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A Key for Predicting Postfire Successional Trajectories in Black Spruce Stands of Interior Alaska

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Abstract

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Black spruce (*Picea mariana* (*Mill*) B.S.P) is the dominant forest cover type in interior Alaska and is prone to frequent, stand-replacing wildfires. Through impacts on tree recruitment, the degree of fire consumption of soil organic layers can act as an important determinant of whether black spruce forests regenerate to a forest composition similar to the prefire forest, or to a new forest composition dominated by deciduous hardwoods. Here we present a simple, rule-based framework for predicting fire-initiated changes in forest cover within Alaska's black spruce forests. Four components are presented: (1) a key to classifying potential site moisture, (2) a summary of conditions that favor black spruce self-replacement, (3) a key to predicting postfire forest recovery in recently burned stands, and (4) an appendix of photos to be used as a visual reference tool. This report should be useful to managers in designing fire management actions and predicting the effects of recent and future fires on postfire forest cover in black spruce forests of interior Alaska.

Keywords: Succession, fire, disturbance, boreal, regeneration.

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Introduction

Background

Black spruce (*Picea mariana (Mill*) B.S.P.) is the dominant forest cover type in interior Alaska, and stand-replacing wildfires are the main form of disturbance in these forests. Fires create important subsistence and economic forest uses and generate crucial habitat for many wildlife species (Chapin et al. 2003) but can also pose a danger to human populations and values. Land managers in Alaska are faced with the challenge of managing fire in a way that preserves human life and property while at the same time conserving the key ecological processes driven by fire. Because managers have little capacity to alter fire behavior by direct fuel manipulations across the large extent of Alaskan boreal forest, the ability to use and interpret natural variations in fire processes provides an important contribution to long-term fuel management in the region.

Fire and successional processes in black spruce forests have traditionally been viewed as a fairly simple cycle of spruce self-replacement, with fire causing few changes in the pre- versus postfire vegetation composition (e.g., Van Cleve et al. 1991). However, a recognition of current changes in fire regime in Alaska, and expected future changes with climate warming, have led to a reevaluation of the sensitivity of black spruce forests to changes in fire conditions. Research on postfire recruitment across many parts of the boreal forest indicate that the degree of fire consumption of soil organic layers has important impacts on patterns of postfire tree recruitment (e.g., Charron and Greene 2002, Chrosciewicz 1974, Greene et al. 2005, Johnstone and Chapin 2006, Zasada et al. 1983). In Alaska, postfire organic layer depth acts as an important determinant of whether black spruce forests regenerate to a forest composition similar to the prefire forest or regenerate to a new forest composition dominated in early succession by deciduous hardwoods (Johnstone and Chapin 2006, Johnstone and Kasischke 2005). It is this variation of residual organic depths, along with other prefire environmental site characteristics, that determines the landscape mosaic of stand types postfire. Under current and future fire regimes, it is possible that increased burn severity and combustion of soil organic layers could lead to altered successional pathways in black spruce forests of interior Alaska.

Increases in deciduous tree cover on sites previously dominated by black spruce are important because deciduous- and spruce-dominated forests differ dramatically in their fuel types and potential fire behavior. Black spruce stands represent a highly flammable configuration of fuels because of the large amounts of fine twigs and needles, high resin content, low moisture content, and large quantities of fine ground fuels that are connected to the canopy by low-lying tree branches. Stands with increasing components of hardwoods are generally less flammable because of the increased moisture content of the fine fuels and reduced ground and ladder fuels (Hély et al. 2000, Johnson 1992, NIFC 1992). The potential for deciduous stands to act as fire breaks makes transitions from conifer- to deciduous-dominated stands one of the main goals for fire hazard reduction in boreal forests. Thus, understanding the factors that can shift black spruce forests to alternative successional trajectories, such as mixed deciduous forests, is a key element in developing adaptive fire management in Alaska and in predicting how changing fire regimes may shape future forest cover in this region.

To address these issues, we have developed a simple, rule-based key that uses our current knowledge of successional processes in black spruce forests to predict future forest composition as a function of prefire vegetation, site moisture, and fire conditions. Although this key builds off decades of research on fire and succession in boreal forests, it is particularly informed by recent research on early postfire recovery across a range of black spruce sites burned by the widespread fires of 2004 in Alaska. This research, funded by the Joint Fire Science Program, has focused specifically on the effects of fire severity and site conditions in driving successional trajectories after fire in black spruce forests. The key that follows distills our research results into a predictive framework that captures what appear to be the major factors controlling postfire tree recruitment and subsequent stand development. Further details on the research in the 2004 burns can be found in the project final report (project 05-1-2-06) available on the Joint Fire Science Program Web site (http://www.firescience.gov/).

Details of the Report

The aim of this report is to provide a rule-based, predictive framework for estimating fire-initiated changes in forest cover within Alaska's black spruce forests. This framework can be used to (a) design fire management actions that promote a desired forest cover type, (b) rapidly assess the effects of recent fires on postfire forest recovery, and (c) provide a general set of rules to estimate forest responses to future changes in fire regime. The framework is specifically intended for use in black spruce forests of interior Alaska, but may be generally applicable to other regions of the boreal forest.

The report is arranged as a four-part workbook. First, we present a field-based system for classifying potential site moisture. Site moisture is used to represent variations in moisture availability that influence successional patterns. Second, we provide a summary of the general conditions that favor a typical spruce self-replacement trajectory versus alternative successional trajectories. This summary can be used to develop guidelines for fuel or fire management actions aimed at influencing patterns of postfire recovery. Third, we present a key to predicting postfire forest recovery in recently burned stands. This key is intended to be used for ground-based assessments during the initial 1 to 2 years after a fire to predict future successional trajectories. It can be used as a tool for predicting the impacts of wildfires or prescribed burns on future forest composition. Finally, an appendix of photographs (app. B) provides a visual reference to different fire conditions and successional trajectories that are referred to in the text.

The summaries and keys in this report are focused on processes acting at the scale of the forest stand, which we intuitively define as a patch of forest that can be easily viewed from a central point (about 0.1 to 1.0 ha). Larger, landscape-level patterns may be at least partially inferred from the aggregation of multiple forest stands, although effects of other large-scale processes should also be considered in the scaling process.

Materials required for making the field assessments described here include (a) a copy of the report, (b) a calibrated steel rod for measuring depth of thaw, (c) a soil corer or spade for obtaining mineral soil samples, and (d) a camera for documenting canopy and surface conditions (recommended).

Defining Site Moisture

For the purpose of this key, site moisture can be defined as the **potential moisture** available for plant growth. We are particularly interested in soil moisture near the surface, because this is the soil layer that most strongly influences seedling establishment. Our classification of site moisture is based primarily on the topographic drainage at a given site. We then modify our initial classification based on factors that control drainage within the soil (permafrost and soil texture). Therefore, a sloping site on fine-textured soils with shallow permafrost might have a **similar site** moisture as a flat site with coarse, sandy soils or no permafrost. Our classification system is based on the topographic system of Komárková (1983), and on work by J. Harden and K. Manies at the U.S. Geological Survey (unpublished) describing site drainage classification in interior Alaska. The steps required to classify site moisture are described in text, below, and as a pictograph in figure 1.

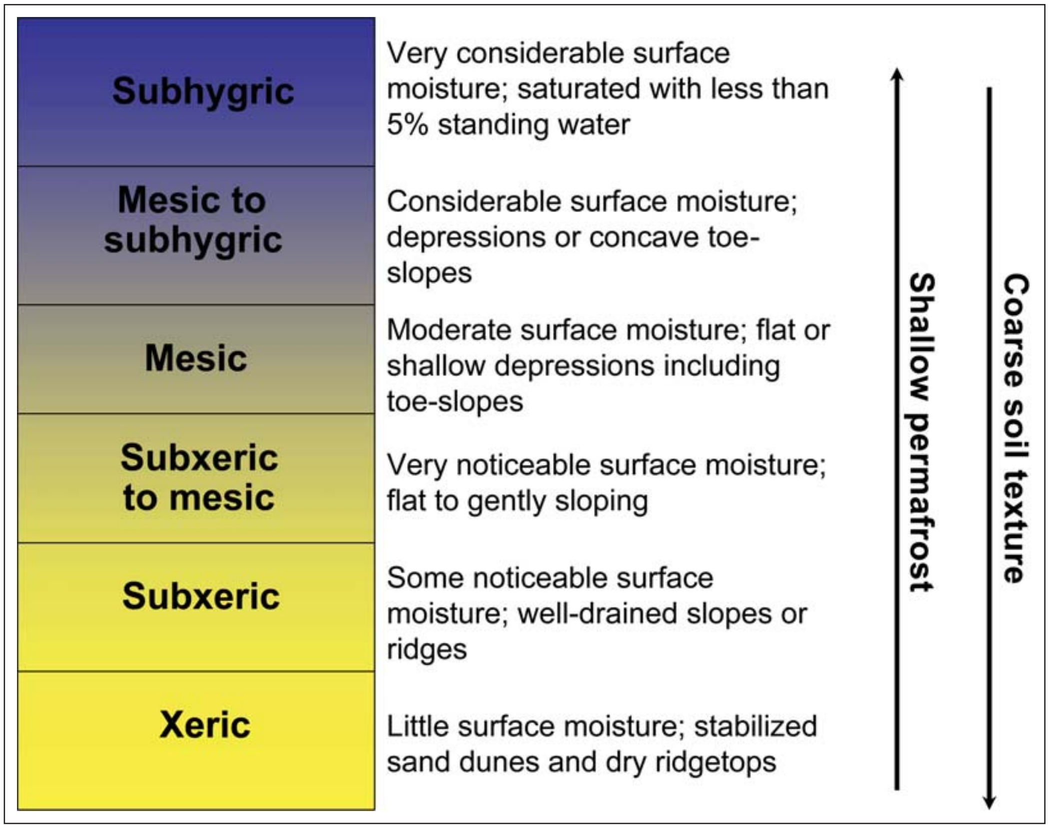

Figure 1—Pictographic key to classifying the potential site moisture of black spruce stands in interior Alaska.

STEP 1: Determine the site moisture based on topography (modified from Komárková 1983).

Dry sites:

- Xeric—little surface moisture: soil surface is perpetually dry except immediately after precipitation. Typical sites are stabilized sand dunes and convex ridgetops.
- Subxeric—some noticeable surface moisture: the soil surface is generally dry but can remain moist for a few days after a precipitation event. Typical sites are well-drained slopes or flat ridges.
- Subxeric to mesic—very noticeable surface moisture: the soil surface remains moist for many days after precipitation before drying out and has some recharge of moisture from lateral water flow. Typical sites are level to gently sloping, flat terrain.

Moist sites:

- Mesic—moderate surface moisture: the soil surface is often moist (not dry and crumbly), with reliable moisture recharge from lateral waterflow. Typical sites are flat or shallow depressions, including toeslopes.
- Mesic to subhygric—considerable surface moisture: the soil surface is almost always moist, with persistent moisture recharge from surrounding areas. Typical sites are depressions or concave toeslopes.
- Subhygric—very considerable surface moisture: surface soil is typically saturated with free water, often with small (< 5 percent of area) patches of standing water. Lateral drainage is generally impeded. Typical sites are lowland depressions with the water table near the surface, often adjacent to hygric wetlands.

STEP 2: Does the site have extensive shallow permafrost?

If there is shallow permafrost, then the site becomes one classification wetter. For example, a site classified as subxeric to mesic based on topography, would be reclassified as mesic if it is underlain by shallow (near-surface) permafrost. Our operational definition of shallow permafrost is a site where the **maximum depth of thaw** is less than 75 cm below the soil or moss surface. The presence of near-surface permafrost inhibits soil drainage by creating a water-impermeable layer near the soil surface.

To assess the importance of shallow permafrost at a site, it is usually necessary to visit a site late in the growing season (August and September) to assess depth of thaw. The depth of thaw, or distance to frozen ground, can be measured by inserting a calibrated steel rod into the ground as far as possible. The presence of frozen soil or rocks will block further penetration of the rod. Carefully differentiate rocks from permafrost when making this assessment.

STEP 3: What is the soil texture of the site?

If the soil is very coarse in texture, then the site becomes one classification drier. For example, a site classified as subxeric to mesic based on topography would be reclassified as subxeric if the predominant soil texture is coarse. We define coarse-textured soils as those dominated by sand or gravel in at least the upper 50 cm of the soil profile, starting at the ground surface (but excluding any green moss). Coarse soil texture tends to increase soil drainage and decrease site moisture by allowing surface moisture to rapidly drain to deeper soil layers (fig. 1).

Factors Predicting Shift in Successional Trajectory

Background

In most situations, we expect black spruce forests (app. photo 1) to regenerate after fire to a stand composition and density that is similar to the prefire community (Van Cleve et al. 1991, Van Cleve and Viereck 1981, Viereck 1983). There are two factors that are particularly important in supporting stand self-replacement as the dominant successional pattern in Alaskan black spruce forests:

- The formation of a moss- or lichen-dominated understory (app. photos 13 and 14) leads to the accumulation of thick (>10 cm) organic layers at the soil surface; the poor combustion of those layers during a fire leads to a postfire seedbed that is dominated by organic substrates.
- The development of aerial seedbanks that are held in the semiserotinous cones of black spruce (app. photo 2), leading to a large supply of onsite seed for black spruce after fire.

Thick, postfire organic seedbeds (>5 cm) are usually porous and subject to rapid drying and often form poor-quality seedbeds for the establishment of tree seedlings (Johnstone and Chapin 2006). However, black spruce can partially overcome this limitation by producing abundant seed after fire from an aerial seedbank held in semiserotinous cones. Thus, even though the success rate of seedling establishment is low, black spruce trees are able to compensate by having a strong local seed source that provides lots of seed. This large number of seeds increases the likelihood that some seeds will land in microsites suitable for germination and growth. Consequently, the combination of organic seedbeds and an aerial seedbank gives black spruce a strong advantage in regenerating in sites after fire.

Some potentially co-habitating species (app. photo 5), such as birch (*Betula neoalaskana* Sarg; formerly *B. papyifera* Marsh) (app. photo 6) or aspen (*Populus tremuloides* Michx.) (app. photo 7), have well-distributed seeds but also very small seed sizes. These small seeds have fewer reserves to support early seedling root growth and consequently have a particularly poor ability to successfully establish on porous organic seedbeds (Greene et al. 2007, Johnstone and Chapin 2006). Other Alaskan conifers, such as white spruce (*Picea glauca* (Moench)Voss) (app. photo 3), have seeds that are similar in size to those of black spruce, but lack the serotinous seed habit that provides a large supply of onsite seeds (app. photo 4).

Nevertheless, exceptions to the general pattern of black spruce self-replacement after fire do occur, and these may be widespread under certain conditions. The potential to initiate stands with alternative successional trajectories is largely driven by interactions between the prefire vegetation composition, site conditions, and fire effects on the reproductive potential of alternate dominant species. However, species interactions such as herbivory and plant competition with understory shrubs may also alter the direction and timing of successional transitions. Below, we list the scenarios likely to result in black spruce stands shifting to an alternative successional trajectory following fire. This is not an exhaustive list, but represents the most likely scenarios of change based on our current understanding of successional processes in black spruce forests of interior Alaska.

Key to conditions that favor the formation of alternative successional trajectories in black spruce forests after fire:

1. **Substantial combustion of the surface organic layers** leads to exposed mineral soil or deep humic layers. These seedbeds provide a more stable moisture supply to support seedling recruitment. Deciduous trees can invade by seed, even at sites many kilometers distant from live seed sources.

    a. Deciduous invasion on **postfire humic layers or moist organic soil** is expected to lead to deciduous trees that grow relatively slowly and do not strongly impact the recruitment of understory spruce. Postfire succession will have an increased deciduous component, but the deciduous phase may functionally resemble the willow-dominated phases of spruce self-replacement.

    b. Deciduous tree growth and productivity is expected to be highest at sites with **widespread exposure of mineral soil (>30 percent) or very shallow organics (<3 cm)**. Where deciduous species invade and grow rapidly, successful recruitment of black spruce may be reduced. Postfire succession is likely to lead to a prolonged deciduous-dominated phase (lasting on the order of 50 to 80 years postfire) that succeeds to low-density, mature black spruce in later stages. High rates of herbivory may change the likelihood or timing of transitions between deciduous and conifer phases by reducing the productivity of deciduous trees (browsing by moose, *Alces alces*) or young conifers in the understory (browsing by snowshoe hares, *Lepus americanus*).

2. **Deciduous tree species are present in the prefire stand.** When present and abundant (>50 stems/ha for aspen, >200 stems/ha for birch), aspen and birch are able to asexually regenerate after fire and give rise to a rapidly growing, early deciduous phase. Asexual regeneration of aspen and birch is likely to be favored by moderate- to low-severity fires that are less likely to damage the sprouting potential of roots and tree bases. Rapid growth and abundant litter production of resprouting deciduous trees may reduce the potential for spruce establishment at well-drained sites. Postfire succession is likely to lead to a prolonged deciduous-dominated phase (lasting on the order of 60 to 90 years postfire) with succession to low-density, mature black spruce in later stages. As stated above, high rates of herbivory may change the likelihood or timing of transitions between deciduous and conifer phases, by reducing the productivity of deciduous trees (moose), or young conifers in the understory (hares).

3. **Adjacent stands of unburned white spruce** provide a strong source of white spruce seed into the burned black spruce stand. Where white spruce seed is abundant, it can recruit on organic surfaces at a level similar to black spruce. White spruce seed availability will be highest where burned stands are adjacent to live white spruce stands, or when a late-season fire allows for the dispersal of viable seed from burned white spruce. In both cases, spatial proximity to a white spruce seed source is a major factor determining whether white spruce can become co-dominant with black spruce in the postfire stand.

4. **Local seed for black spruce is reduced by fire effects** (trees fallen, cones burned, cones not open, or young trees burned after a short fire interval). Because all of these factors reduce the availability or dispersal of black spruce seeds from an aerial seedbank, they reduce the potential for black spruce regeneration. In these cases, postfire succession will have reduced black spruce density.

    a. If postfire seedbeds are dominated by **organic soils**, succession will proceed to a prolonged shrub- or graminoid-dominated phase with the eventual development of a very open canopy of black spruce.

    b. If postfire seedbeds are dominated by **mineral soils**, deciduous species are likely to successfully establish and lead to the development of deciduous stands with only a sparse or absent component of understory spruce. Return to black spruce may not occur before the stand burns again.

Dichotomous Key for Predicting Successional Trajectory (0 to 2 Years Postfire)

Initial key: Site factors driving recruitment potential

1. Site is moist (mesic to subhygric) with the upper duff layer largely intact and low exposure (<5 percent) of humic or mineral soils (app. photos 24 to 27).
2. Site is moist (mesic to subhygric) and the organic layer has been severely burned, leading to shallow (<5 cm average depth) residual organic layers and at least moderate (> 5 percent) ex-posure of humic or mineral soil (app. photos 28 to 31).
3. Site is dry (mesic/subxeric to xeric) with an intact organic layer and low (<15 percent) mineral soil exposure (app. photos 32 to 34).
4. Site is dry (mesic/subxeric to xeric) with extensive (>15 percent) mineral soil exposure (app. photos 35 to 37).

1. **Moist sites (mesic to subhygric) with postfire organic layers intact.** These sites may experience a range of conifer recruitment, depending on the availability of local conifer seed. Where seed is abundant, wetter sites will have higher densities of conifer seedlings. For deciduous species, the potential for seedling recruitment is generally low on thick organic layers. If deciduous trees were present in the prefire stand, some recruitment may occur through resprouting. However, the cool and moist soils are likely to keep the biomass or cover of deciduous trees low in all stages of succession. Consequently, most sites of this type will rapidly return to dominance by black spruce.

    IA. There are multiple standing black spruce trees with open cones at the site providing a strong local seed source.

    I. The residual organic layer is thick (>20 cm), with abundant scorched tussocks (app. photo 8) or sphagnum moss (app. photo 10) . Thick moss layers may prevent the penetration of seedling roots to a stable moisture supply at sites without freely available moisture. Thick moss also favors cold soil temperatures that are likely to limit seedling growth. The expected successional tra-jectory is **open-canopy black spruce** (app. photo 15).

II. The residual organic layer is less than 20 cm thick, and is composed primarily of burned or scorched feathermoss (app. photo 11) rather than sphagnum. Thinner moss layers combined with moist site conditions allow higher rates of black spruce establishment. The expected successional trajectory is **intermediate- to closed-canopy black spruce** (app. photo 16).

IB. The local seed source for black spruce is limited by most trees having fallen over, trees being too young to bear many cones, or the cones being either deeply charred (severe crown fire) or not open (fire did not crown). Consequently, seedling establishment is likely to be very low, leading to the formation **of open-canopy black spruce, or spruce-lichen woodland** (app. photo 17).

2. **Moist sites (mesic to subhygric) with shallow surface organic layers or exposed mineral soil.** These sites generally have a high recruitment potential for both conifer and deciduous species. The exposed mineral or humic soils have high bulk densities and are able to wick moisture to the soil surface, increasing the germination and survival of conifer and deciduous seedlings. Where there is extensive mineral soil exposure, mosses may rapidly colonize and cover the substrate surface, limiting successful establishment to mostly those seeds that arrive immediately after the fire (often deciduous seed). These sites have a range of possible successional trajectories.

2A. There are multiple standing black spruce trees with open cones at the site that provide a strong onsite seed source for black spruce.

I. Prefire aspen or birch trees are present at the site, with intact roots or stumps, **or** there is a stand of live deciduous trees in the area (within 1 to 2 km) that can provide a local seed source for deciduous trees.

a. There is extensive exposure of mineral soil (>30 percent of surface).

1. Mineral soils are very moist and support rapid colonization by broad-leaved liverwort (*Marchantia polymorpha* L.) (app. photo 12). Deciduous trees can establish rapidly from seed or resprouting, but seedbed quality rapidly declines

and limits black spruce establishment. The expected successional trajectory is **closed deciduous forest** (app. photo 20) with a sparse understory of black spruce.

2. Mineral soils are less moist, and support slower colonization by small, single-stemmed mosses such as firemoss (*Ceratodon purpureus* (Hedw.) Brid.) (app. photo 9). Both deciduous trees and black spruce have high potential rates of establishment. The expected successional trajectory is **mixed deciduous-black spruce forest** (app. photo 19).

b. Mineral soil exposure is intermediate (5 to 30 percent) or limited to only exposure of humic soil. Deciduous trees are likely to have variable establishment success on the mixed seedbed, and black spruce is expected to be able to establish on all substrate types. The expected successional trajectory is **mixed deciduous-black spruce forest.**

II. There are few deciduous trees in prefire stand or surrounding unburned forest. Deciduous trees have few opportunities to establish from seed or by resprouting. The expected successional trajectory is **intermediate- to closed-canopy black spruce forest.**

2B. The local seed source for black spruce is limited by most trees having fallen over, trees being too young to bear many cones, or the cones being either deeply charred (severe crown fire) or not open (fire did not crown).

I. There is a stand of live deciduous trees in the area (within 1 to 2 km) that can provide a local seed source for deciduous trees, and/or prefire deciduous stems are common at the site with roots or stumps intact. Deciduous recruitment is likely to be abundant, but low seed availability will limit black spruce establishment. The expected successional trajectory is **open deciduous forest with sparse or absent understory of black spruce** (app. photo 18).

II. There are few live deciduous trees in the area and no prefire birch or aspen at the site. Recruitment of both deciduous trees and black spruce is likely to be strongly limited by low seed availability. The expected successional trajectory is **nonforested shrubland/grassland** (app. photo 23), where grasses rapidly colonize, or **open spruce-lichen woodland** where the understory is dominated by low shrubs.

3. **Drier sites (mesic/subxeric to xeric) with postfire organic layers largely intact.** Sites may have moderate recruitment potential for conifers, but deciduous recruitment from seed will be limited by dry conditions at the surface of the intact organic layers. Establishment of deciduous species will be largely limited to asexual regeneration (resprouting).

3A. There are multiple standing black spruce trees with open cones at the site that provide a strong onsite seed source for black spruce.

I. Prefire aspen or birch trees are present at the site, with intact roots or stumps to support asexual regeneration. The expected successional trajectory is **mixed deciduous-black spruce forest**.

II. Prefire aspen or birch trees are rare or absent from the site. Intact organic layers restrict deciduous colonization from seed. The expected successional trajectory is **intermediate- to closed-canopy black spruce forest**.

3B. The local seed source for black spruce is limited by most trees having fallen over, trees being too young to bear many cones, or the cones being deeply charred (severe crown fire).

I. Prefire aspen or birch trees are present at the site, with intact roots or stumps to support asexual regeneration. The expected successional trajectory is **open deciduous forest with sparse or absent understory of black spruce**.

II. Prefire aspen or birch trees are rare or absent from the site. Intact organic layers restrict deciduous colonization from seed. The expected successional trajectory is **nonforested shrubland/grassland, or spruce-lichen woodland**.

4. **Drier sites (mesic/subxeric to xeric) with organic layers largely consumed, leading to exposed mineral soil**. These sites have a moderate to high recruitment potential for both conifers and deciduous trees. Conifer recruitment density is likely to be moderate at the driest sites owing to dry surface conditions even where mineral soil is exposed. Recruitment of deciduous species will be affected by the potential for asexual regeneration. These sites also have the potential to support establishment of white spruce if there is a live stand of white spruce close to the site (<1 km). Sites in this category have the highest potential to shift from black spruce to alternate successional trajectories.

4A. There are multiple standing black spruce trees with open cones at the site that provide a strong onsite seed source for black spruce.

I. Prefire aspen or birch trees are present at the site, with intact roots or stumps. Resprouting of deciduous species is likely to be abundant, and high litter production in the early postfire years may reduce levels of black spruce recruitment. The expected successional trajectory is **closed-canopy deciduous forest with an open understory of black spruce** (app. photo 21).

II. Prefire aspen or birch trees are rare or absent from the site.

a. There is at least one stand of live deciduous trees in the area (within 1 to 2 km) that can provide a local seed source for deciduous trees, and there is good seed production in the year after the fire. The expected successional trajectory is **mixed deciduous-black spruce forest**.

b. There are few live deciduous trees in the area or bad seed years after fire, resulting in low deciduous recruitment. The stand is likely to develop into **intermediate- to closed-canopy black spruce forest**.

4B. The local seed source for black spruce is limited by most trees having fallen over, trees being too young to bear many cones, or the cones being deeply charred (severe crown fire).

I. Prefire aspen or birch trees are present at the site, with intact roots or stumps. Resprouting of deciduous species is likely to be abundant, with little recruitment of black spruce. The expected successional trajectory is **open deciduous forest with sparse or absent understory of black spruce**.

II. Prefire aspen or birch trees are rare or absent from the site.

   a. There is at least one stand of live deciduous trees in the area (within 1 to 2 km) that can provide a local seed source for deciduous trees, and there is good seed production in the year after the fire. The expected successional trajectory is **open deciduous forest with sparse or absent understory of black spruce**.

   b. There are few live deciduous trees in the area or bad seed years after fire. Both conifer and deciduous recruitment is low, leading to **open aspen parkland** (app. photo 22) **or nonforested shrubland/grassland.**

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English Equivalents

When you know:	Multiply by:	To find:
Centimeters (cm)	0.394	Inches
Meters (m)	3.28	Feet
Kilometers (km)	.621	Miles
Hectares (ha)	2.47	Acres

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Appendix A: Operational Definitions

Spatial Scale of Assessment

The key has been designed to assess potential successional trajectories at the scale of individual forest stands. Forest stands can be intuitively defined as a patch of forest that can be visually assessed from a central point (approximately 20- to 30-m radius around the observer). On an areal basis, the scale of assessment is expected to be on the order of 0.25 ha, with a reasonable range of 0.1 to 1.0 ha.

Classifications of Postfire Seedbeds

Sites are classified with respect to the availability of different postfire seedbeds, largely on the basis of the depth and coverage of any remaining surface organic layers. Assays with a shovel or soil corer should be used at a site to estimate the characteristics of the soil organic layer. Stated thresholds in seedbed classifications are based on empirical observations of 2004 burns in Alaska studied as part of the Joint Fire Science Program.

1. Mineral-soil dominated: seedbeds dominated by more than 30-percent exposure of mineral soil or shallow organic layers (dense, humic layers <3 cm deep)

2. Organic-soil dominated: seedbeds dominated by cover of low-density organic layers, particularly soils with >5 cm organic layer depth and less than 15 percent mineral soil exposed.

3. Intermediate soils: seedbeds have moderate cover (15 to 30 percent) of exposed mineral soil or shallow (<3 cm deep) organic layers. Local conditions will determine whether these behave as “mineral-” or “organic”-dominated soils with respect to tree regeneration and successional trajectories.

Appendix B: Reference Photo Gallery

Site Identifier Species

Black spruce (*Picea mariana* (Mill) B.S.P.)


T. Hollingsworth

Photo 1—Black spruce stand.


T. Hollingsworth

Photo 2—Black spruce needles and cones.

White spruce (*Picea glauca* (Moench)Voss)

T. Hollingsworth

Photo 3—Lone white spruce.

J. Johnstone

Photo 4—White spruce needles and cones.

Decidious trees *(Betula neoalaskana* Sarg. and *Populus tremuloides* Michx.)


T. Hollingsworth

Photo 5—Mixed birch and aspen stand.


T. Hollingsworth

Photo 6—Closeup of birch bark.


T. Hollingsworth

Photo 7—Closeup of aspen bark.

Tussocks: Sedges that form tight clumps; predominantly cotton grass (*Eriophorum vaginatum* L.)

J. Johnstone

Photo 8—Cotton grass (*Eriophorum vaginatum*).

Firemoss (*Ceratodon purpureus* (Hedw.) Brid.): One of the most common types of small, unbranched mosses that colonizes organic and mineral soil after fire.

T. Hollingsworth

Photo 9—Firemoss (*Ceratodon purpureus*).

Sphagnum moss *(Sphagnum* spp.): mosses in the genus *Sphagnum.*

T. Hollingsworth

Photo 10—Sphagnum moss *(Sphagnum* spp.*)*.

Feathermoss: Pleurocarpous mosses commonly found in later successional stages of black spruce forest, such as *Hylocomium splendens* (Hedw.) Schimp. and *Pleurozium schreberi* (Brid.) Mitt.)

T. Hollingsworth

Photo 11—Feathermoss (*Hylocomium splendens* and *Pleurozium schreberi*).

Marchantia: A broad-leaved liverwort (*Marchantia polymorpha* L.) that is an abundant early colonist after fire of moist to wet mineral soils and exposed humic layers.

T. Hollingsworth

Photo 12—Broad-leaved liverwort (*Marchantia polymorpha*).

Lichen: An association of fungus and phytosynethic symbiont resulting in vegetation body with a recognizable structure.


T. Hollingsworth

Photo 13—Fruticose lichens especially *Cladonia* spp. and *Cladina* spp. but also including *Stereocaulon* spp. and *Cetraria* spp.


T. Hollingsworth

Photo 14—Broad-lobed lichens including *Lobaria linita*, *Nephroma arcticum*, and *Peltigera* spp.

Examples of successional trajectories

Emily Tissier

Photo 15—Open-canopy black spruce.

T. Hollingsworth

Photo 16—Intermediate- to closed-canopy black spruce.

J. Johnstone

Photo 17—Spruce-lichen woodland.

J. Johnstone

Photo 18—Open deciduous forest with sparse or absent understory of black spruce.

Brian Charlton

Photo 19—Mixed deciduous-black spruce forest.

Bonanza Long-Term Ecosystem Research Program

Photo 20—Closed deciduous forest.

Photo 21—Closed-canopy deciduous forest with an open understory of black spruce.


J. Johnstone

Photo 22—Open aspen parkland.

Postfire site assessment

These photos were taken in late May in the year after the stands had burned. All sites were dominated by black spruce prior to burning. Sites are taken as examples as part of a larger study of postfire succession in black spruce forests.

J. Johnstone

Photo 23—Nonforested shrubland/grassland.


J. Johnstone

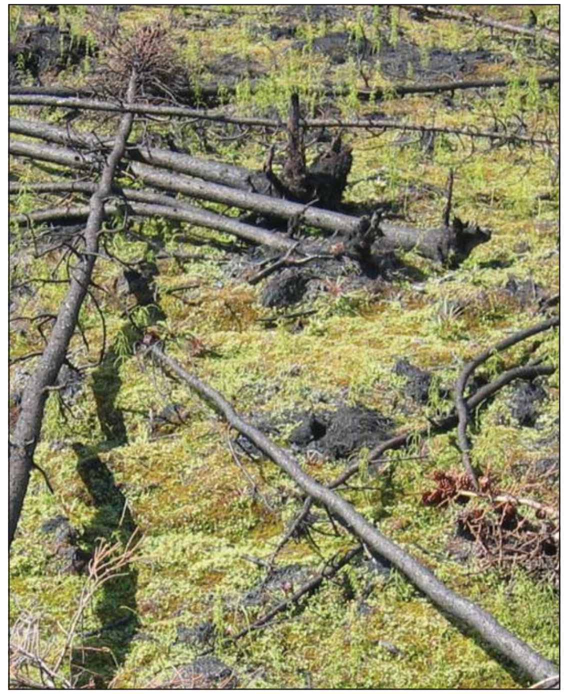

J. Johnstone


T. Hollingsworth


T. Hollingsworth

Photos 24-27—Moist site with the organic layer largely intact.

J. Johnstone



T. Hollingsworth

T. Hollingsworth

Photos 28-31—Moist sites with shallow residual organic layers and frequent patches of exposed humic or mineral soil.

J. Johnstone

J. Johnstone

J. Johnstone

T. Hollingsworth

Photos 32-34—Dry sites with the organic layer largely intact after the fire.

T. Hollingsworth all photos

Photos 35-37—Dry site where much of the organic layer has been consumed by the fire, exposing frequent patches of mineral soil.

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