

Fire Science

RESEARCH SUPPORTING SOUND DECISIONS

Brief



Highly flammable black spruce in Alaskan interior during 2004 fire. Photo by D. Sandberg and R. Ottmar.

Fire and Ice: Fire Severity and Future Flammability in Alaskan Black Spruce Forests

Summary

In Alaska, the unusually warm, dry summer of 2004 brought wildfires that burned a record setting 6.7 million acres, mostly in the flammable black spruce forests of the interior. Less flammable deciduous tree species were known to sometimes replace black spruce in areas where fire was severe enough to burn away the organic layer. Based on study of the 2004 fires, researchers developed methods for measuring the depth of pre-fire organic layers, and predicting patterns of post-fire regeneration and future forest flammability.

They investigated how variations in site moisture and organic layer consumption affect subsequent patterns of post-fire vegetation recovery. At sites with low to moderate moisture, fire severity can determine whether black spruce will regenerate or shift to a less flammable, deciduous dominated successional trajectory. Frequent fire can eventually cause high moisture sites to dry out and favor a deciduous system, supporting the idea that prescribed fire can be used to create deciduous fire breaks. This knowledge will help inform strategies for both wildfire suppression and prescribed fire that can potentially reduce future flammability in black spruce ecosystems at landscape scales.

Key Findings

- Black spruce returned as the dominant tree after low to moderate severity fire in cool, wet, poorly drained sites where the organic layer remained.
- The potential for the switch to deciduous dominance was high in well-drained sites where high severity fire exposed mineral soils.
- Invasive weeds are using wildfires as a conduit for colonization of burned areas up to 20 years old in interior Alaska.
- Fire severity is tightly linked to both pre-fire site characteristics and burning conditions.
- Fire severity, site moisture and pre-fire vegetation strongly influence vegetation composition after burning.

Black spruce or deciduous trees?

Alaska is a land of extremes, and the range of conditions that Alaskan black spruce will tolerate is no exception. The presence or absence of unique soil layers and their moisture content determine how and where this adaptable, flammable conifer will grow. Site moisture also determines whether spruce trees are likely to have the forest to themselves or share it with more fire resistant deciduous species like aspen and birch.

Alaskan black spruce thrive in wet, nearly frozen soils that deciduous trees can't tolerate, as well as in relatively dry, warm soils. Aspen and birch on the other hand aren't nearly as flexible and require the warmer, dry soils for growth. In sites where soil conditions lack temperature and moisture extremes, black spruce and deciduous trees often grow in tenuous balance with each other.

A wildfire burning under the right conditions can upset this balance giving deciduous species a competitive advantage. After severe fire, deciduous species can replace black spruce, relegating the more flammable conifers to the confines of the understory.

Recent record setting fires in Alaska's interior have put a fine point on the need for more information about this process and the implications for flammability of future forests. This project generated a wealth of information about the processes driving change in species dominance. Results will help managers maximize long-term benefit for the forests of Alaska's interior, and provide the tools needed to manage fire proactively at landscape scales.

The fires of 2004 provided a perfect opportunity to study how vegetation develops after fire in this ecosystem. Based at the University of Alaska Fairbanks and the Boreal Ecology Cooperative Research Unit, Jill Johnstone and Teresa Nettleton Hollingsworth have long standing interest in the vegetation dynamics of boreal forests and tundra ecosystems and how disturbance processes interact with climate change. With Joint Fire Science Program support, they investigated the idea that fire severity determines how likely it is that vegetation conditions that existed before a fire will eventually return, to what degree, and the implications of these changes for the flammability of future forests.

"Fire managers in Alaska can't fight fires just with fire suppression," explains Johnstone. "They have to have other tools. The area is simply too big and sparsely populated.



Black spruce inferno burns with aspen standing by. Photo by D. Sandberg.

Wildfires get out of control before anyone can get to them. We wanted to give managers what they need to develop prescribed burns, and to help them make decisions about whether or not to fight certain wildfires at all. Simply increasing the proportion of deciduous dominated stands in the landscape reduces the probability of severe fire, not only for deciduous forests but ultimately for black spruce too."

Three elements of the 2004 fires made them exceptional opportunities for research on fire effects in Alaskan black spruce forests. Fires burned through existing research sites where pre-fire vegetation had been intensively studied, providing concrete information about pre-fire conditions. Fire weather was unusually extreme—a trend that is expected to continue. These conditions gave researchers a sneak preview of what may be in store if weather continues to be warmer and drier than historical norms.

Lastly, fires burned adjacent to three of the state's few highways, providing unprecedented access to burned areas. Taking quick advantage of the situation, Johnstone, Hollingsworth and their colleagues set to their task in May 2005. Working from the charred, black spruce bogs to dry ridge tops, they assessed the recent past, the blackened present and the likely future of these landscapes. They studied the roles of site moisture, drainage and fire severity, and how the germination requirements of deciduous seeds make severely burned areas more supportive of their growth. In addition, they investigated whether or not firebreaks of deciduous stands could be deliberately created through prescribed fire. They also studied the mechanisms



Dalton Fire. Johnstone and Hollingsworth began their project in May of 2005 by establishing 90 study sites in burned, black spruce forests within three large fire complexes along the Dalton, Taylor and Steese highways. Photo by Jill Johnstone.

behind the spread of invasive weeds into remote burned areas.

Severe fire Alaskan style

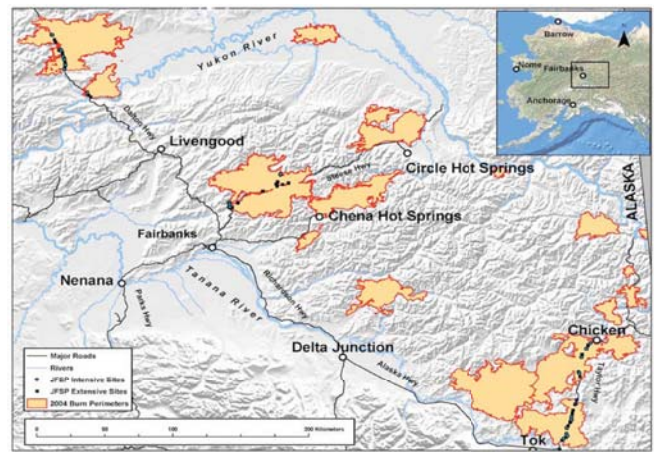
The terms “severe” fire or “highly flammable” can mean different things in different ecosystems. These differences are important when talking about fire severity as a primary determinant of post-fire changes in the flammability of vegetation.

Severe burns are those that change the ecosystem the most. They clear out the old and make room for the new. In the lower 48, severe fire and big change usually come in the form of crown fire. Crown fires are typically stand replacing, meaning that they kill nearly all of the trees with the exception of a few fire-adapted conifers. The result is a blank slate primed for the establishment of new plant communities that weren’t there before.

When fire kills all of the Alaskan black spruce trees in a stand however, it doesn’t necessarily mean that drastic change is on its way—or that the fire qualifies as ‘severe.’ The system may not see any change in species composition. Only a shift from mature black spruce trees back to spruce seedlings. It depends on the moisture content of the organic layer—which determines how deep it burns.

“When we talk about fire severity up here it’s not about how many trees were killed, because we have almost 100% tree mortality every time,” explains Hollingsworth. “It’s about how much organic layer has been consumed. That’s what’s really going to tell you about potential for shift in the successional trajectory and how much overall change a fire is likely to bring to the system.”

“Yes, black spruce is really highly flammable,” she says. “When a black spruce tree catches fire it’s going to burn completely.” But after the fire has burned an individual tree it typically drops down and creeps slowly along the ground, depending on how wet the site is. More trees will burn as the fire reaches them at their base—and if the organic layer remains, more black spruce will replace them. “Unless conditions are dry enough to allow the fire to burn down through the organic layer,” Hollingsworth continues, “chances are the system is going to regenerate exactly how it was before the fires.”



2004 fire locations and study areas.

This is because after low to moderately severe ground fire, black spruce still has what it needs to thrive and dominate; a cool, moist layer of acidic organic material and an underlying natural refrigerator keeping conditions the way they’ve been for centuries. Black spruce evolved to burn and regenerate in a manner that preserves these key, underlying supporters, keeping change at bay. But when weather conditions shift, so can the delicate system that keeps these components intact.

The permafrost-peat partnership

In these northern latitudes this critical organic layer consists of moss, peat and permafrost. Drainage and site moisture is strongly controlled by the depth and condition of these elements and how they interact with each other.

Permafrost is defined as solid ground that remains below 32°F for longer than two consecutive years. This frozen soil acts as a barrier to the movement of water and occurs in flat, lowland areas or on north or east facing slopes where direct sunlight is scarce. The deepest portion of permafrost can remain frozen solid for thousands to tens of thousands of years. Its upper reaches, which are closer to the fleeting heat of the short Alaskan summers, tend to thaw and re-freeze to varying degrees with the passing seasons—binding up water when frozen and releasing it back in to the system when it thaws.

Blanketing the permafrost is a layer of mosses, primarily sphagnum moss, which plays a critical role in the maintenance of permafrost. Like black spruce, sphagnum is entirely at home in very wet, cool, acidic sites where few other plants can survive. Unlike black spruce, however, it can’t live in warm, dry soils. Sphagnum is known for its ability to hold up to 30 times its own weight in water.

As sphagnum moves through its life cycle, dead moss accumulates faster than it can decompose, creating thick layers in various stages of decay known as peat, or peat moss. It’s the same stuff we buy in big bags in summer to mix into our garden soil, and it has the same effect—it increases the ability of the soil to hold water.

The living sphagnum moss and decaying peat combine to create the organic layer. It protects the system against

drastic changes by keeping conditions on and under the ground cool, moist and acidic. It maintains permafrost by insulating it from the heat of the summer sun and wildfires. In black spruce bogs, sphagnum perpetuates the conifers' sovereign reign by excreting even more acid into the system, making the real estate uninhabitable for deciduous trees.

For much of the year this organic layer is so wet that if it catches fire at all, not much of it will burn. Fire will often leave sphagnum moss untouched when it's saturated—resulting in a feature known affectionately among the scientists as 'sphagnum sheep': sheep sized mounds of unburned moss dotting a blackened landscape.

But unusually warm, long, dry summers like the summer of 2004 can dry out the organic layer to the point where it will easily burn, sometimes deeply and completely. It's uncommon for the organic layer to dry out to this degree at sites that have historically been very cold, but it's happening more frequently. The deep dryness leaves them vulnerable to complete consumption by late season fires. When fire is severe enough to consume the entire organic layer, the path is cleared for big change.

The tipping point

"This is a critical crossroads for the system," says Hollingsworth. "Will that black spruce bog transition to aspen parkland—something it's never been before? Or will it return to its former state? It all depends on how much moss was burned."



Sphagnum moss often holds so much water that fire will pass it by, leaving "sphagnum sheep"—sheep sized mounds of light colored, unburned moss peppering the blackened landscape. Photos by Teresa Nettleton Hollingsworth.

After moderate to severe fire, researchers found that the abundance and diversity of moss species decreased—particularly sphagnum. Reduced moss means less moisture

which can affect future flammability by taking historically wet sites another step closer to complete consumption in a future fire.

The team found that deciduous species were most sensitive to the depth of the residual organic layer and black spruce were most sensitive to changes in site moisture. In drier sites, fire was more likely to burn severely, exposing mineral soil that supports establishment of deciduous-dominated systems.

So an increase in organic soils that are becoming incrementally drier likely means an increase in severe fires—until the changes eventually result in a more fire resistant system. "Here we have one of the few potential ways to put the brakes on a runaway kind of climate driven fire system," Johnstone explains. "In a warmer climate we're going to get more fires and they'll be more severe. But if these fires initiate more deciduous forests we may actually get a less flammable landscape that will decrease fire frequency and severity."



Birch, horsetail and fireweed seedlings sprout in a moist site burned with high fire severity, formerly dominated by black spruce. Photo by Jill Johnstone.

They also found that invasive weeds use fire to establish themselves in remote areas that burned up to twenty years ago, prompting the recommendation that invasive species management extend into all areas that burned in the last 20 years, regardless of fire severity.

The time machine of adventitious roots

You can't really know how severe a fire was, or how much change it created, unless you know what was there before. Getting an accurate measurement of pre-fire organic layer depth has always been problematic, as have accurate assessments of the amount of carbon released during burning. Johnstone and her team developed a technique for assessing fire severity in black spruce forests that measures both—and they found the answers in black spruce roots.

As a black spruce tree grows, its true roots grow downward as moss grows up. The sphagnum and peat accumulate, rising up the trunk like a dark, spongy snowdrift. During this process the permafrost table rises too. Tree roots can only go down so far before they hit ice or cold waterlogged soil, at which point they have a tough time growing and taking up nutrients. In order to compensate for this, the tree initiates growth of new roots close to the

relatively warm surface of the organic layer—directly out of the sides of the trunk. These “adventitious roots” grow horizontally, tracking just a few centimeters below the top of the sphagnum. They help nourish the tree when its true roots get put in the fridge.

The depth of the organic layer is always changing. As adventitious roots grow out across the sphagnum, they follow the surface of this layer over time. When fire has burned severely and all the moss and peat are gone, the origins of adventitious roots can still be seen on the burned spruce trunks. Their locations serve as beacons from the past, signaling how deep the moss was before the fire.

“We measure the distance between the true roots and origins of the adventitious roots and get an accurate result,” says Johnstone. “This is very useful from a management standpoint because we can finally determine how much was lost and how much carbon was released in the process.”



Adventitious roots of black spruce trees lay exposed because the organic soil layer was consumed by wildfire. Photo by Jill Johnstone.

The adventitious root method proved to be an effective supplement to a tool commonly used in other ecosystems to determine fire severity; the Composite Burn Index (CBI). Accuracy of the CBI relies heavily on the percentage of tree mortality and a wide variation in the amount of fuel consumed during a fire—from the ground all the way up through the tree crowns. As a whole, the CBI doesn’t work as well in Alaskan black spruce systems where there is little variability in tree mortality—it’s usually at or near 100%. In addition, there isn’t much fuel above the sphagnum other than sparsely growing spruce, so some of the fuel layers that CBI requires for complete analysis don’t exist.

“There were times when the CBI worked better than we thought it would, and there were times when we had to modify it to get enough information out of it,” Hollingsworth notes. “I have my students use only the understory component of the CBI in combination with more information that’s more applicable to our system.”

Fires of today take the guesswork out of the future

The project generated several new resources about fire in Alaskan black spruce including a comprehensive website and permanent demonstration plots. The Fire Successional Trajectory Key provides specifications for using pre-fire vegetation, site moisture and fire weather conditions to predict future forest composition, and it includes a section for planning in unburned forests.

Management Implications

- Prescribed fire can be used to create fire breaks of deciduous forest in Alaskan black spruce forests.
- New measurement method is used in the field by managers to estimate how much of the organic layer was consumed by fire and how much carbon it released.
- Invasive plant monitoring should not be restricted to recent burns. Fires 10–20 years old in black spruce are likely to be the most vulnerable to invasion. Even low severity burns are susceptible to invasive species.
- The *Fire Successional Trajectory Workbook* provides managers with a way to use pre-fire vegetation, site moisture and fire weather conditions to predict future forest composition. It includes a section that assists with planning for unburned forests, and a key for identifying general categories of available site moisture.

“We feel like the real contribution has been to give managers the data they need to make more informed decisions about managing fire in Alaskan black spruce,” concludes Johnstone. “When a wildfire is burning at the end of the season with a high probability of both deep burning and a shift to deciduous forest—maybe you don’t want to fight it. We also wanted to spread the word about how even old, remote burned areas are vulnerable to invasive plants.”

“It’s hard to get a handle on all this when you’re trying to look at it from a landscape perspective,” she concludes. “When you throw climate change in there it’s really a moving target—and it’s all connected.” Thanks to this work, those connections are now much easier to see—and follow—as they build a path to a better understanding of fire in Alaska’s future forests.

Further Information: Publications and Web Resources

Final Report - JFSP Project 05-1-2-06. Managing Fire with Fire in Alaskan Black Spruce Forests: Impacts of Fire Severity on Successional Trajectory and Future Forest Flammability. Available from: http://www.firescience.gov/projects/05-1-2-06/05-1-2-06_final_report.pdf

The most up to date results are available at the project website: Boreal Ecology Cooperative Research Station, University of Alaska Fairbanks
<http://www.firesbecru.uaf.edu/JFSP.htm>

Scientist Profiles

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Managing Fire with Fire in Alaskan Black Spruce Forests: Impacts of Fire Severity on Successional Trajectory and Future Forest Flammability

Written By: Paige Houston

Purpose of this opinion piece

Manager's Viewpoint is an opinion piece written by a fire or land manager based on information in a JFSP final report and other supporting documents. This is our way of helping managers interpret science findings. If readers have differing viewpoints, we encourage further dialogue through additional opinions. Please contact Tim Swedberg to submit input (timothy_swedberg@nifc.blm.gov). Our intent is to start conversations about what works and what doesn't.

Problem

Much of Alaska is dominated by black spruce that contributed to the species composition that burned in high proportions during the 2004 fire season when a total of 6.7 million acres burned. Areas that sustained the most fire severity and fire activity were those with high road densities. The 2004 fire season will help answer: why this coincidence aligned itself to be one of the most severe fire seasons on record, how to predict those flammability patterns to plan for future potential problems, and what types of rehabilitation processes will be needed.

This study analyzed data collected before and after fires by looking at pre- and post-fire species, composition, soil consumption rates, fuel loadings, burning conditions, composite burn index, nitrogen, plant/root growth, rehabilitation of plants naturally and artificially, and moisture values. All of this data was then used to organize possible trends in stand flammability and predicting scenarios for managing fires in the interior of Alaska (Johnstone 2007). The study's successional trajectory workbooks are intended to

provide fire managers a dichotomous type workbook as guidance for going through the process that is in draft stages (Johnstone 2007).

Application for Land Managers: The Drawbacks of Using Successional Trajectory Workbooks

The idea of successional trajectory workbooks for determining potential flammability across a landscape in Alaska black spruce could confuse managers conducting field surveys. This is due to the successional trajectory workbooks' different classification methods, unlike those used for the Fire Regime Condition Classification (FRCC). In addition, these workbooks become one

more layer of the lengthy processes already in place for fire and fuels managers when trying to put projects on the shelf for implementation.

The workbook, although linked to a potential flammability mapping system, does not have the same strategy for determining potential vegetation, nor does it have the same biophysical descriptions used in the already required program of the FRCC, which is also linked to the rapid assessment mapping system Landfire.

For instance, one example that could be misleading is how the successional trajectory workbook describes a site as either “dry” or “moist,” with limited selections. The FRCC, on the other hand, describes vegetation strata across multi-varied landscapes within the Alaska region. The FRCC program also provides more options based on geographic area, physical setting, biophysical classification, and fire regime—giving the user a closer depiction of actual landscape and potential vegetation (FRCC 2005).

Fire managers don't want added layers or multiple programs of how to get to the same end point. Streamlining the processes might not be the answer either. Furthermore, this added layer of the trajectory workbook might not necessarily give accurate information like that of the FRCC model.

“Fire managers don't want added layers or multiple programs of how to get to the same end point. Streamlining the processes might not be the answer either.”

When determining potential flammability across a landscape using a model that provides basic or limited vegetation—or how one would get to that decision—would not give the fire manager the confidence about the model to make informed decisions about future fire planning. A fire manager has an abundance of accountability riding on those decisions. Thus, having models that give limited information should make managers cautious about the assumptions resulting from those trajectory models.

Rapid Assessment Might Overlook Key Elements in Planning Process

The study also suggests the close connection between severity and moisture values correlating to how well nitrogen influences plant growth and how well those plants exhibit vigor on site (Johnstone 2007). Data showed significant results that the higher severity and drier sites also had a higher shift in the potential vegetation that came back. Inversely, the sites with the higher moisture and lower severity had less change in species composition (Johnstone 2007).

Fire managers know how to model for extreme fire behavior weather based on the indices that they are already using. However, due to how lichens and mosses transport moisture that burn much like that of fine dead fuel, other studies show that black spruce presents very unique conditions that are difficult to model when it comes to predicting fire behavior (Norum 1982). Fire managers already weigh the variables closely when making predictions—knowing that rapid assessment might overlook key elements in the planning process.

One other glaring piece of information showed that proximity to roads illustrated a more dramatic shift in the change of vegetation (Johnstone 2007) that would assist fire managers in focusing attention to those problem areas. In addition to this glaring fact, this dramatic shift in species along roads includes weeds, thus contributing to a whole new set of management

implications and options that managers must consider. Fire managers understand that weeds management is just one of the tiers within the planning processes.

Other fire effects from the study reveal how the variation in lichen showed increase in browse for moose. Similarly, mosses showed a decrease that also affects how the permafrost responds to fire disturbances (Johnstone 2007). This decrease will further increase future fire severity and flammability probabilities.

This study provides application in how fire severity relates to potential flammability as a concept that can be used at various levels from project to landscape level planning. The process of this information came from intensive sampling methods that will be useful in making assessments of fire severity in the Alaska region. In contrast, other works show how Alaska presents characteristics much unlike the Lower 48 states that makes it difficult to model effectively, thus requiring additional scientific evidence for determining how to accurately predict fire behavior in Alaska (Norum 1982).

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Manager Profile

Paige Houston is the Regional Aviation Training Specialist at the Northern Rockies Training Center in Missoula, MT. She has 22 years experience in fire management across several USDA Forest Service regions, and a few years with the USDI Bureau of Land Management. She currently serves as a primary Division Group Supervisor on the Northern Rockies Type 1 Incident Management Team and instructs a variety of fire and leadership courses in northwest Montana, at the Wildland Fire Apprentice Academy, and with the National Smokejumper Association. She spent eight years with the Bitterroot and Lolo hotshot crews and worked two seasons with the Alaska Smokejumpers. She has several more years of experience in other primary firefighter and fuel management positions, including a season with the rappellers out of Chelan, WA. She's a graduate of the University of Montana where she received a degree in resource conservation.



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