also be present. The tall shrub layer typically contains beaked hazel, green alder, and junberry but the layer is not normally very dense. The ground vegetation is often sparse, dominated by blueberry, sweet fern (*Comptonia peregrina*), large-leafed aster, and wild sarsaparilla (*Aralia nudicaulis*). Less abundant are bearberry (*Arctostaphylos uva-ursi*), wintergreen, and pipsissewa. Mosses and lichens can cover 50% of the surface and include broom mosses, Schreber's moss, reindeer moss, and lichens (Ohmann and Ream 1971, Rudolf 1990).

Red pine owes its persistence on a site to its longevity and periodic fire. Fire is needed for regeneration as it reduces competition, prepares a mineral soil seed bed, and creates canopy gaps. These requirements lead to relatively even-aged cohorts. Though red pine only produces a good seed crop every 3 - 7 years (Rudolf 1990), favorable conditions for cohort establishment can last for 10 to 20 years following fire (Bergeron and Brisson 1990, Heinzelman 1996). Thirty-five to 60% canopy closure is optimal for regeneration and recruitment (Shirley 1932). This is quite thin, looking much like a savanna or city park. Historically, during a normal fire year, regeneration likely occurred in patches where small areas of the overstory were killed, therefore the entire stand may not have regenerated all at once, or no regeneration may have occurred at all. During drier years, hotter fires may have killed much of the overstory causing even-aged regeneration throughout the stand. The fire that burned Shoepack Island in 1980 shows this well.

3.2.1.2 White Pine

White pine occurs on moist nutrient-medium sites to dry nutrient-rich sites, but is also commonly found as an associate of red pine, on the very dry nutrient poor sites described earlier. Due to fire suppression and the removal of seed trees via logging, aspen, paper birch, and boreal conifers now, almost exclusively, dominate the deep soil, moist sites. White pine is thus often relegated to drier sites. White pine can grow up to 140 feet tall in the region, and therefore occupies canopy and super canopy positions giving stands a two-layered appearance. Historically, white pine occurred in semi-pure stands, as well as a scattered super-canopy tree within the mixedwood type. Balsam fir dominates the seedling and saplings classes but jack pine, red maple, paper birch, aspen, black spruce, and white spruce are also common. The tall shrub layer is relatively open and includes beaked hazel, mountain maple, junberry, and downy arrowwood (*Viburnum rafinesquianum*). Due to fire suppression this layer has become very dense in places. Ground vegetation includes bush honeysuckle, blueberry, bracken fern, prickly rose, large-leaved aster, wild sarsaparilla, Canada mayflower, bunchberry, and various graminoids (Ohmann and Ream 1971, Carey 2007).

White pine is a mid-tolerant species (with reference to shade), and unlike red and jack pine, stands tend to be more uneven-aged, not requiring exposed mineral soil for germination or a high light environment for survival. Germination can occur in as much as 2 inches of duff (Smith 1951) and optimal height growth occurs at 45% full sun (Shirley 1945). Given this, disturbance is not necessary for germination. However, for successful establishment of a new cohort, disturbance is necessary and it should be proximal with a bumper seed crop, which occurs every 3 to 5 years. Stand establishment typically takes 20 to 30 years (Frelich 2002), with germination tapering off over time. Germination and survival depend largely upon litter type, light availability, blister rust (*Cronartium ribicola*), and deer browsing. Hardwood litter and dense shrub cover greatly inhibit germination and survival, respectively (Weyenberg 2001). Competition and white pine blister rust appear to be the two most important factors regulating white pine survival and subsequent recruitment at Voyageurs (Personal observation).

3.2.2 The Fire Regime and Succession (Figure F-2)

The fire regimes for red and white pine are very similar at Voyageurs, characterized by frequent surface fires and infrequent crown fires with red pine stands burning more frequently than white

pine. Observations of fire frequency for low severity surface fires by Heinselman (1973) ranged of 5 – 100 years. The average frequency for red pine is in the range of 10 – 40 years (Frissell 1973, Heinselman 1973) (Fig. F-2). The lower bound frequency for white pine is slightly longer with a range of 20 – 40 years. These periodic surface fires can perpetuate the stand indefinitely, barring other disturbances such as logging or windthrow. Additionally, these fires will thin pine saplings, which need 30 to 50 years to develop fire resistant bark (Heinselman 1996). A windthrow event is not disastrous in the presence of periodic surface fires as the understory, consisting of mainly pine with some hardwoods, will be released. The stand will then progress to a state similar to the previous one. Extended periods without fire allow invasion of spruce and fir, increasing future fire severity eventually resulting in a stand replacement fire. Stand replacement fires occur every 150 – 200 years and 200 – 250 years for red and white pine respectively. Without the presence of a nearby pine seed source, the stand will convert to aspen birch forest. With a pine seed source the stand will be mixed pine and hardwoods. Due to the longevity of red and white pine, stands may persist without fire for 400 – 500 years (Heinselman 1973). However, as stands age and break apart, due to windthrow and disease, the pines are slowly replaced by invading shade tolerant species, such as white spruce, balsam fir, and white cedar, which will eventually dominate in the absence of fire.

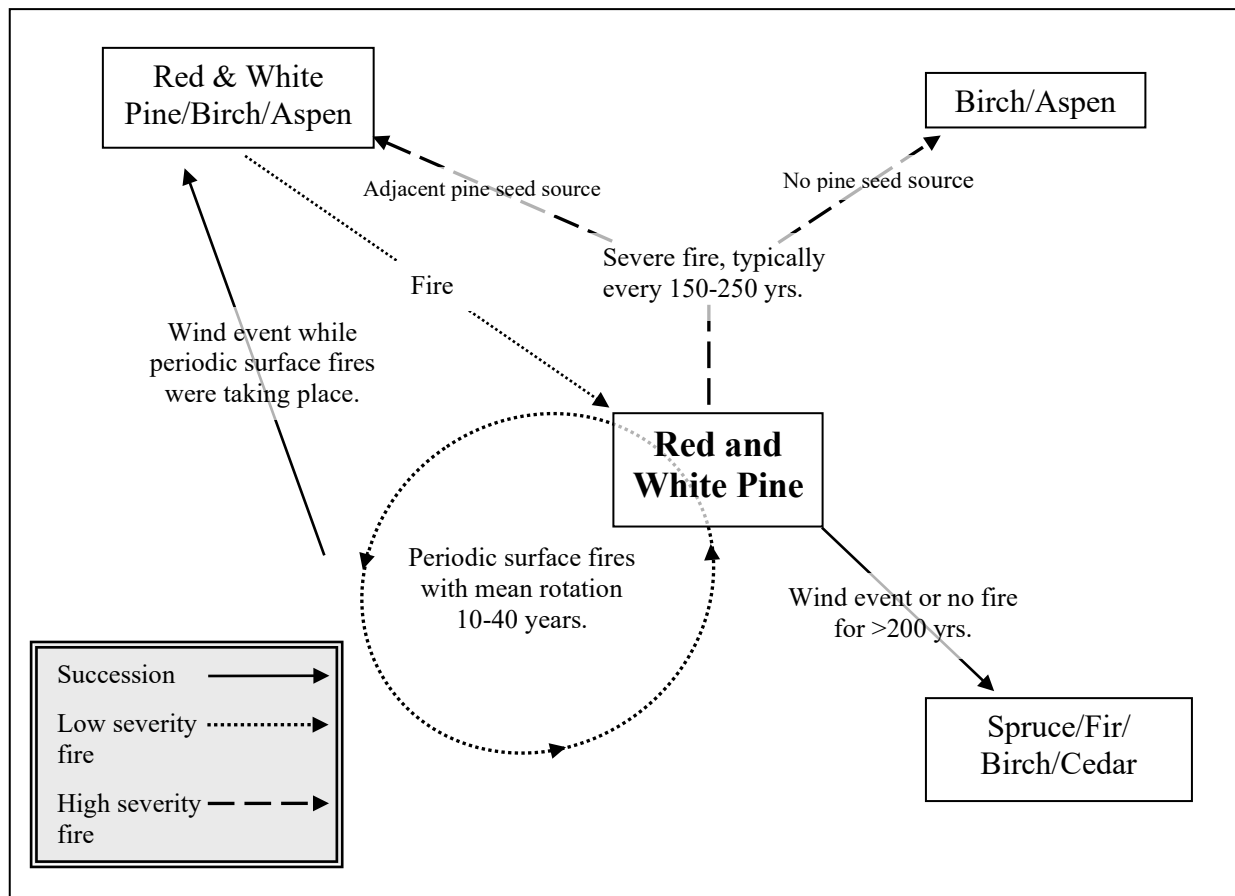


Figure F-2. Ecological Model for the Red Pine – White Pine Forest Community.
Adapted from Frelich (2002).

3.2.3 Restoration with Prescribed Fire

3.2.3.1 Red Pine

For successful red pine regeneration and recruitment, prescribed fires must achieve the following objectives: expose mineral soil, reduce understory competition, and kill portions of the overstory (Van Wagner 1971). Multiple high frequency burns will often be necessary to restore the stand structure without excessive mortality to the overstory. Prescribe fire experiments undertaken by Van Wagner (1963) and Buckman (1964) give some parameters for underburning red pine to achieve the above objectives.

Partial removal of the duff layer to exposed mineral soil was achieved when duff moistures were below 60%, however for substantial removal of the humus layer achieving greater than 50% cover of bare mineral soil, moisture levels should be around 15 – 20 % (Williams 1958, Van Wagner 1963). If the duff layer is excessively deep, caution should be observed in removal of the duff layer during dry conditions. This may cause excessive heat penetration into the soil, girdling tree roots and potentially killing much of the overstory. It may also expose fine roots, which moved into the duff layer during the fire exclusion period, thus killing the trees through desiccation. This has been a problem with the re-introduction of fire in western ponderosa pine (*Pinus ponderosa*) stands where large amounts of duff have accumulated around tree bases. To successfully expose mineral soil without killing the large amounts of the overstory, multiple low intensity burns are recommended, limiting heat penetration and allowing fine roots to establish further down prior to the next fire. This has not been problematic in this region as yet, however most burns are done during the spring when duff moistures are high and consumption is low. Additionally, duff accumulation around tree bases is not nearly as deep in this region as it is in western ponderosa pine stands (6" vs. 12"+).

Reduction in competition from beaked hazel is strongly related to fire frequency, season, and depth of burn. Buckman (1964) experimented with fire frequency and seasonality finding significant reductions in hazel density and volume through annual and biannual summer (June) treatments. Conversely, significant increases were found following spring (April) treatments. Over 40 years after the experiment, the reduction is still apparent on summer treatment plots while spring treatments still show the increase (Kern 2006). Van Wagner (1963) found similar reductions with a single severe fire and with two consecutive light severity burns. These reductions are tied to the depletion of root reserves associated with summer burns and increased depth of burn associated with lower duff moistures in the summer.

Mortality in red pine associated with burning is often attributed to crown scorch not cambial damage, i.e. girdling. Mortality generally occurs when 75% or more of the crown is scorched but this varies depending on the phenologic stage of the stand (Van Wagner 1971, Rudolf 1990). Van Wagner (1971) concluded that red pine can survive surface fire intensities of approximately 500 Btu/sec-ft and are relatively untouched by intensities of up to 200 Btu/sec-ft (approximately 2 – 4 ft flame lengths). It is necessary however that small portions of the stand be killed to ensure regeneration. He maintains this can be achieved through variability in severity across the burn. This creates an overlap in age classes securing red pine's dominance on the site (Van Wagner 1971 and Heinzelman 1996). This is an important point given that much of the overstory must be removed to accommodate the high light requirements for germination and recruitment. Attempting to regenerate smaller portions of a stand is more prudent and visually

appealing than attempting the entire stand. If one were to attempt to regenerate an entire stand, seed source density and seed dispersal distance must be considered (Weyenberg et al. 2004).

3.2.3.2 White Pine

White pine is less restrictive in its regeneration requirements than red pine and success can be achieved with far less difficulty. In general the same principals mentioned for red pine can be applied for white pine. White pine stands tending to occur on wetter sites will have more competition from shrubs, hardwoods, and balsam fir than what is found on a typical red pine site. For this reason multiple burns are also recommended here. Initial burns should be spring burns if the balsam fir density, shrub cover or fuel loading is unusually high. Spring burning will reduce fuel loading and fir density without scorching the overstory since early burns are generally of low intensity. Also, in stands containing dense shrub coverage summer burns may not be possible after leaf out due to the dense shade. Initial efforts should focus on restoring physical stand attributes that allow for successful regeneration and recruitment rather than on germination. This includes controlling red maple, balsam fir and beaked hazel, reducing duff depth and total crown coverage, and removing the tangle of dead balsam left from the first burn. Though exposed mineral soil is not necessary for white pine regeneration, it does help immensely.

Forty-five percent of full sun is recommended for regeneration and growth. Increased growth can be achieved at higher light levels however due to the biology of two pathogens moderate light levels are preferable. A more closed overstory prevents dew from settling on regeneration thus decreasing the occurrence of blister rust. Additionally, too much light increases the terminal leader diameter and increases attacks of white pine weevil (*Pissodes strobi*) (McRae et al. 1994), however this is merely a minor setback and the trees are not severely damaged.

Decisions concerning restoration of red and white pine systems should be made on an individual stand basis, given the numerous factors regulating the success of treatments. Although summer burns are recommended for control of brush and hardwoods, it may not always be prudent during the restoration phase. After restoration, more generic objectives and prescriptions may be established across numerous sites. It is important to note that although regeneration of the next stand should be considered in planning, it is not always the objective of each individual burn.

3.3 MIXEDWOOD

The mixedwood community described for Voyageurs encompasses a variety of communities described by other authors (Heinselman 1996, Ohmann and Ream 1971, Hop et al. 2001, Frelich 2002) namely, aspen-birch, aspen-birch-boreal conifer, birch-fir, maple-aspen-birch, spruce-fir-aspen, and spruce-fir-birch-cedar. Each of these can be considered a different successional stage of the same community with some variation. An early and a late successional stage are discussed below, those being aspen-birch and spruce-fir-aspen community types respectively. They are the most abundant types in the park due in part to soil type, the park's logging history, and the lack of recent fire on the landscape.

Many stands in these types once contained scattered super-canopy and canopy white, red, or jack pines prior to logging. Whether these stands were once dominated by pine and underwent conversion via removal of the pine seed source and succession, or were always mixedwood stands containing scattered pines, is debatable. Nevertheless, managers are interested in restoring and maintaining the presence of pine in some mixedwood stands. Therefore, stands that are of most interest, from a monitoring standpoint, are those that still contain or have a nearby red, white, or jack pine seed source. Resource managers are concerned that these stands will soon lose the pine seed source thereby eliminating pine from the community indefinitely.

3.3.1 Description: Aspen-Birch & Spruce-Fir-Aspen

These forest communities occur over a wider range of site conditions than any other forest community in the park. Together they cover approximately 51,000 acres (20,500 ha) in the park, occurring under nearly all site conditions except for the very driest and wettest.

Both types have similar species assemblages. Major deciduous species are trembling and big-tooth aspen, paper birch and red maple. Trembling aspen is often the most abundant species in early successional stages while big-tooth aspen, paper birch, and red maple are common minor associates. Species considered late successional such as balsam fir, northern white cedar, and black and white spruce are usually present, though not abundant, during the early successional stages. By the later successional stage, stands consist mainly of balsam fir with lesser components of aspen, birch, spruce, and sometimes cedar. White pines naturally occurred as isolated super-canopy trees, though their presence is now quite rare. Isolated red and jack pines may also occur in the overstory as remnants of previously logged stands. However, isolated occurrences of these two species are not uncommon. Shrub cover is often dense especially on rich sites, with beaked hazel being the most abundant tall shrub followed by mountain maple, round-leaf dogwood (*Cornus rugosa*), and green alder. Low shrubs are not always abundant and consist of bush honeysuckle, blueberry, and dewberry. Depending on shading and site physiography, the ground layer varies in abundance and diversity. Moist and more open sites are more abundant containing numerous herbs. Large-leaved aster is normally most abundant with wild sarsaparilla, bluebead-lily, star flower (*Trientalis borealis*), twisted stalk, lily-of-the-valley, ground pine (*Lycopodium dendroideum*), and club moss (*Lycopodium* spp.) being very common. As conditions become drier and more nutrient poor, blueberry, bracken fern, veiny pea (*Latyrus venous*), and bunchberry become the most abundant species. In later successional stands the coverage of Dicranium and Schreber's mosses tend to increase, while the herb layer becomes sparse, though still having many of the same species (Ohmann and Ream 1971, Heinselman 1996).

3.3.2 Fire Regime and Succession (Figure F-3)

The natural fire regime is one of stand replacement fires every 70 to 110 years (Frelich 2002). Beginning with an aspen-birch early successional stage, spruce and fir present in the stand will increase in abundance over time moving the stand progressively through each successional phase (Fig. F-3). After 70 - 80 years, the overstory aspen and birch trees begin to break apart due to insects, disease, and windthrow. The conifers are usually well established in the understory at this point and will soon assume dominance in the overstory. The stand becomes more

susceptible to fire and spruce budworm attacks as conifers increase in abundance. Periodic outbreaks of spruce budworm will kill much of the conifer overstory increasing the susceptibility to fire even more. After a stand replacing fire, the stand typically retains the composition of the former parent stand, however with a greatly shifted dominance. Assuming birch, aspen, and maple were relatively abundant in the pre-fire stand, the post-fire stand will consist of a dense thicket of birch, aspen, and maple sprouts with scattered spruce, fir, and pine. The abundance of the latter species depends greatly on the availability of nearby seed sources typically in unburned patches. In the absence of fire, the spruce-fir-birch-cedar type is self-perpetuating through gap phase succession.

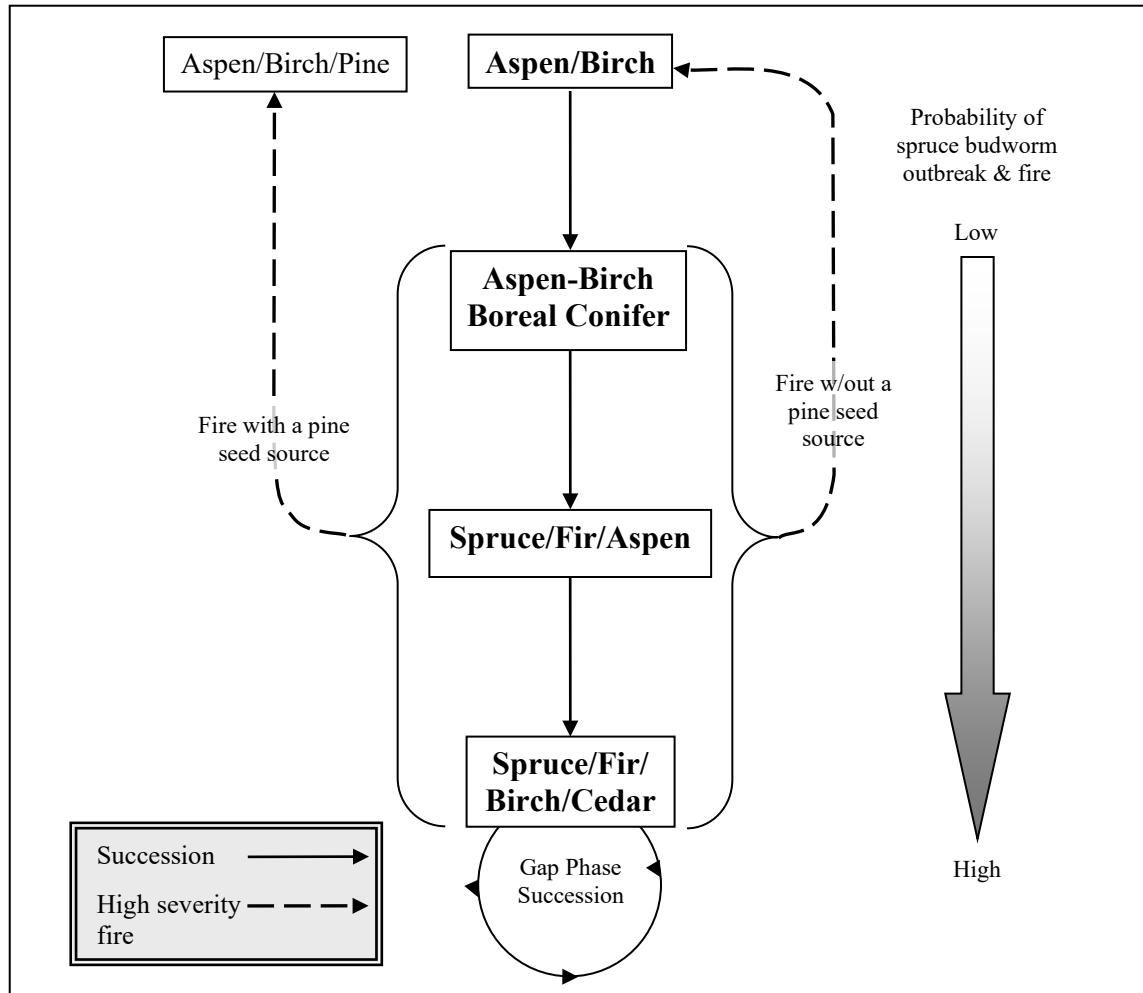


Figure F-3. Ecological Model for Aspen-Birch and Spruce-Fire-Aspen Communities.
Adapted from Frelich (2002).

3.3.3 Restoration with Prescribed Fire

In most cases it would not be prudent to burn this type under conditions that do not support a stand replacement fire since mortality of the overstory is needed to regenerate the stand. Shading and lack of carrier fuels typically prevent surface fires anyway.

In some areas this type has replaced pine dominated types as a result of logging. Restoring the dominance of pines to these areas will be difficult. Under the natural stand replacement fire regime jack pine and red pine may seed in and regain dominance on drier sites. On moister sites and where fire has been absent for some time, white pine can invade sporadically into the understory in favorable areas. As the birch and aspen fall out of the overstory due to windthrow and natural decline, the balsam fir and spruce suppress suckering and sprouting aspen birch. Also, due to the old age of the parent trees sprouting is not as prolific. White pine may recruit into the overstory after sufficient time. Burning the stand with high intensity or before the advanced growth of white pine is fire resistant, will likely regenerate the stand back to aspen and birch. Theoretically, if the stand is burned at low intensity after the pines are fire resistant the stand may shift toward a more pine dominated community. Climatic conditions, particularly the occurrence of drought, will likely be the deciding factor in regulating shifts in species dominance.

3.4 UN-FORESTED WETLANDS

The state of knowledge regarding fire in un-forested northern wetlands, such as those at Voyageurs, is sparse. Local knowledge from qualified experts is based on intuition and is inferred through knowledge of related systems, since few if any formal studies have taken place in the region (N. Aasing, J. Almendinger, and A. Harris 2004 pers. comm., J. Meeker 2005 pers. comm.). Regional information can be garnered from informal accounts where fire has been re-introduced into wetlands in varying degrees, e.g. Chippewa N. F., Crex Meadows Wildlife Area, and our own park. Most of the formal studies on fire in wetlands take place in the Southeastern U.S.

Six wetland groups were identified in the VOYA vegetation mapping project (Hop et al. 2001). These include bogs, northern shrub and graminoid fens, wet meadows, marshes, and northern conifer and hardwood swamps. Fire frequency varies widely among these types, therefore not all need to be considered for burning. Based on fire frequency and prudence, the two types that can realistically be considered for burning are the northern shrub and graminoid fens, and wet meadows. Of these two, the wet meadow type is by far the most abundant at VOYA and has a relatively high fire frequency. Therefore, only this type will be considered further.

3.4.1 Description: Wet Meadow

The Minnesota DNR classifies the wet meadow type as the Wet Meadow/Carr system (Aaseng et al. 2003). This consists of two sub-types, sedge meadow (wet meadow) and willow-dogwood shrub swamp (shrub carr). They typically have a fluctuating water-table; often times associated with beaver activity, and can develop from flooding lowland forests or drying of marshes (Aaseng et al. 2003).

Wet meadow types provide habitat for over 70 vertebrate wildlife species (Sprang, 2002). The sedge type, being more floristically diverse than the shrub type, provides forage, while the latter being more structurally diverse provides nesting habitat. Therefore, neither should be excluded. However, their dominance on the landscape should not necessarily be equal.

3.4.1.1 Sedge Meadow

The sedge meadow type is dominated by wide-leaved graminoids including Canada bluejoint (*Calamagrotis canadensis*), lake sedge (*Carex lacustris*), tussock sedge (*C. stricta*), and beaked sedge (*C. utriculata*). Shrub cover is less than 25% and includes willows (*Salix* spp.), speckled alder (*Alnus incata*), and red-osier dogwood (*Cornus sericea*). Forb diversity varies from low to high depending on the sub-type. Systems dominated by lake sedge, create dense thatch which limits forb diversity. Conversely, in systems where tussock-forming species occur diversity can be high (Aaseng et al. 2003). The graminoid type depends on fire to maintain it in an open condition (Sprang 2002) similar to the case with upland prairies. Periodic flooding and fire prevent invasion of shrubs and trees, however in the absence of either, the community will succeed to a shrub carr.

3.4.1.2 Shrub Carr

Shrub carr type, as mentioned, is a later successional stage of the sedge type and dominate areas where fire has been absent for long periods. Typical shrubs include willows, red-osier dogwood, speckled alder, and spirea (*Spirea alba*). The ground is often void of vegetation beneath dense clumps of shrubs but is dominated by graminoids between the clumps.

3.4.2 Fire Regime

Though not intuitive, wetlands are fire adapted communities (Lugo 1995, DeBano et al. 1998). Therefore, it is not a question as to whether these systems burn, it is a question of how often. Fire frequency in wetlands, as with uplands, varies widely depending on the system and regional climate. Fire frequency increases from treed to graminoid dominated systems (Lugo 1995) and from east to west (Kuhry 1994). Black spruce bogs at Voyageurs have a fire frequency of 100-500 years (Frelich 2002), while graminoid dominated wet meadows in northwestern Minnesota likely burned every 5 to 30 years (Heinselman 1981). Fire frequency for the latter system has not been formally classified for the Voyageurs region but it is likely similar. DeBano et al. (1998) states graminoid dominated wetlands, occurring as inclusions in a forest landscape, typically burn at the same frequency as the nearby uplands. Wetlands do not need to be adjacent to burning uplands, but merely within spotting distance, as the grasses are very receptive to fire brands. Many wetlands have variable moisture regimes and typically burn during low water periods (Wein and MacLean 1983, Lugo 1995, DeBano et al. 1998). These periods can be induced by drought, normal seasonal fluctuations, and changes to the hydrology, e.g. beaver dam blowout. Given drought periods occur in this region approximately every ten years, this seems to be a reasonable maximum fire frequency. However, this does not equate to burning every ten years under prescribed fire conditions.

The diagram illustrates the Wetland Succession Continuum, showing the progression of wetland types based on water table levels and various disturbances.

Water Table Axis: A vertical arrow on the left indicates the water table level, ranging from **Low** at the top to **High** at the bottom.

Succession Continuum: A horizontal arrow on the right indicates the direction of succession, from **Open water** to **Rich or poor fen**.

Wetland Types and Transitions:

- Wet Forest or Forested Peatlands** (Low water table) transitions to **Shrub Carr** via a dashed line.
- Shrub Carr** transitions to **Wet Meadow** via a dashed line, influenced by **Fire interval ≥ 30 years & low water table** (indicated by a dotted arrow).
- Wet Meadow** (containing **Water table at substrate surface**) transitions to **Cattails/Reeds** via a dashed line.
- Cattails/Reeds** transitions to **Deep Marsh** via a dashed line.
- Deep Marsh** transitions to **Open water** via a dashed line.
- Wet Meadow** can transition to **Rich or poor fen** via a solid arrow labeled **Water level fluctuation**, which is **Unstable** (dotted arrow) and **Self sustaining** (solid circle).

Disturbances:

- Beaver damming or catastrophic fire** (indicated by a grey arrow pointing up) leads to **Shrub Carr**.
- Beaver dam breakage** (indicated by a grey arrow pointing down) leads to **Open water**.
- Ground fire** (indicated by a dashed arrow pointing down) leads to **Open water**.

Legend:

- Succession:** Solid grey arrow
- Low severity fire:** Dotted arrow
- High severity fire:** Dashed arrow
- Continuum:** Dashed arrow

3.4.2.1 Model Explanation (Figure F-4)

F-17

causing premature succession to a rich or poor fen. Impoundment by beavers or ground fires on peat-based sites can cause succession to a deep water community and possible invasion of cattails (*Typha spp*) and phragmites (*Phragmites australis*). Conversely, dam breakage in association with the absence of fire leads to a shrub carr community and depending on the substrate, a wet forest such as black ash or a forested peatland usually dominated by black spruce. Regular fire every 10 – 30 years will help maintaining species diversity and thwarts invasion of shrubs along meadow margins.

3.4.3 Restoration with Prescribed Fire

The Chippewa National Forest monitoring data provides some information on the effects of fire on wet meadows (Sprang 2002). Their data shows changes in plant species composition after burning. Diversity is increased on burned sites to include 5 species of sedges and 51 species of forbs. No species appear to be excluded with the introduction of fire. However, light demanding species are excluded on unburned sites due to a heavy build-up of thatch.

Multiple short interval burns tended to reduce the presence of shrubs on the site. Complete eradication of shrubs however, is not recommended, nor is it natural. Invasive species such as reed canary grass and Canada thistle were also reduced, with a concurrent increase in native grasses and forbs.

If performed, the primary objectives for burning wet meadows at Voyageurs should focus on,
1. maintaining the sedge meadow type by inhibiting encroachment of trees and shrubs, and
2. increasing floristic diversity through the removal of heavy thatch.
Each site will need to be assessed individually for more tailored objectives.

3.5 OAK COMMUNITIES

The oak communities at Voyageurs are somewhat unique to the park and have not been researched in depth. Communities include mesic oak forest/woodland and dry oak woodland/barren, which are described separately below.

3.5.1 Descriptions

3.5.1.1 Mesic Oak Forest/Woodland

Mesic Oak Forests/Woodlands occur on the western islands of Lake Kabetogama. The community is disjunct from similar communities occurring in the tallgrass regions from western Minnesota to northeast Nebraska. At Voyageurs it occurs on shallow and deep soils which are mesic to dry-mesic. The overstory is commonly composed of bur oak (*Quercus macrocarpa*), green ash (*Fraxinus pennsylvanica*), red maple, and basswood (*Tilia americana*). The shrub layer density ranges from low to high and commonly consists of service berry (*Amelanchier spp.*), beaked hazel, ironwood (*Ostrya virginiana*), and downy arrowwood (*Viburnum refinesquianum*). The herb layer is well developed and consists of large-leaved aster, wild sarsaparilla (*Aralia nudicaulis*), bracken fern, raspberry (*Rubus idaeus*), and fringed bindweed (*Polygonum cilinode*) (Hop et al. 2003).

3.5.1.2 Dry Oak Woodland/Barren

The Dry Oak Woodland/Barren type is common on ridge tops and south facing slopes with shallow soils and/or exposed bedrock. The overstory is dominated by short scrubby pin oak (*Quercus ellipsoidalis*) and sometimes bur oak. Jack and red pine are common associates, sometimes comprising a majority of the canopy layer. The overstory cover can vary from as low as 30% to as high as 90% depending on the soils and amount of exposed bedrock. Downy arrowwood, beaked hazel, and serviceberry are common tall shrubs. Dwarf shrubs such as blueberry and common juniper are often present. The herb layer is variable in cover ranging from 20 – 80%. Common herbs are bracken fern, wild sarsaparilla, and large-leafed aster. Schreber's and dicranium mosses are sometimes present beneath the canopy and reindeer lichens are common in open bedrock types (Aaseng et al. 2003, Hop et al. 2003).

3.5.2 Fire Regime

Specifics on the nature of fire in these oak systems in the immediate region are not well studied. Fire history of the bur oak mesic forest/woodland and dry oak woodlands/barrens likely differed due to their structure, composition, and position on the landscape.

3.5.2.1 Mesic Oak Forest/Woodland

The current mesic oak forest/woodlands succeeded from land that was grazed and/or had Native American settlements on them. Photos from 1927 reveal that many of the islands and shorelines in western Lake Kabetogema had sparse tree cover and were likely grass dominated. Areas were maintained in this condition through fire and/or grazing. These areas succeeded in the absence of disturbance to the current conditions. Though this type is to some degree the direct result of human manipulation, it mainly differs from a "natural" state by its degraded understory condition.

This type likely burned with low to moderate severity surface fires. The fuels do not support high severity or crown fires, since the mid- and overstory are composed of non-volatile broad-leafed species. The primary fuels are litter and low shrubs. Additionally, most stands are located on islands or in protected areas close to the lake shore and burned independent of large scale stand replacement fires, which characterize much of the landscape. The natural fire frequency has not been specifically researched, however it can be inferred from similar systems in western Minnesota and from pine stands which occupy similar sites in the park. Given this the fire frequency is likely in the range of 5 to 25 years.

3.5.2.2 Dry Oak Woodland/Barren

Dry oak woodland/barren, though similar in structure to the mesic type, likely had a mixed severity fire regime since it typically occurs as an inclusion within the mixedwood jack pine mosaic. Heinzelman (1996) and Ohmann and Ream (1971) found that stands similar to this type in the BWCA were even-aged and dated to the most recent large scale fire event. From the few trees sampled at Voyageurs this appears to be the case here as well. These stands likely burned

collectively with stand replacement fires which consumed adjacent jack pine and mixedwood stands. However, given the structure and composition of these stands and recent observations in the Section 33 fire use fire (Personal observation), the overstory is not always killed. Unless stands are well mixed with jack pine or have an abundant fuel load, the characteristic open structure, light fuel loading and low volatility of the overstory facilitates only low to moderate severity surface fires. The fire regime is likely one of occasional low to moderate severity surface fires every 10 – 40 years with stand replacement fires every 80 – 120 years. Much depends on the site physiography and the nature of adjacent forests.

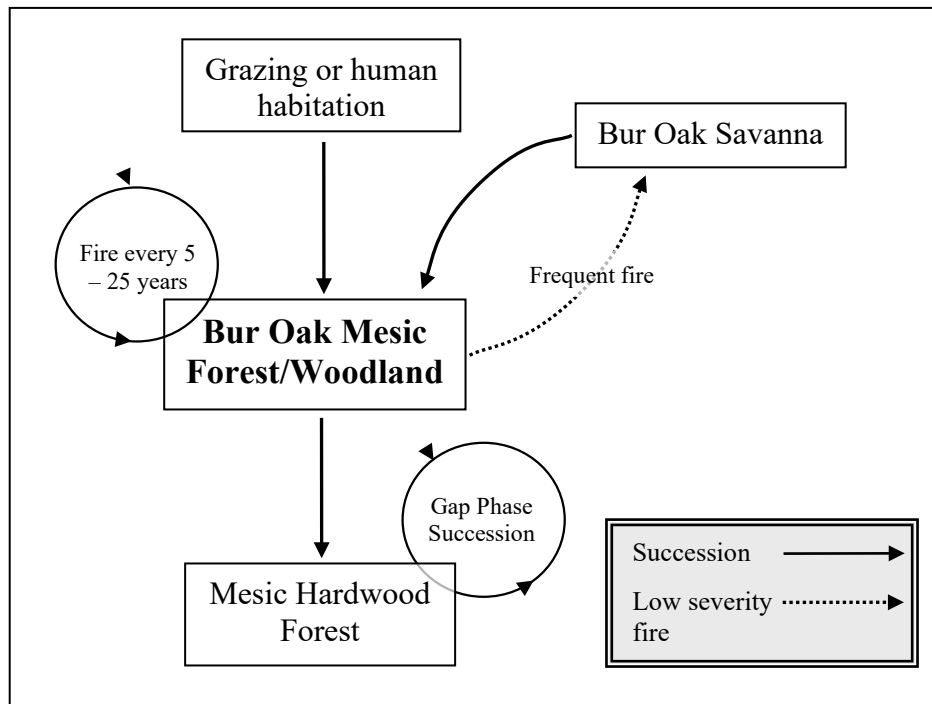


Figure F-5. Ecological Model for Mesic Oak Forest/Woodland.

3.5.2.3 Model Explanation: Mesic Oak Forest/Woodland (Figure F-5)

At Voyageurs this type succeeded from previously inhabited sites and operates much like oak woodlands elsewhere in the Midwest. It is maintained by low to moderate intensity surface fires every 5 – 25 years. A prolonged period of high fire frequency, less than every 5 – 8 years, will eventually convert the site to an oak savanna. This can succeed back to woodland with a longer fire frequency. Lack of fire allows succession to a mesic hardwood forest.

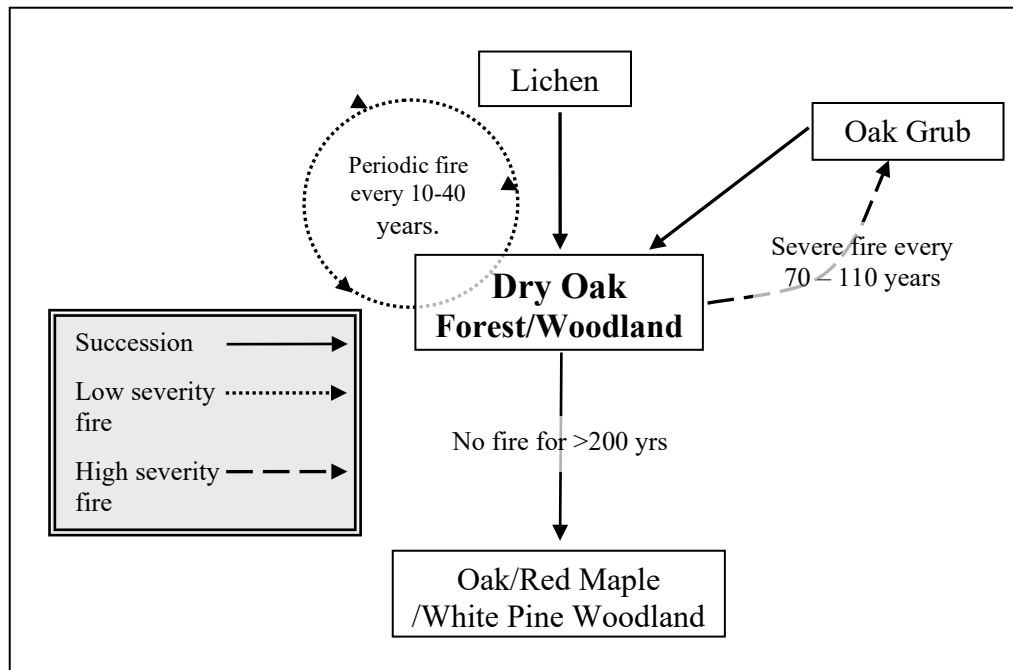


Figure F-6. Ecological Model for Dry Oak Woodland/Barren.

3.5.2.4 Model Explanation: Dry Oak Woodland/Barren (Figure F-6)

Dry oak woodland or barren may succeed from a bedrock lichen community. Both woodland and barren oak communities are maintained through periodic surface fire every 10 – 40 years. Severe fires will cause conversion to an oak grub state, which will eventually succeed back to the former oak community. A prolonged period without fire, about 200 years, will cause succession to an oak/maple/white pine woodland. Changes in the community are not drastic on the dry site due to the harsh conditions and the limited number of species that can occupy such sites.

3.5.3 Restoration with Prescribed Fire

Prescribed fire is recommended to maintain and restore these types. In both mesic and dry community types fire should be applied as low to moderate intensity surface fires. Currently, there do not appear to be any ecological concerns surrounding fire treatments in these types. Fuel loads in most areas are not high and high mortality in the overstory should not be a concern. General objectives on the dry sites should be to reduce mid- and overstory densities. On mesic sites objectives should be to reduce the cover of shrubs and invading shade tolerant hardwoods.

4.0 MANAGEMENT OBJECTIVES

4.1 INTRODUCTION

The park's vegetation has been changed dramatically by humans. Due to uncontrollable factors such as climate change, incomplete records, and limited budgets, we may never know the historic vegetation pattern. Therefore, the park developed management objectives for each monitoring type to help guide the actions toward a result. Knowledge of likely past vegetation of the park and the disturbance regimes for each ecosystem were used as a template for the objectives.

Within the context of vegetation management, the mission is to create a scene similar to what the Voyageurs saw. This encompasses restoring the vegetation structure and composition of the selected types to their "natural" condition. At which point natural processes should sustain the ecosystem with minimal management. Important aspects of the natural condition are selected as management objectives.

4.2 DESIRED FUTURE CONDITION

The "Desired Future Condition" outlined in this plan is based on the Natural Range of Variability for each "Vegetative Growth Stage" or successional stage within a community type. This is a range in the number of acres that is expected to occur on the landscape, and is given as a percent of the total acreage per community type. Since all community types cannot occupy all site types, these percentages are thus applied to the current total acres per each community type. They cannot be applied to the total landscape to determine how many acres of each community type should be on the landscape. The range is computed based on the hazard index for each community (Frelich 1999). This index is a function of the fire return interval and the probability that a stand of type x will burn at age y . This has been determined for the community types found at Voyageurs by Frelich (1999). The growth stages were replaced with ten year age classes as found in Brown and White (2002), which are graphed below. The final result is a stand age distribution that the park or its partners can shoot for on a landscape scale. Though the projected acreage is given for the park in each figure, the results are best considered on a regional basis to include Quetico P.P. and most of northeastern Minnesota. The TNC continues to analyze data for the Border Lakes region to assess the current conditions with the theoretical goals. Though suggestions are made for park level goals, such goals should be determined in concert with regional partners and the entire landscape in mind.

Many of the older age groups cover larger percentages of the landscape than others. This is a result of the later classes encompassing a larger time span and also from the fact that the rate of movement from one growth stage to another is not consistent. Thus, there is an accumulation into certain age classes as compared to others.

Tables F-3 – F-6 present the results of modeling to determine the occurrence of specific vegetation growth stages (VGS). The results show overlapping age classes containing different VGS since different disturbance events produce different vegetation communities. Refer to the ecological models in Section 3 for a visual representation of general pathways for these

communities and more complete explanation of how this occurs. Percents in the tables were rounded to the nearest percent.

4.2.1 Jack Pine Forest Community

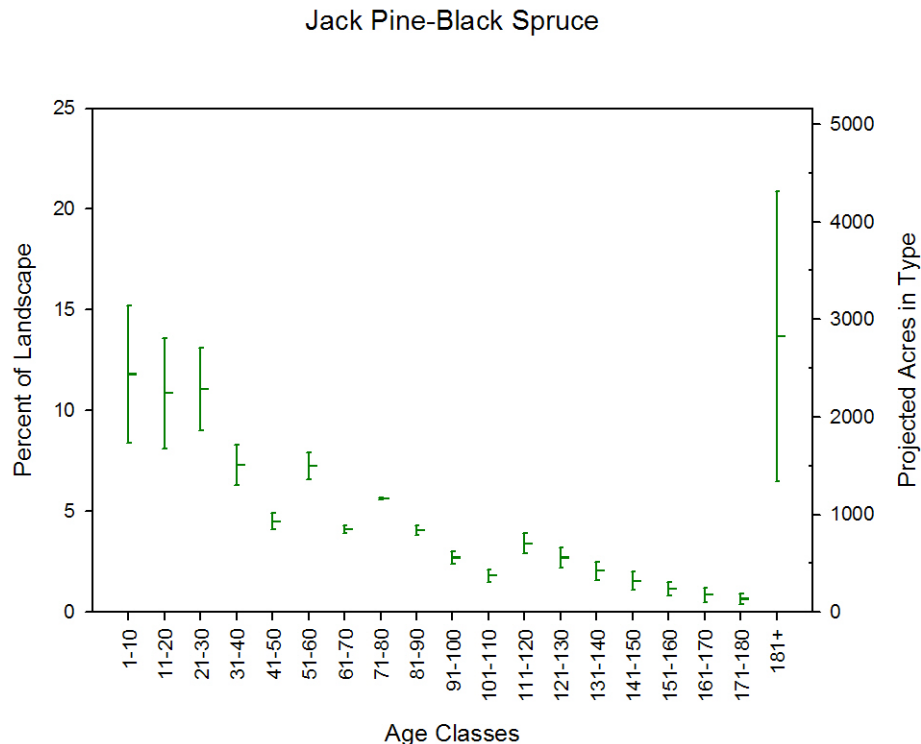


Figure F-7. Age class distribution for jack pine and upland black spruce.

Adapted from Brown and White (2002).

Data for the jack pine upland black spruce type are in reference to dry upland jack pine communities which tend toward mixtures of black spruce, the same as the general jack pine community described in Section 3 of this plan. Based on the current acreage in the jack pine type the figure shows the projected acres in each age class. The percentage of stands occurring in the 181+ year class at Voyageurs will likely be in the lower end of the range since stands usually succumb to windthrow or jack pine budworm prior to achieving such an age (Fig. F-7). Most of the jack pine stands at Voyageurs date to the 1923 or the 1936 fires and therefore fall in the 70-90 year age classes. Very few stands date from either before or after these events and there is a great need to regenerate these younger age classes.

Park Level Goals:

- Increase the acreage by 5 to 10 thousand acres.
- Begin regenerating stands to increase the acreage in the younger age classes.
- Convert, via fire, some mixedwood stands to jack pine.
- Identify bug killed jack pine stands and prioritize those stands for burning within 5 years of mortality.

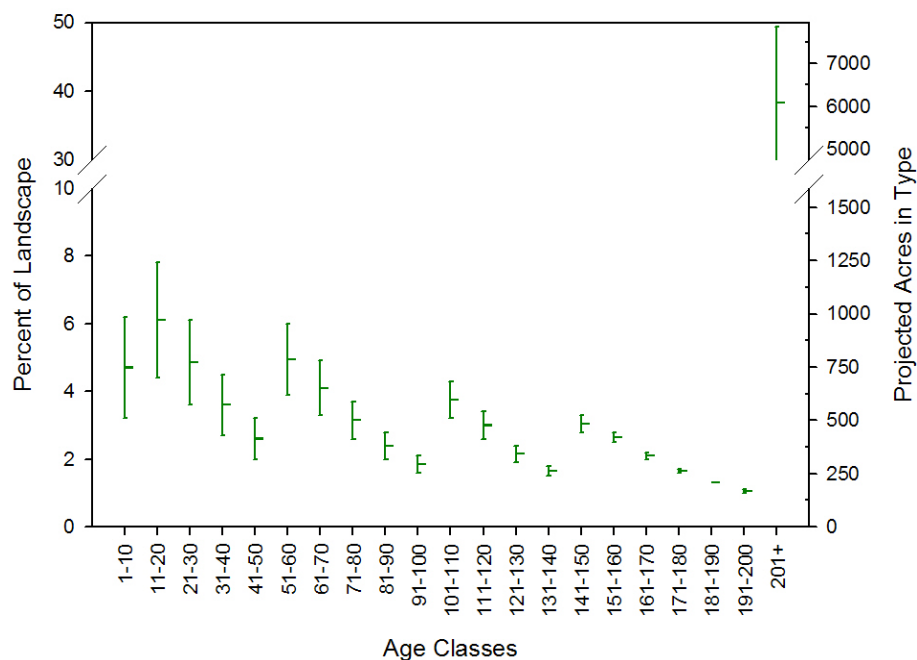
Table F-3. Estimated range of variability for dry jack pine, black spruce.

Vegetation growth stage	Disturbance Event	Age	% Landscape
Seedling jack pine	Fire	1-10	9-17
Sapling jack pine	Fire	11-20	8-14
Pole jack pine	Fire	21-50	19-27
Mature jack pine	Fire	51-70	11-12
Large jack pine	Fire	71-110	13-15
Jack pine-fir-spruce	Fire	111-180	9-15
Multi-aged fir-spruce-cedar	Fire or wind	≥181	7-21
Seedling fir-spruce-cedar	Wind	1-30	0.6
Sapling fir-spruce-cedar	Wind	31-50	0.3
Pole/mature fir-spruce-cedar	Wind	51-80	0.2-0.4

Data taken from Frelich 1999.

4.2.2 Red and White Pine Forest Community

Dry Red & White Pine

**Figure F-8. Age class distribution for dry red and white pine forest.***Adapted from Brown and White (2002).*

The majority of the red and white pine forests at Voyageurs are 80 to 120 years old. Most have not burned in over 75 years giving way to dense undergrowth. There are very few if any stands of red and white pine less than 50 years old found in the park. Again the abundance in the 201+

age class is due this class encompassing 100+ years. Given the age of our current stands large scale regeneration of this stand type would not be appropriate. However, secondary cohorts can be establish within larger stands to create a mosaic of different age classes, thereby increasing stability and producing a more natural stand age distribution (Fig. F-8).

Park Level Goals

- Increase the acreage of this type by 5 to 10 thousand acres through conversion of the mixedwood type.
- Restore the stand structure in current stands.
- Restore a regular fire rotation to prevent further conversion of this type to mixedwood.
- Maintain optimal conditions for pine regeneration to establish secondary cohorts.

Table F-4. Estimated range of variability for dry-mesic red and white pine.

Vegetation growth stage	Disturbance Event	Age	% Landscape
Sapling birch-pine	Severe Fire	0-10	3-6
Pole-mature birch-pine	Severe Fire	11-50	11-20
Mature birch-pine	Severe Fire	51-100	12-18
Mature pine	Severe Fire or wind	101-140	9-12
Multi-aged pine-spruce-fir	Severe Fire	141-200	9-10
Multi-aged spruce-fir	Severe Fire	≥201	24-46
Sapling-pole pine	Wind	0-50	0.6-1.4
Sapling-pole spruce-fir	Wind	0-50	1.2-1.3
Multi-aged white pine	Surface fire	≥121	7.7-8.1

Data taken from Frelich 1999.

4.2.3 Mixedwood Community

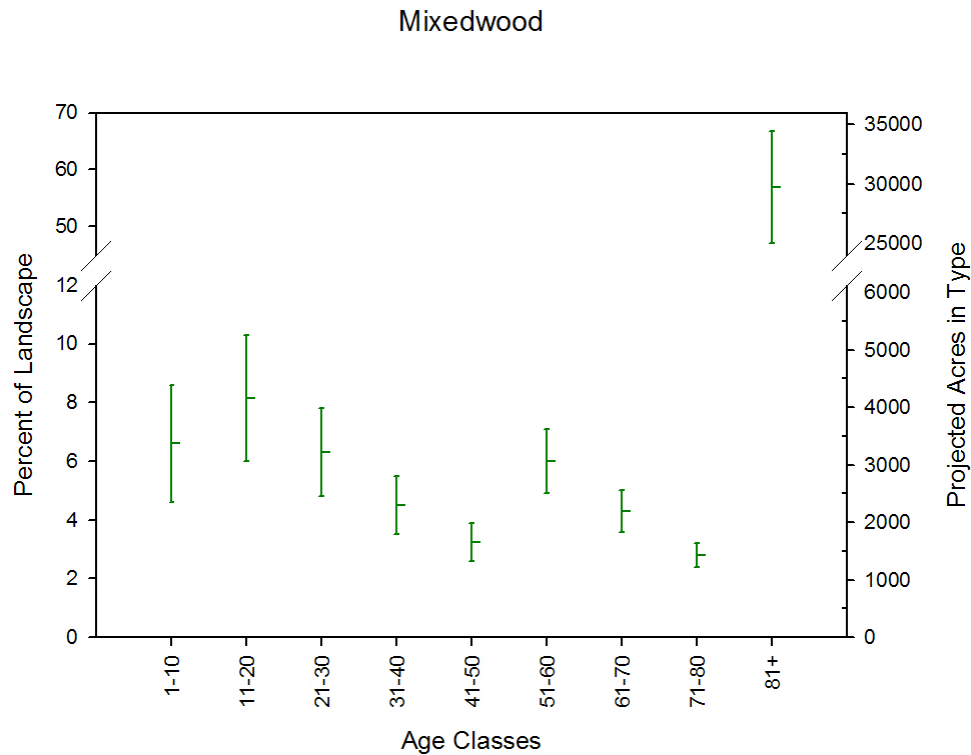


Figure F-9. Age class distribution for mixedwood forest.
Adapted from Brown and White (2002).

The mixedwood type has increased on the landscape, in the park and elsewhere, due to logging in the early 1900's. Current estimated acreage of this type within the park is ~50,000 acres. The age distribution is not clear since pulpwood was logged in the park up until the 1970's. However, most stands originate from the 1923 or 1936 fires, which collectively burned nearly 45,000 acres on the Kabetogema Peninsula. Though many stands likely predate these fires many more will need to be regenerated to acquire a natural age class distribution (Fig. F-9).

Park Level Goals

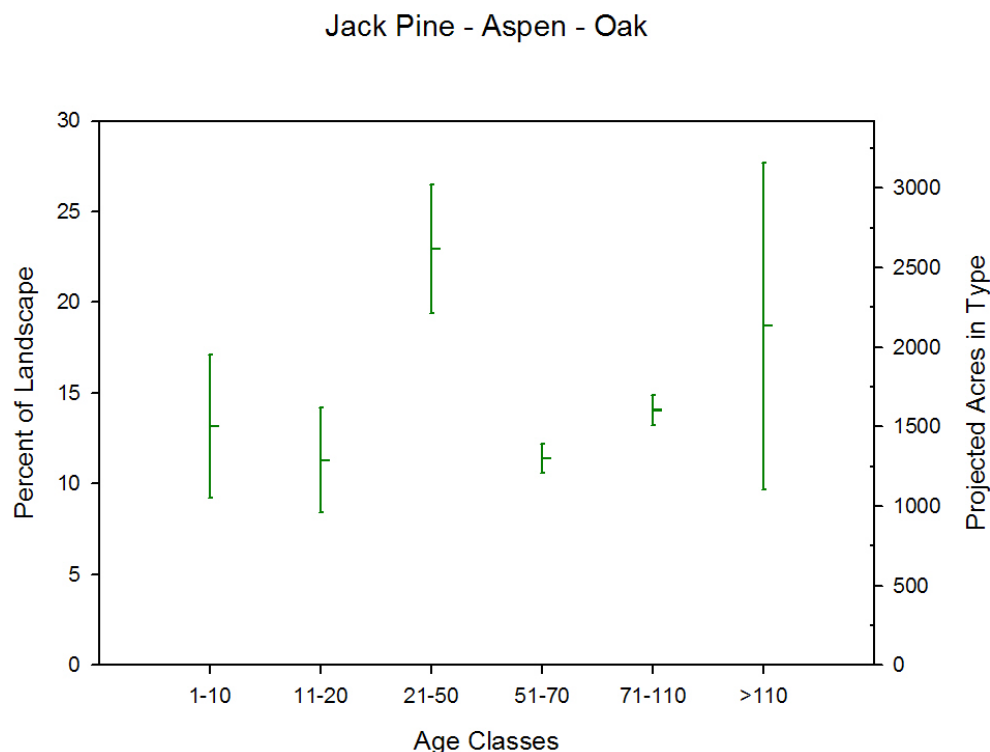
- Reduce the acreage by ~20,000 acres through conversion to other types.
- Establish younger age classes through stand replacement fires.

Table F-5. Estimated range of variability for mesic birch, aspen, spruce, fir (mixedwood).

Vegetation growth stage	Disturbance Event	Age	% Landscape
Sapling birch	Fire	0-10	5-9
Pole-mature birch	Fire	11-50	16-26
Mature birch-conifer	Fire	51-80	10-15
Multi-aged conifer	Fire or wind	≥81	47-67
Sapling-pole conifer	Wind	0-50	1.6-2.1
Pole-mature conifer	Wind	51-80	0.1-0.8

Data taken from Frelich 1999.

4.2.5 Oak Communities

**Figure F-10. Age class distribution for jack pine and upland black spruce.***Adapted from Frelich (1999).*

These data (Fig. F-10), taken from Frelich (1999), were only broken down by vegetative growth stages, not ten year increments. This community is the closest approximation available to the oak barrens that exist at Voyageurs. It does not apply to the oak savanna type. From the limited data available on this community type at Voyageurs, it appears that most of the stands are 50 to 80 years old. It was be prudent to regenerate some of these stands.

Park Level Goals

- Maintain the structural integrity of the community through periodic fire treatments.
- Establish younger age classes.

Table F-6. Estimated range of variability for dry jack pine, aspen, oak.

Vegetation growth stage	Disturbance Event	Age	% Landscape
Seedling pine-oak-aspen	Fire	1-10	9-17
Sapling pine-oak-aspen	Fire	11-20	8-14
Pole pine-oak-aspen	Fire	21-50	19-27
Mature pine-oak-aspen	Fire	51-70	11-12
Large pine-oak-aspen	Fire	71-110	13-15
Multi-aged fir-spruce-oak	Fire or wind	≥110	10-28
Sapling fir-spruce-oak	Wind	1-30	0.6
Pole fir-spruce-oak	Wind	31-50	0.3
Pole/mature fir-spruce-oak	Wind	51-80	6 -9

Data taken from Frelich 1999.

4.3 PRESCRIBED FIRE OBJECTIVES

General prescribed fire objectives for select community types are listed below. These may and should be adjusted on a site by site basis, as they may not be compatible with every situation.

4.3.1 Jack Pine Forest Community

The management goals for the jack pine community include:

1. Reestablishing jack pine dominance in stands that are now becoming decadent and mixed with hardwoods.
2. Increasing the coverage of jack pine as near to pre-settlement conditions as possible (5 – 10,000 acre increase).
3. Establishing a stand-age distribution coincident with the natural fire regime.

Specific prescribed fire objectives for this community type include:

- a) Generate sufficient crown scorch or cambial heating to produce >75% mortality of overstory trees.
- b) Generate sufficient heat in to open serotinous cones.
- c) Regenerate jack pine as the dominate species.
- d) Attain at least 60% mineral soil exposure immediately post burn.

4.3.2 Red and White Pine Forest Community

The management goals for the red and white pine forest community are to:

1. Increase its occurrence across the park (5 - 10,000 acre increase).
2. Maintain and improve current stands by:
 - a. Preventing and reducing balsam fir and hardwood encroachment.
 - b. Promoting multi-aged cohorts where appropriate.
 - c. Regenerating red and white pine.
 - d. Reduce brush cover.

Specific prescribed fire objectives for this community type include:

- a) Decrease dead and down woody fuel loading by 40% to 80% after the 3rd re-entry burn.
- b) Achieve 50% to 80% mortality in sapling and pole sized (1 – 6” DBH) tree densities, within two years post-burn.
- c) Achieve canopy closure between 50 and 75% percent after three burns. Basal area can be used instead of canopy closure for an assessment, as BA and canopy closure are high correlated. However, the correlation must be determined first.
- d) Achieve at least 50% cover of exposed mineral soil after the second burn.
- e) Reduce average duff depth to one inch or less after the second burn. Areas without duff are not included in the average.
- f) Regenerate a new cohort of red and white pine within 30 years post burn.
- g) Reduce brush cover to less than 20% after the 2nd burn.

4.3.3 Mixedwood Community

The management goals for this type are to:

1. Decrease the overall coverage by converting stands with a pine seed source to pine-dominated.
2. Regeneration some stands of aspen and birch thereby creating a more diverse age distribution.

Specific prescribed fire objectives for this community type include:

- a) Achieve 75 to 100% mortality of all trees, within two years post-burn (see *b* and *c* below for exceptions).
- b) Reserve advanced regeneration of red, white, or jack pine where practical.
- c) Reserve red or white pine seed trees where practical.
- d) Achieve pine regeneration in any amount, not species specific.
- e) Regenerate some stands to the earliest successional stage of aspen-birch.

4.3.4 Un-Forested Wetlands

The management objectives for un-forested wetland communities include:

1. Maintain current area of wet meadow communities.
2. Increase the quality (plant diversity) of un-forested wetland communities.
3. Establish more wet meadows through conversion of some shrub carr areas.

Specific prescribed fire objectives for these communities include:

- a) Establish burn units in these community types.
- b) Burn at least 80% of a unit's area.
- c) Reduce litter coverage by 80%.
- d) In wet meadows, reduce shrub cover to less than 25% within three years post-burn.
- e) In shrub carrs, maintain shrub cover of between 25 and 75% within three years post burn.

4.3.5 Oak Communities

The management objectives for the oak communities include:

1. Maintain current area of oak communities.
2. Increase the quality (plant diversity) of these communities.

Specific prescribed fire objectives for the oak communities include:

- a) Establish burn units in the oak communities.
- b) Reduce litter coverage by 80%.
- c) In mesic oak woodlands, increase the cover of grass species to >25% by the 2nd burn.
- d) In dry oak woodland/barrens, maintain canopy closure between 40 and 80%.

5.0 MONITORING OBJECTIVES

The monitoring objectives build upon the management objectives listed above by adding quantitative measures of precision (how narrow of a confidence interval around the sample statistic is acceptable), power (the ability to detect a trend if one is really occurring) and alpha level (a measure of how willing we are to say a change has occurred when in fact it has not or visa versa).

For the sake of brevity, time frames, minimal detectable change and other specifics per variable are not included as they are stated previously under management objectives. Additionally, for all change monitored variables we are willing to accept a 20% chance of saying that a change took place when it really did not, ($\alpha=20\%$). All implied changes regard pre- vs. post-burn levels.

Note: Lettering corresponds with the lettering in prescribed fire objectives. Monitoring objectives may refer to more than one prescribed fire objective.

5.1 JACK PINE FOREST COMMUNITY

- a) Detect with 80% certainty changes in mean pole sized and overstory tree densities.
- b-c) Detect with 80% certainty changes in mean seedling densities.
- d) Detect with 80% certainty changes in mean litter and duff depths.
- d) Be 80% certain that the mean mineral soil coverage is within 20% of a true mean of greater than 60%.
- e) Detect with 80% certainty changes in the total dead and downed fuel loading.*

5.2 RED AND WHITE PINE FOREST COMMUNITY

- a) Detect with 80% certainty changes in the total dead and downed fuel loading.
- b) Detect with 80% certainty changes in mean pole sized and overstory tree densities.
- c) Be 80% certain that the mean canopy closure is within 20% of a true canopy closure of 50 to 75%.
- d) Be 80% certain that the mean mineral soil coverage is within 20% of a true mean of greater than 50%.
- e) Be 80% certain that the mean duff depth is within 20% of a true mean of less than 1 inch.
- f) Detect with 80% certainty changes in the mean seedling density.
- g) Be 80% certain that the mean brush coverage is within 20% of a true mean of less than 20%.

5.3 MIXEDWOOD COMMUNITY

- a-c) Detect with 80% certainty changes in mean pole sized and overstory tree densities.
- d) Detect with 80% certainty changes in mean seedling densities.
- e) Identify transition to an earlier successional stage of aspen-birch.
- f) Detect with 80% certainty changes in the total dead and downed fuel loading.*

5.4 UN-FORESTED WETLANDS

- a) Assist in selecting areas to be burned.
- b) Be 80% certain that the burned area is within 20% of a true mean of greater than 80%.
- c) Detect with 80% certainty changes in the mean litter coverage.
- d) Be 80% certain that the mean brush coverage is within 20% of a true mean of less than 25%.
- e) Be 80% certain that the mean brush coverage is within 20% of a true mean of between 25 and 75%.

5.5 OAK COMMUNITIES

- a) Assist in selecting areas to be burned.
- b) Detect with 80% certainty changes in the mean litter coverage.
- c) Be 80% certain that the mean grass coverage is within 20% of a true mean of greater than 25%.
- d) Be 80% certain that the mean canopy cover is within 20% of a true mean cover of between 40 and 80%.

* Although fuel reduction is not an objective in this type monitoring is needed for fire behavior predictions.

6.0 MONITORING LEVELS

Voyageurs National Park has adopted the NPS FMH protocols for fire effects monitoring. The FMH handbook identifies four levels of monitoring and describes the monitoring parameters which will be measured at each level.

Different monitoring levels are employed to assess fire effects. Levels 1 and 2, Environmental and Fire Observation, provide background information needed for decision making and assess fire behavior. This knowledge is critical for implementing prescribed fire and when analyzing the after effects on vegetation. Level 3, surveying Immediate post-fire effects, and Level 4, evaluating Long-term change, address whether the management objectives are being met, and whether any negative impacts are being produced. Data gathered per monitoring level are listed below.

6.1 LEVEL 1

6.1.1 Environmental

Weather, fire danger rating, fuel conditions, resource availability, concerns and values to be protected, other biological, geographical and sociological data.

The above elements are fulfilled by the fire management staff as a whole. Weather is monitored hourly via two RAWs stations located at the Kabetogama VFD and near Kettle Falls. From these data, fire danger ratings, drought indices, and fuel moistures are computed. Additionally, fuel moistures are occasionally monitored throughout the summer. Fuel loading is determined via fire effects plots with the data being maintained by the fire effects staff. Resource (people) needs and availability are determined by fire management and are based on fire hazard and current activities. Distribution of resources for the Park is administered through the Minnesota Interagency Fire Center. Concerns and values to be protected, as outlined in FMH (USDI National Park Service 2003) are included in all burn plans. Various resource managers are consulted prior to burning to address natural and cultural resource concerns. Research projects and fire effects plots are also considered in prescribed fire planning.

6.2 LEVEL 2

6.2.1 Reconnaissance

Fire cause/origin, location, size, fuel type, vegetation, activity, potential for spread, current and forecasted weather, resource or safety threats and constraints, and smoke volume and movement.

The origins, locations and sizes of all fires greater than 0.1 acres are mapped in GIS. Depending on the situation the IC, fire monitors, or other qualified personnel document fuel and vegetation type(s), fire activity, spread potential, weather, smoke characteristics, and threats to safety and cultural and natural resources. These data are maintained at the fire management office. A fire report is produced by the fire incident commander including all the above information plus logistical information.

For prescribed fires, reconnaissance information is detailed in the burn plan. It includes a prescription describing acceptable weather conditions such as temperature, relative humidity, wind direction, mixing height, and transport winds for smoke dispersal.

6.2.2 Fire Observation

Fire monitoring period, ambient conditions, duff moisture, fuel models, and fire and smoke conditions.

On the day of the prescribed fire, weather observations are taken on site just before the test burn and hourly thereafter for at least one hour after ignition is complete. Spot weather forecasts are requested from the National Weather Service as needed. Weather observations include: location, dry and wet bulb temperatures, relative humidity, wind speed and direction, and cloud cover.

Fire behavior and smoke dispersal data are collected during the burn. Data include flame length and depth, rate of spread, ignition pattern, fuel characteristics, smoke dispersal, and visibility. Pictures are taken of ignition, holding, and fire behavior. The ignition pattern and method, and any unusual occurrences are documented, i.e. media on scene, smoke complaints, etc.

Post-burn and fire reports are filed in the fire effects and fire management offices respectively. The post-burn report may include: prints or a CD of pictures taken, a map, the incident action plan, the spot weather forecast, weather observations, and discussion of the fire effects.

6.3 LEVELS 3 AND 4 MONITORING

6.3.1 Immediate Post-burn & Long-term Trends

Attributes collected to identify trends are selected based on the goals and objectives for the burn and the vegetation community. These attributes are listed below.

- *Tree Layer* – Density, diameter & height by species, and canopy closure.
- *Dead and Downed Fuel Loads* – Loading by size class, duff & litter depths, and fuel moisture.
- *Brush and Herbaceous Layer* – Percent cover &/or density by species.
- *Postburn Conditions* – Average scorch and char height, and burn severity based on substrate and vegetation mortality.

Wildland fires that are suppressed will be monitored at Level 1 and, if possible, Level 2. Wildland fires for resource benefit (fire use fires) will be monitored at Levels 1 and 2. In the event that FMH plots are burned in a wildfire, they will be read according to the standard post-burn-treatment monitoring schedule.

Prescribed fires will be monitored at least at Levels 1 and 2. When FHM plots occur in a unit, monitoring will be at levels 3 and 4 also.

7.0 SAMPLING PROTOCOLS

7.1 INTRODUCTION

There are several different protocols in use at Voyageurs for a variety of reasons. All FMH plots conform to protocols found in the NPS Fire Monitoring Handbook (USDI National Park Service 2003). Project level monitoring plots began to be installed in 2004. Protocols for these plots are designed specifically to answer questions in a particular area or burn unit. Procedural changes, modifications and additions to these methods continue to take place.

As of 2007, there were 59 Forest FMH plots, 101 project level plots, and 9 photo plots.

7.2 TIMING OF MONITORING

All plots are monitored during the growing season, between early June and mid-August, so flowers may be used as aid in plant identification. Plots are read pre-burn, post-burn (within a month of burning), and one, two, five, ten, and 20 years post-burn. The 1-yr read for all plots is the first calendar year following the year the plot was burned. Each time a plot is burned, whether by a scheduled prescribed burn or due to wildfire, the schedule will re-set. Control plots and pre-burn plots, which are not burned within five years, are reread every five years.

7.3 PLOT LOCATION

Coordinates of plot locations are recorded using UTM's and NAD83. Directions to each plot are available in electronic form and in hard copy at the park Fire Management Office. A geographic information systems (GIS) data layer with the plot locations is available from the Fire Effects Monitoring staff. See also Appendix A, figures F-10 and 11, for maps of plot locations.

7.4 FMH PLOT PROTOCOLS

Fifty-nine standard FMH forest plots are installed in four monitoring types, 22 in white pine, 12 in red pine, 12 in jack pine, and 13 in mixedwood. See FMH (2003) Chapter 5 for specific details on sampling methods and categorical codes. The general and most pertinent methods are described below. A protocol summary table is included in Appendix B for the FMH Forest plots.

7.4.1 Plot Selection

All treatment plots are located within burn units, but not all units have plots. New plots are located in proposed burn units by randomly placing a dot in the dominant monitoring type on an aerial photo, and then hiking to that location. Two or more plots may be located in larger units or in units with large acreage of multiple monitoring types. Two control plots per monitoring type were located in non-treatment areas. However, the mixedwood forest type only has one.

Plot installations are based on prescribed burn priorities and minimum plot analyses for each monitoring type. New plots are installed the summer before burning, and are oriented to one of the cardinal directions. Plots are marked with 17 pieces of 0.5 m tall rebar each wired with an aluminum tag indicating the plot number and the position of the stake within the plot. Plot stakes are painted orange and the fuels stakes are blue. A tree is chosen near selected stakes and is painted with a band the same color as the stake. The origin tree is painted with two bands. The selected stakes are: the four corner stakes, the end stakes for the fuel transects, 0P, O, and 50P.

7.4.2 Trees

All live and dead trees >15.0 cm in diameter are tagged and mapped within 4 - 25 X 10 m plots (Fig. F-7). The species, status (live or dead), diameter at breast height (DBH (4.5', 1.37 m)) in inches, crown position and damage codes are recorded. Current protocols follow those established in FMH (2003)

7.4.3 Poles

The species, status, DBH and categorical height in meters of all live and dead trees ≥ 2.5 and ≤ 15.0 cm DBH are recorded within one 25 X 10 m plot (Q1) (Fig. F-7).

All poles were mapped, numbered, and tagged, however as of 2009, individual trees are no longer tracked due to the large number of stems and lack of usefulness of such data. All other protocols follow FMH (2003).

7.4.4 Seedlings

All live tree seedlings <2.5 cm DBH tallied by species and height class in a 5 X 10 m subplot within Q1 and along P1 (Fig. F-7).

7.4.5 Shrubs

Shrubs are recorded with the herbaceous vegetation along the two point intersect transects. See Herbaceous section below for protocols.

7.4.6 Herbaceous

Two 50 m point intercept transect are used to assess plant cover below 2 m in height. Plant and substrate intercepts are recorded every 0.3 m for vegetation ≤ 2 m high (166 total points). All annuals live or dead and all live perennials are recorded. Intercepted dead portions of live plants are ignored. Only one intercept is recorded per species per point. The height of the first intercepted species is recorded as well as the species, order and status of all other plants intercepted at that point. Foliage or branches of trees or shrubs > 2 m tall are not recorded.

As of 2009, sampling will be done every 1m instead of every 0.3 m. Analyses show that there is no significant difference in plant cover between the two methods.

All species observed within 2 m either side of each transect, and not previously “hit”, are recorded.

7.4.6 Fuels

Fuels are recorded using four - 50 foot planar intercept transects (Brown 1974). General methods follow those outlined in FMH (2003) and Brown (1974). The starting points for the four lines are located on the 0P – 50P plot segment at 10, 20, 30 and 40 m (Fig. F-7). A random azimuth is chosen and a stake is placed at the end of each 50' transect. One hour and ten hour fuels are tallied from 0 - 6', 100's from 0 – 12', and 1000's for the entire 50'. Litter and duff depths are measured in inches at 1, 5, 10, 15, 20, 25, 30, 35, 40, and 45'.

7.4.7 Canopy Cover

Beginning in 2005 a densiometer was used to measure canopy cover at each point along the 0P – 50P plot segment. The observer faces the direction of the transect, (i.e. towards 50P) and takes one reading at each 10 m point.

7.4.8 Plot Photos

Eight plot photos are taken, one from each corner toward the adjacent stakes (Q1-Q4, Q4-Q1, Q2-Q3 & Q3-Q2) and one from each of the line midpoint stakes (0P, 50P, P1 and P2) toward the origin (Fig. F-11). A dry erase board labeled with the date, burn unit, plot code, burn status, and line segment (i.e. Q1-Q4) is used to identify each photo. A range pole is not used in the photo.

When photographing revisits, a copy of the previous events photos are taken into the field and used to help match the scene exactly.

7.4.9 Burn Severity and Fuel Consumption

Burn severity data is collected within a month of burning. Severity assessments of vegetation and substrate are conducted on the fuel lines every 5 feet at the litter/duff measurement locations. FMH definitions of severity are used. Char and scorch heights are measured on overstory trees only. Char height is measured as the average of the highest and lowest points of continuous black and scorch height to the average height of black fleck. Fuel lines are re-measured as well.

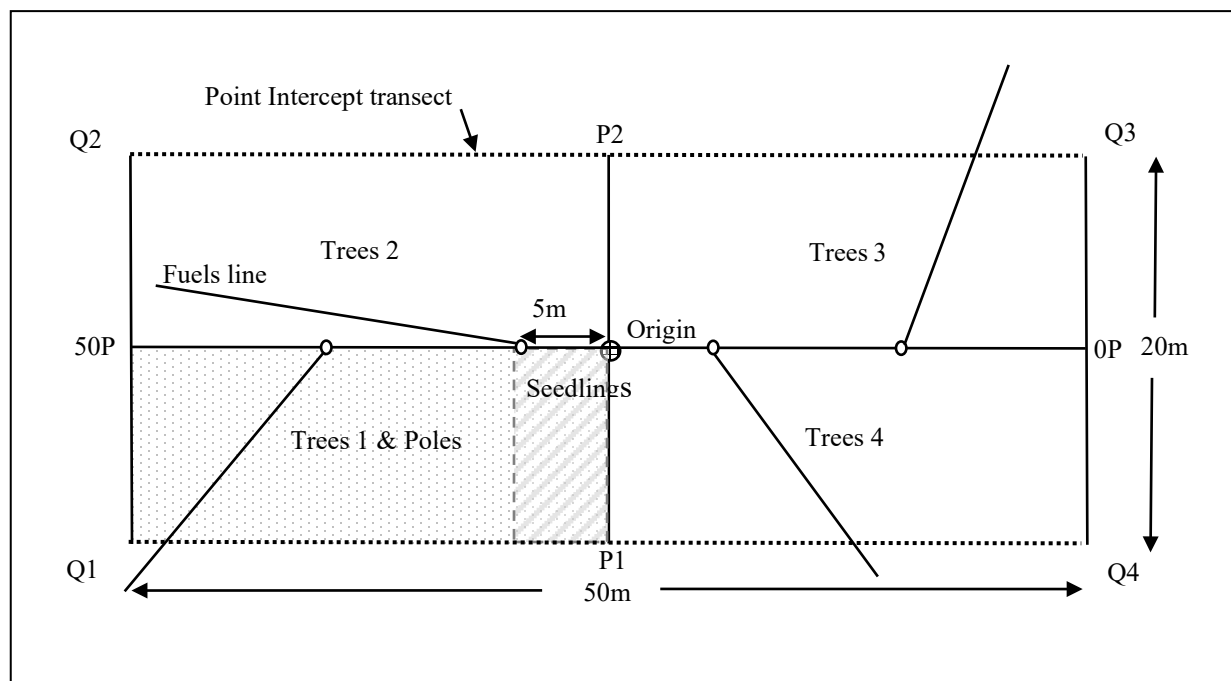


Figure F-11. Full sized FMH forest plot

7.5 PROJECT LEVEL MONITORING PLOTS

Project level monitoring plots were established in the fall of 2004 to help determine if short-term prescribed fire objectives were being met on a burn unit basis. Questions regarding fuel consumption and vegetation change could not be answered at this scale with any confidence using the standard FMH plots. Project level plots were designed to be easily installed and quickly measured allowing for a greater number of plots to be established.

A detailed description of the methods that have been used for project level monitoring follows (Fig. F-12). Since each set of plots is independent from another, all or some of the protocols listed may be used or altered, e.g. use different plot sizes, to suit the needs of the sampling environment for each unit. Additionally, more than one method may be listed per element as more than one protocol may be used to measure the same element. The specific protocols for each project are available from the Great Lakes Eco-region Fire Ecologist. As data are analyzed some protocols will be eliminated.

7.5.1 Plot selection & Establishment

Plots are established within burn units or burned areas. Plots are located systematically with a random start to ensure good coverage across the monitoring type within each unit. At least 10 plots are typically installed but the number greatly depends on unit size and what is being monitored. No control plots have been installed using these methods to date.

Priorities for plot installation are based on prescribed burn priorities and are installed prior to burning. A starting point for plot installation is selected and geo-referenced. From this point plots will be established throughout the unit at fixed points along transects. Plots must be at least 2 chains (40 m) apart and 2 chains from type boundaries. Transects are straight and parallel running the length of the unit or type. The distance and direction from one plot to the next are recorded. Plots centers are marked with one piece of rebar with an aluminum tag. Fuel transect if installed are also marked with rebar. All plot locations are geo-referenced.

7.5.2 Overstory

All live and dead trees >6.0 in DBH will be tallied by species using a 10 BAF prism. Diameter classes if used are: 1: 6 – 12", 2: 12.1 – 16", 3: 16.1 – 24", & 4: 24+. An ocular estimate of the DBH of each tree is often recorded in lieu of size classes. Live and dead trees will be recorded.

Data will provide basal area estimates to be used for species dominance, stand density and canopy cover analysis.

7.5.3 Poles

All live and dead trees ≤ 6.0 in DBH and taller than DBH are tallied by species in an 11.8' radius plot. Diameter classes if used are: 1: 0 – 2", 2: 2.1 – 4", & 3: 4.1 – 6". The average DBH for each species is often recorded instead of diameter class. Average height will be recorded for all species as a whole.

Only stems with at least half of the basal stem within the plot are counted. Trees forked below DBH are tallied as two trees. Stems that, because they are bent over, do not reach 4.5' but are obviously longer than 4.5' are counted.

Density and species dominance will be analyzed using this data.

7.5.4 Seedlings

All live tree species shorter than breast height (4.5') are tallied by species within an 8.3' (2.5 m) radius plot. Estimates should be done for tallies >25 stems.

7.5.5 Brush

Sampling of brush is being done via repeat photography.

Photography of a cover (Purina) board is used to monitor moderate to dense brush. The board is placed 20' (6m) from the photo point. The board is photographed such that the top and bottoms of the board are just in the picture. The photos are analyzed on the computer by counting the dots which are covered or uncovered, whichever is easiest. Two photographs are taken of each plot.

7.5.6 Herbaceous and Small Shrubs

The percent cover of all forbs and small shrubs is recorded within an 11.8' radius plot. Dead annuals will be recorded as live; all other dead plants will not be recorded.

Alternatively the presence of each forb or small shrub species is recorded within four-1m² sampling frames. Frames are placed at the edges of the 11.8' radius pole tree plot in each of the cardinal directions.

7.5.7 Fuels

Downed woody fuels are measured using Brown's planar intercept method (Brown 1974). One to three Brown's transects will be established per plot with no more than 30 lines per burn unit. The end of each line will be marked with a metal stake and the azimuth is recorded. One and ten hour fuels are tallied from the plot center (PC) to 6', 100-hour fuels are tallied from PC to 12', and 1000-hour fuel diameters are measured to 0.1 inches per species and rot class, sound or rotten, from PC to 50'.

Litter and duff are measured in tenths of inches at 10, 20, 30 & 40'. If moss or rock is encountered that is recorded.

Duff pins are also being used to assess litter and duff consumption. Duff pins may be a thin steel rod or a survey pin with a cross piece welded to it. The pin is inserted into the ground up to the cross bar or tip of welding rod. Litter depth will be carefully measured at the pin taking care not

to disturb the integrity of the layer. Pins will be inserted at measured one-foot intervals radiating out from the PC in the cardinal directions. A pin is not placed at the PC. After burning, measurements will be taken from the cross bar to the burned surface and then from the cross bar to mineral soil (Fig F-13).

7.5.8 Canopy Cover

Four densiometer measurements will be taken from the edge of each 11.8' radius plot facing outward. Measurements are taken in each of the cardinal directions.

This will provide a crosswalk with the BA measurements to relate BA to canopy coverage so in the future we may do away with densiometer measurements.

7.5.9 Stand Age

Dominant, Co-dominant, and intermediate trees will be selected within the stand for coring. Approximately five trees of each cohort will be cored to obtain a reasonable estimate of the stand age structure. Large areas are likely to be the same age therefore, one must judge whether all stands must be aged. Selecting a few trees from each stand may be more appropriate depending on the circumstance. The species, diameter (in), height (feet), and location (UTM) will be recorded for each tree. All cores will be collected in straws and labeled with site, date, species, and tree number. Cores are then glued to boards and sanded for analysis.

This will help the park to establish a stand age map.

7.5.10 Disease and Damage

The frequency of common tree diseases and damage will be recorded at each plot. Diseases such as *Phyllinus tremulae*, *Hypoxylon* cancer, white pine blister rust, white pine weevil, and deer browse are recorded by percent of trees affected per species. It will be noted which stratum(s) the disease occurs.

This information will be useful in the future to determine if burning has an effect on controlling tree diseases. As well as assessing the impact each is having on the species.

7.5.11 Physiographic Class

The physiographic class will be recorded as xeric, xero-mesic, mesic, hydro-mesic or hydric. It is only necessary to record this data once since these will not change over time.

7.5.12 Disturbance History

Any evidence found providing information on the disturbance history of the stand will be recorded. Such information may include, pit and mound topography, fire scars, charred snags or fragments, and stumps. A brief synopsis regarding the stand history, as determined from on the ground evidence or whatever information one might have, will be recorded.

7.5.13 Burn Severity and Fuel Consumption

Burn severity measurements are not done for these plots. Fuel consumption is estimated by re-sampling the fuels lines within a month after burning. Data on trees, shrubs, and herbs are collected the first growing season after burning as per the schedule.

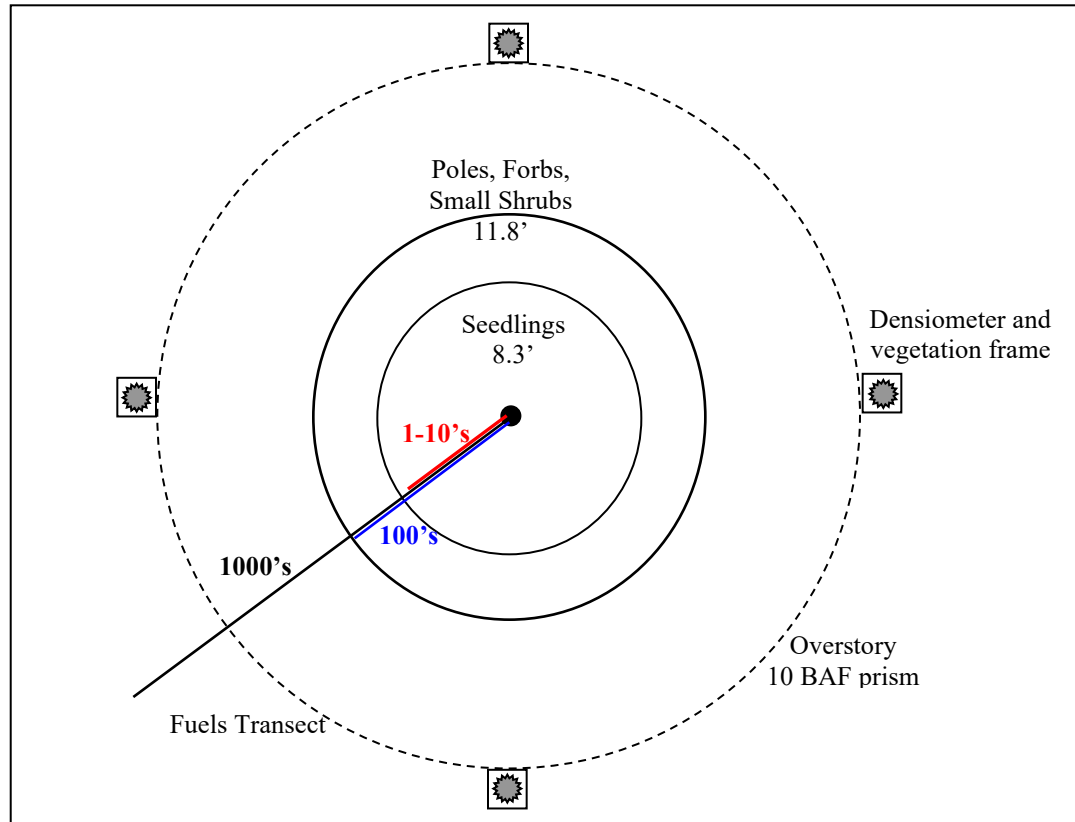


Figure F-12. Project level sampling plot.

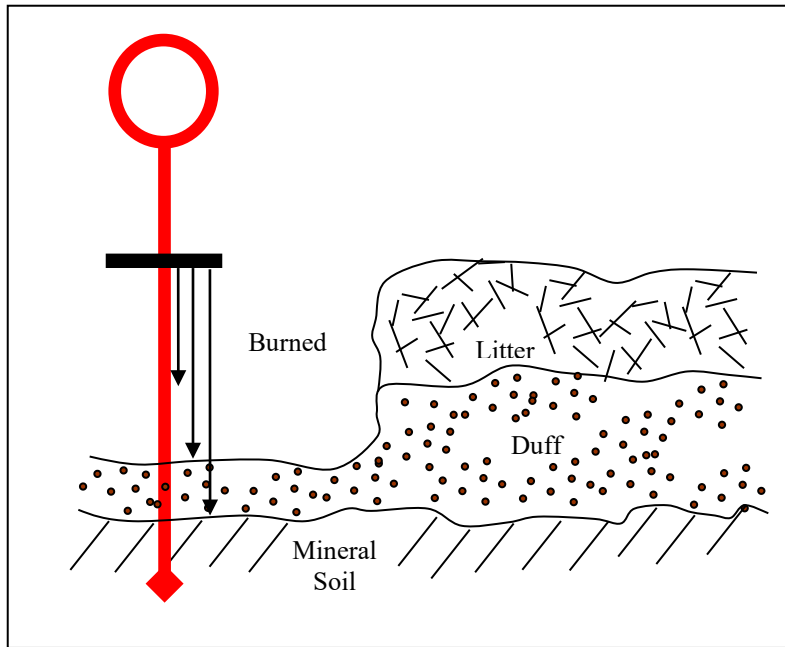


Figure F-13. Duff pin measurements.

7.5.14 Plot Photos

Plot photos were taken from northern and southern edge of the 11.8' radius plot facing the plot center for some units. As of 2008 all future plot photos will be taken from the plot center facing north unless otherwise stated. Digital photographs are taken at eye level, approximately 5 -5.5' above the ground with the camera fully zoomed out, i.e. 28 - 35 mm. A dry erase board is placed in each photo to record the site, date, status (PRE, POST, etc.), plot number, and azimuth of the photo.

When photographing revisits, a copy of the previous events photos are taken into the field and used help match the scene exactly.

7.6 PHOTO POINTS

Care should be taken when using repeat photography as it is surprisingly difficult to duplicate a photograph of the same exact location without considerable effort. Digital photographs are taken from the stake, not of the stake as with some project level plot photos. They are taken at eye level with the camera fully zoomed out. The camera is aimed parallel to the slope. A rebar stake labeled with an aluminum tag is placed at the photo point. A dry erase board is placed in each photo to record the site, date, status (PRE, POST, etc.), plot number, and azimuth of the photo.

When photographing revisits, a copy of the previous events photos are taken into the field and used help match the scene exactly.

7.7 FIRE MONITORING

7.7.1 Fuel Moisture

Fuel moisture measurements are taken the day of, or prior to, the burn. Moisture estimates are determined from one or more of the following, the calculated fine dead fuel moisture, RAWs 10-hour fuel moisture stick, or direct fuel moisture sampling of live and dead fuels.

Calculations of fine dead fuel moistures are based on temperature, humidity, shading, elevation, aspect, and time of day and year. Tables used to perform the calculations are found in the 2004 Fireline Handbook.

Ten-hour fuel moisture is calculated directly by the RAWs and obtained from a website.

To obtain more precise fuel moistures, samples are collected per fuel type in air-tight tins. The tins are labeled and tabulated as to their contents. The tins and contents are weighed and oven dried at 100°C for 24 hours and weighed again. The moisture is then calculated.

7.7.2 Weather Parameters

Temperature, wind and relative humidity are recorded every hour during the burn. Weather may be obtained from a weather station or field observer using a sling psychrometer.

7.7.3 Fire Behavior

Fire behavior measurements include flame length, flame zone depth, and rate of spread.

7.8 MECHANICAL TREATMENTS

The one mechanical treatment done thus far is being monitored with seedling plots and photo points described above in 7.5.4 and 7.6. All future mechanical treatments will be monitored similarly depending on the treatment objectives.

8.0 DATA SHEET EXAMPLES

All FMH forms are found in the Fire Monitoring Handbook (2003). All project level monitoring forms are on file with the park's fire effects office as is the 'Jakala' form once used to collect data on stand origin and BEHAVE inputs. See also Appendix C for a list of FMH and Project Level forms in use.

9.0 DATA MANAGEMENT AND ANALYSIS

9.1 STANDARD DATA

Data will be managed by the Great Lakes Eco-region Fire Ecologist. All non-photographic FMH and project level monitoring data are entered and checked in FFI (FEAT and FireMon Integrated) by the fire effects crew member. These data files are backed-up by the fire monitor and copies are sent to the eco-region fire ecologist. Original hard copies of all data as well as descriptions and directions to plot locations are kept in binders at the Voyageurs Fire Effects Office. A GIS data layer of the plot locations is stored at the park's GIS office and on the fire ecologist's computer. All data will be shared with Resource Management.

Monitoring results are summarized as needed and are presented to the park Fire Management Officer, Chief of Operations, and the Regional Fire Ecologist. This information is used to help coordinate fire activities, including prescribed fires and new plot installations, and assess whether objectives are being met or if unwanted results are occurring. Goals, burn prescriptions, and other management techniques will be reviewed and adjusted as necessary. Review and analysis may also generate questions that will identify fire effects research needs in the park. Information from Voyageurs may be analyzed with other Great Lakes Eco-region parks as appropriate and may be presented to other parks and at scientific meetings and in publications.

9.2 PLOT PHOTOS

All digital photos are stored on the fire ecologist's computer and backed up on an external hard drive. Prints are made of all photos and are stored in the plot binders with the original data.

9.3 QUALITY CONTROL

Plant identification errors will be mitigated through training, collecting voucher specimens, reading plots during peak phenology, and utilizing herbarium specimens, plant photos and other experienced personnel.

The impacts of monitoring procedures, such as compaction and disturbance of fuel bed and vegetation, are lessened through crew awareness, and collection of voucher specimens outside the plot.

Data quality will be ensured through proper crew training to guarantee consistency in data collection and entry procedures. Before leaving a plot, all data sheets will be checked by the

lead crewmember for accuracy and completeness. Data entry errors will be minimized through cross-checks with the original forms and data analysis and manipulation.

Plot protocols are reviewed annually to call attention to procedural errors or inconsistencies. A program review by the regional and/or eco-region fire ecologist should take place every 3-5 years or as needed to maintain consistency of data collection and analysis, and to re-assess program requirements. More frequent reviews may be needed if there are significant staffing changes, additional ecological or other special concerns.

9.4 NAMING CONVENTION

Monitoring types are coded as outlined in the 2003 FMH.

The naming convention for FMH control plots is as follows: the first visit is 00 PRE; subsequent visits are at five-year intervals and are named 00 yr05, 00 yr10, etc. The naming convention for FMH treatment plots follows that of the controls till the plot is burned. After each burn the first number is changed to account for each treatment. For example 02 yr05 signifies the 5 year read after the second burn.

Project level monitoring events are named in the same manner.

10.0 RESPONSIBLE PARTIES

Administrative duties will be assigned as follows:

- Plan revision and data analysis – Great Lakes Eco-region Fire Ecologist
- Crew supervision – Great Lakes Eco-region Fire Ecologist
- Park liaison – Voyageurs NP Chief of Operations
- Data collection, data entry – Voyageurs NP Fire Effects Monitoring Crew
- Program reviews – Midwest Region Fire Ecologist

11.0 FUNDING

FIREPRO funding for the Voyageurs Fire Effects Monitoring Crew will support all monitoring activities.

12.0 ADAPTIVE MANAGEMENT

To more adequately achieve objectives, monitoring results should serve as feedback to the Park's fire and resource management staffs so appropriate adjustments can be made to prescribed fire prescriptions. However, care should be taken to avoid making hasty management decisions based on only a few years' data. Effective long-term fire management will require a comprehensive understanding of the various interactions between vegetation and fire, which can only be obtained from long-term monitoring and analysis.

The ecological models and reference sections of this plan may serve as a brief summary of current knowledge, which can guide management decisions. The information summarized for mixedwood, jack, red and white pine forests, wet meadows, shrub carr, dry oak woodlands/barrens and mesic oak forests/woodlands come from only a small portion of the available literature, while information pertaining to the types which are more unique to the Park come from only a few general sources or expert opinion.

Status reports concerning the program and progress toward or away from specified objectives will come in the form of annual reports and/or results summaries. Annual reports are submitted to the regional and national ecologists. This report is intended to highlight program changes, successes, failures, and future plans. Results summaries of any pertinent data analysis will be submitted as available. These are intended to report on the status of a particular monitoring type or a specific site. All analyses are up to the discretion of the ecologist, but in general they will focus on identifying trends and determining whether objectives are being met. When appropriate, suggestions will be made to help fire and resource management to realize their objectives.

13.0 CONSULTATION AND COORDINATION

The Voyageurs Fire Effects Monitoring Crew must coordinate and consult with the Great Lakes Eco-region and Midwest Region Fire Ecologists, and fire management staff from other parks. The resource management staff is responsible for coordinating and consulting with all other cooperators. Persons consulted in the development and/or review of this document are:

- Cody Wienk, Fire Ecologist for the Midwest Region
- Scott Weyenberg, Fire Ecologist for the Great Lakes Eco-region

14.0 PEER REVIEW

Peer and technical review for this plan was provided by:

Cody Wienk, Regional Fire Ecologist
National Park Service, Midwest Region
Omaha, NE

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16.0 APPENDICIES

APPENDIX A. PLOT LOCATIONS

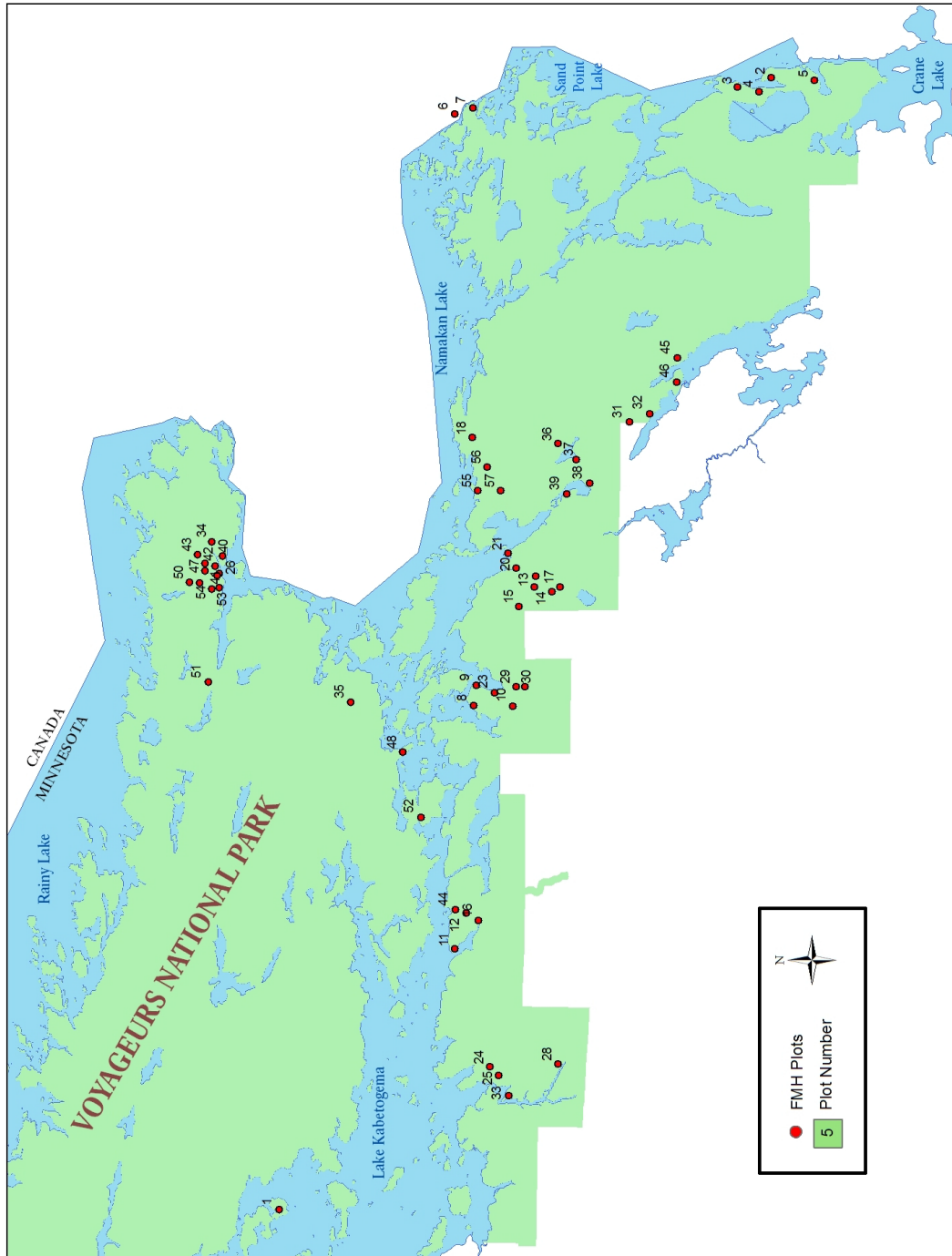


Figure F-14. FMH plot locations.

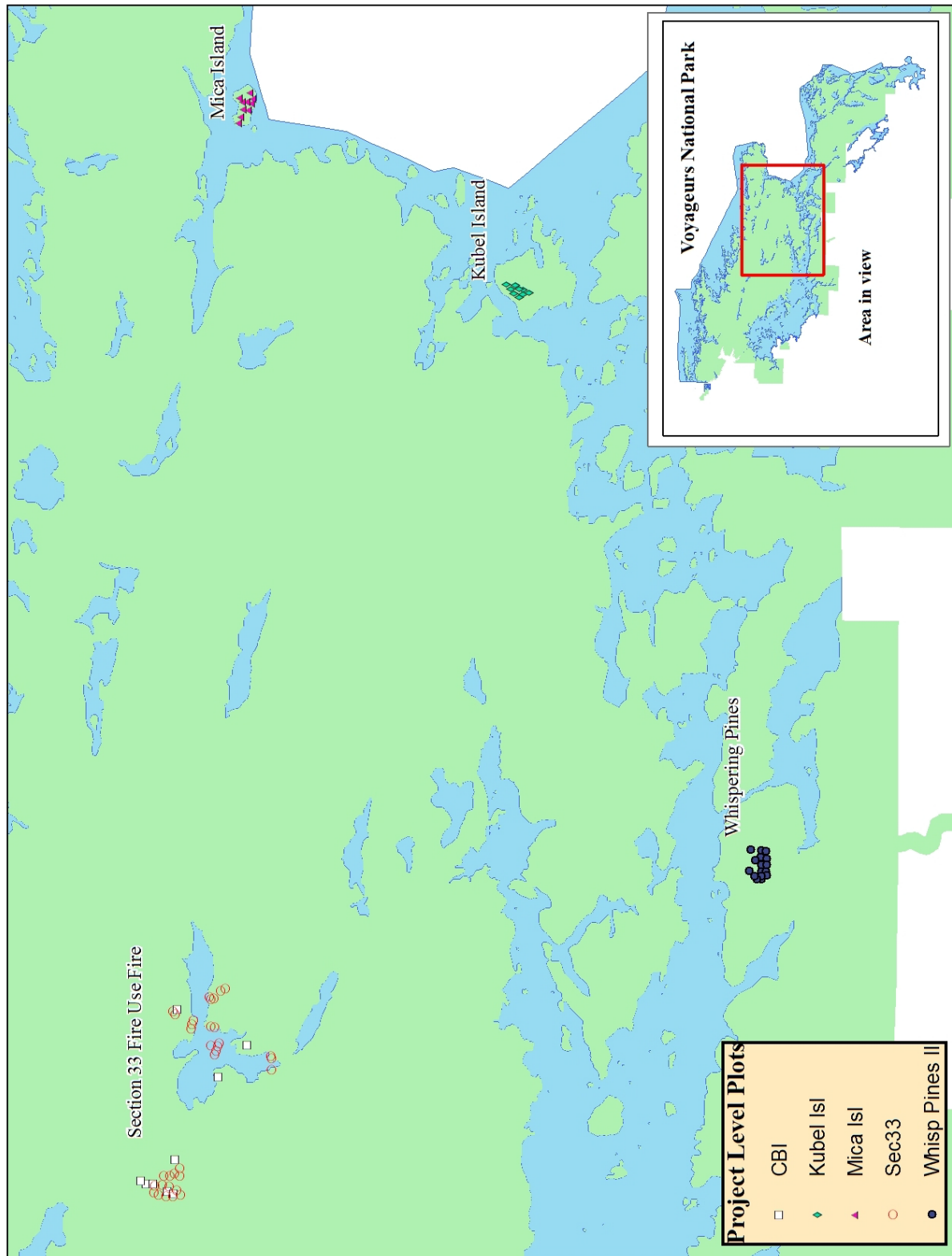


Figure F-15. Project level plot locations.

APPENDIX B. PROTOCOL SUMMARY TABLE

Table F-7. FMH plot protocols for all forest plots.

GENERAL PROTOCOLS						
Pre-Burn	Control Plots (Opt)	Y		Abbreviated Tags (Opt)	Y	
	OP/Origin Buried (Opt)		N	Herb. Fuel Load (Opt)		N
	Voucher Specimens (Opt)	Y		Brush Fuel Load (Opt)		N
	Count Dead Branches of Living Plants as Dead (Opt)					N
	Width of Sampling Area for Species Not Intercepted but Seen in Vicinity of Herbaceous Sampling Area:				5 m	
	Shrubs Sampled?		N	Stakes Installed: ALL	17	
Burn	Duff Moisture (Opt)	Y		Flame Depth (Opt)	Y	
Post-burn	100 Pt. Burn Severity (Opt)		N	Herb. Fuel Load (Opt)		N
	Herbaceous / Shrub Data (Opt): FMH-15 / 16 / 17 / 18				NA	
FOREST PLOT PROTOCOLS						
			(Circle One)	(Circle One)		
Overstory (>15 cm)	Live Tree Damage (Opt)		Y	Live Crown Position (Opt)	Y	
	Dead Tree Damage (Opt)		N	Dead Crown Position (Opt)		N
	Record DBH Year-1 (Opt)	Y		Overstory Min. Diameter	15 cm	
	Sample Area:	50 x 20 m		Quarters Sampled: Q1♦Q2♦Q3♦Q4		
Pole-size (2.5–15cm)	Height (Opt)	Y		Poles Tagged (Opt)	Y	
	Record DBH Year-1 (Opt)	Y		Dead Pole Height (Opt)	Y	
	Pole Size Class	2.5-15 cm				
	Sample Area:	25 x 10 m		Quarter Sampled: Q1 ♦		
Seedling (< 2.5 cm)	Height (Opt)	Y		Seedlings Mapped (Opt)		N
	Dead Seedlings (Opt)		N	Seedling Size Class	<2.5cm	
	Sample Area:	10.0 x 5.0 m		Quarter Sampled: Q1		
Herbs	Herb Transect Sampled: Q4 - Q1 & Q3 - Q2					
	Herbaceous Density (Opt)		N	Herb Height (Opt)	Y	
Fuel Load	Sampling Plane Lengths: 1 hr - 6' ♦ 10 hr 6' ♦ 100 hr 12' ♦ 1,000 hr-sound 50' ♦ 1,000 hr-rotten 50'					
Post-burn	Char Height (Tree & Pole)	Y		Poles in Assessment (Opt)	Y	
	Collect Severity Along: Fuel Trans.			Mortality	Y	

APPENDIX C. DATA SHEET EXAMPLES

C-1 FMH Forms

The following forms are used directly from the FMH handbook (2003):

FMH-5 Plot Location Data Sheet
FMH-7 Forest Plot Data Sheet
FMH-8 Overstory Tagged Tree Data Sheet
FMH-9 Pole-Size tree Data Sheet
FMH-10 Seedling Tree Data Sheet
FMH-11 Full Plot Tree Map
FMH-12 Quarter Plot Tree Map
FMH-15 50m Transect Data Sheet
FMH-19 Forest Plot Fuels Inventory Data Sheet
FMH-20 Tree Post Burn Assessment Data Sheet
FMH-21 Forest Plot Burn Severity Data Sheet

C-2 Project Level Forms

Tree Data Sheet
Seedling & Sapling Data Sheet
Litter and Duff Data Sheet
Herbaceous and Brush Data Sheet
Densiometer & Stand Age Data Sheet
Fuels Data Sheet
CBI Data Sheet