FIRE EFFECTS ON THE ECOSYSTEM
Background

ARE FIRES NATURAL?

Fires have occurred in the boreal forest of interior Alaska for thousands of years. This is clearly shown by charcoal layers in soil, fire scars on trees, and the mosaic pattern of the boreal forest. The history of fire in tundra regions is less studied and less obvious. However, there are historical records of tundra fires since the early 1900's, and lightning is known to have caused some recent tundra fires. Scientists believe that lightning-caused fires have occurred in Alaska's boreal forest and tundra since at least the last ice age, 10,000 years ago.

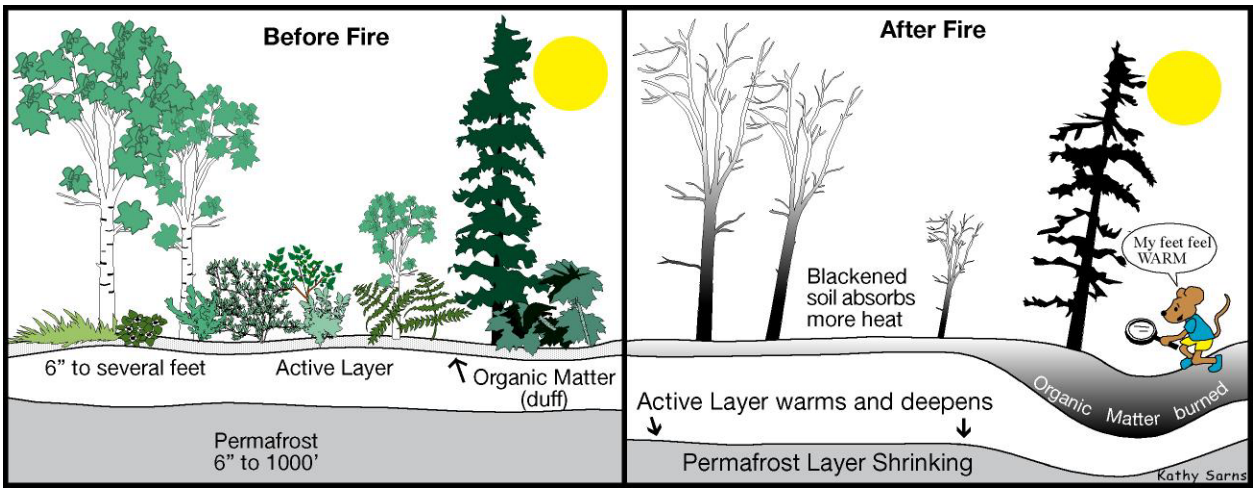
Fire records compiled by the U.S. Bureau of Land Management show that in interior Alaska, during the 20 years between 1980 and 2001, more than 4,000 fires were ignited by lightning. These lightning-caused fires burned over 13 million acres of boreal forest and tundra (over four times the area burned by human-caused fires during the same period). This provides clear evidence that lightning-caused fires are a powerful, natural phenomenon.

Humans have caused fires since their arrival in the boreal forest and tundra. Humans caused over half fires between 1980 and 2001. However, lightning-caused fires accounted for 90 percent of the lands burned. This discrepancy is probably a result of human-caused fires being more common along road systems and near human habitations. Here they are more likely to be detected, to be an immediate threat, and to be put out (see Figure 1 and Figure 2). Also land managers try to suppress most unplanned human-caused fires, while some natural fires may be managed as natural process.

HOW LONG BETWEEN NATURAL FIRES ON THE SAME SITE?

A **fire Interval** is the length of time that passes between naturally caused fires in a given location. Fire intervals can be estimated by examining the occurrence of ash layers in the soil, or by looking at the age of trees on various sites. Such research in the boreal forest indicates that the fire interval varies widely from site to site. However, most boreal forest sites burn at least once every 200 years. Many burn as frequently as every 40 to 130 years.

Less research exists on the occurrence of fire in tundra. Some tundra sites are thought to burn as often as every year. In other tundra areas fires may never occur under natural conditions due to the absence of lightning or inadequate supplies of dry fuel. In general, tundra fires tend to be much smaller and less frequent than boreal forest fires.



HOW DOES FIRE AFFECT THE BOREAL FOREST AND TUNDRA?

Research on the occurrence and effects of fire in Alaska's boreal forest and tundra is still underway, and much remains to be learned. But scientists have discovered that fires have many important, beneficial effects in the boreal forest ecosystem. Fires also have some beneficial effects in tundra areas but they are less understood. Fires affect the soil, vegetation, and wildlife of burned areas.

How Does Fire Affect Forest And Tundra Soil?

Changes in soil nutrients and temperature are among the first environmental changes triggered by fire. When plants and dead vegetation are burned, the minerals trapped in their leaves, stems, and wood are released and returned to the environment in the form of gases and ash. The ashes left by fire are rich in calcium, phosphorus, potassium, and other minerals. These minerals, previously trapped in organic material, enrich the soil.

Fire also helps enrich the soil indirectly by affecting the depths of the permafrost and active layers. Few fires directly thaw the permafrost layer. It is usually insulated from the heat of fire by the active layer, a thick mat of organic material and soil. But fire indirectly thaws the permafrost by burning some of the organic mat, blackening the soil surface, and reducing the insulating qualities of the active layer. These changes cause the soil to absorb more of the sun's heat. The depth of the active layer increases as the permafrost layer shrinks. In interior Alaska, researchers measured the active layer of soil in a burned site. They discovered that it increased from only 18 inches (45 cm) before the fire to 72 inches (183 cm) 8 years later (and the depth was still increasing).

In a few cases, the warming of the active layer and the melting of permafrost sometimes leads to soil erosion problems. This can be a serious problem on ice-rich permafrost soils on steep slopes. More often, however, deepening of the active layer has positive effects on the soil. It can

improve drainage and create drier soils. Warmer soil conditions and a deeper active layer on permafrost sites lead to increase decomposition by bacteria, fungi, and invertebrates that remain in or invade the soil of a burn site. Increased decomposition adds more minerals to the soil, in addition to those contributed directly by the fire. The resulting warmer, better-drained, mineral-rich soil provides good conditions for lush plant growth.

How Long Does It Take For A Burned Site to Return To Its Pre-Fire Appearance?

The most obvious effect of a fire is the burning and blackening of most plant material. But this dramatic visual change does not destroy the forest or tundra. Instead, it changes the site's appearance by reverting to an earlier successional stage (see Unit 1 on succession). Through succession, most burned sites gradually return to their pre-burn appearance. In the boreal forest, succession from a burn site to a mature aging forest may take 50 to 200 years.

The exact pattern and timing of succession on any site is difficult to predict because of variations in the physical environment and variation in fire impact. Most burned tundra sites are not as drastically changed by fire, and most return to their pre-burn appearance in only 6 to 8 years. The return to pre-burn appearance takes more time in tundra areas where lichens dominate. Lichens are often entirely consumed, even by light fires. Since lichens are slow growing and slow to invade burned sites, they may not return to a burned tundra site for 60 years or more.

HOW DOES THE PHYSICAL ENVIRONMENT AFFECT SUCCESSION?

The rate and pattern of succession depends partly upon the physical conditions of the burned site as different species of plants have different soil, temperature, and moisture requirements. Boreal forest succession on permafrost sites proceeds differently from that on non-permafrost sites. Similar differences occur in tundra. Certain sedges and mosses grow only in wet soils; many shrubs and cushion and mat-forming plants prefer dry sites.

As mentioned previously, a fire can deepen the active layer of soil in permafrost areas by blackening the soil surface and removing a portion of the organic layer. This in turn can affect soil drainage. In places where fire has indirectly caused the permafrost to melt, wet meadows, ponds, and even small lakes may be created. Not surprisingly, these changes in soil conditions have a strong influence on the kinds and numbers of plants that return to a burned site.

HOW DOES FIRE AFFECT SUCCESSION?

Succession is the natural, orderly change in plant and animal communities that occurs over time. (See “Succession of the Boreal Forest After Fire”).

The pattern of succession can be disrupted by disturbances such as weather, fire, flood, insects, and human activity. Lightly burned sites recover much more quickly and in a more predictable fashion than heavily burned

sites. On lightly burned sites, thousands of **rhizomes** (root-like stems,) roots, and seeds remain alive underground. In some places, even aboveground parts may survive. Nourished by the minerals released by the fire, surviving plant parts may sprout within days after the fire. Re-establishment of plants thus occurs very quickly on lightly burned sites.

In boreal forest areas, most of the surviving seeds, roots, and rhizomes are from the plant species that occurred on the site before the fire. However, some of the seeds buried in the soil may be from plants that have not grown on the site for 150 to 200 years. The seeds of wild geranium sprout only after a fire removes the shading trees and creates the warm, nutrient-rich soil conditions, which this plant needs to grow. Generally, the plants that return to a lightly burned forest site are those that grew on the site before the fire.

In tundra areas, most fires burn lightly due to lack of fuel so the extensive underground parts of most tundra plants usually survive fire. Their roots usually re-sprout within a year. Little change generally occurs in the species of tundra plants following a fire. However, due to the influx of nutrients from ash and increased decomposition, the returning plants may grow faster and produce more leaves, flowers, seeds, and berries than they did prior to the burn--at least during the few years immediately following fire. Most tundra sites return to their pre-burn appearance and productivity in less than ten years. Lichen-dominated tundra may require 100 years or more to return to its pre-burn appearance.

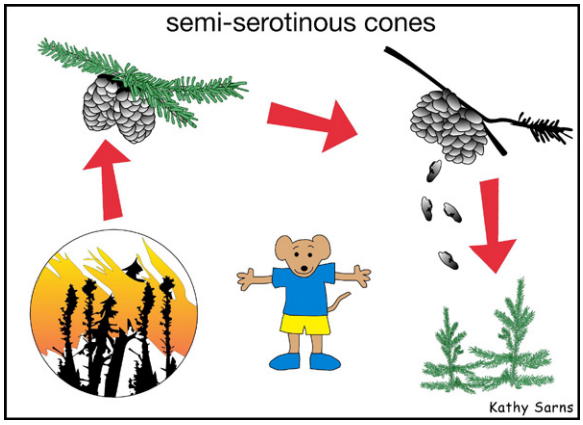
WHAT HAPPENS ON A HEAVILY BURNED SITE?

Heavily burned sites frequently occur in the boreal forest. But due to lack of accumulated dry fuel, heavily burned sites are rare in tundra areas. Heavily burned sites lack the full storehouse of roots and seeds that exist in lightly burned soils. Plants must generally re-invade these areas by seed. This kind of reestablishment may take some time, especially if the burn occurs late in the growing season.

The kinds of plants that re-invade a heavily burned site depend upon what seeds reach the site. The kind of seeds that reach a site are affected by 1) the kinds of plants present before the fire, 2) the kinds of plants present on adjacent, unburned sites, and 3) the timing of the fire. Variability in these factors makes it difficult to predict the exact pattern of succession on a heavily burned site in the boreal forest.

1) The kinds of plants present before the fire affect the revegetation of a heavily burned site because the dead plants may still be a source of seeds. This is particularly true if the plants on the site were black spruce. Black spruce trees do not drop their seeds each year like other conifers. Instead, these trees retain their cones, which are sealed shut with a touch of resin. The cones do not open until the resin is dried by many years of summer sun or by the intense heat of a fire. As the cones of black spruce open after a fire, millions of seeds rain down onto the charred forest floor. If conditions are suitable, the seeds

germinate, and a dense forest of black spruce forms. (The black spruce cone is called **semi-serotinous** because it can remain on the tree long after the seeds have matured. The cone opens and releases the seeds in response to the heat of a fire or a hot, dry summer. No other Alaskan tree has serotinous or semi-serotinous cones.)



Occasionally, post-fire conditions allow other kinds of trees to reseed themselves after a fire. Sometimes a ground fire in a stand of birch, aspen, or white spruce may kill trees without burning the seeds, which are produced in the upper branches. If the fire occurs at a time when the seeds are ripe, the unburned seeds can reestablish these species.

2) The kinds of plants in adjacent unburned sites are important seed sources for heavily burned sites. Seeds from adjacent areas may be blown into the burn site by wind or carried in by animals. The lightweight, cottony seeds of fireweed, aspen, and balsam poplar can be carried long distances by wind; these species can easily invade a large burn. The heavier seeds of white spruce rarely fall further than 150-200 feet (45-61 m) away from the tree that produced them. Thus, white spruce cannot easily invade a heavily burned site, unless white spruce trees survive in unburned patches within the burned area.

3) The timing of a fire also affects the kind of plants that invade a heavily burned site as different kinds of plants produce seeds at different times of year. Aspen and balsam poplars drop their seeds in June. White spruce and birch seeds ripen in late summer. Seeds that arrive on the site first germinate first and grow into seedlings. These seedlings generally out-compete seedlings that sprout later. The available space, water, sunlight, and nutrients are limited - the plants that flourish on a burn site are generally those that arrive first.

In summary, a fire kills some of the plants in the areas it burns. Plants regrow on burn sites from roots, rhizomes, and seeds that survived in the soil and/or from seeds blown or brought in from elsewhere. The exact pace and pattern of plant succession on a burn site is extremely difficult to predict because of the great variability in physical environments, fire impact, the kinds of plants present before the fire, the kinds of plants present on adjacent, unburned sites, and the timing of fires.

DO FIRES EVER CAUSE UNEXPECTED CHANGES IN PLANT COMMUNITIES?

Exceptions to the general patterns of plant succession do exist. In places where the boreal forest grades into tundra, fires can change forest into tundra - or tundra into forest - by altering the depth of the active layer. The addition of minerals from fire may create such lush tundra plant growth that the depth of the active layer decreases due to increased vegetative insulation. If the active layer decreases too much, trees cannot survive. Tundra created in this fashion has been called **pyrogenic tundra** - fire-created tundra. Pyrogenic tundra has been reported in Siberia and Canada, but so far no one has determined whether or not it occurs in Alaska. In contrast, Dr. Les Viereck (now retired) from the Institute of Northern Forestry, speculated that when fires expose mineral soil and provide a suitable seed bed, trees may become established in areas formerly dominated by tundra vegetation.

DON'T FIRES HARM WILDLIFE?

Certainly some animals, including nesting birds, voles, squirrels, and hares, are killed by fire. But surprisingly few dead animals are found after fires. Many birds and large mammals apparently escape the flames by flying or running away. Small mammals, such as voles and squirrels, sometimes escape fire by moving into underground burrows. Scientists think most vertebrate animals killed by wildland fires die of suffocation from the smoke rather than from the heat. Most invertebrate organisms in the surface soil and on vegetation are killed by fire.

The most important effects of fire on wildlife are not the deaths caused by the flames and smoke, but the indirect effects caused by changes in plant communities. Some wildlife species are harmed by these changes, while other species benefit. By removing trees, shrubs, herbs, and lichens, fire essentially removes the food and cover (habitat) for some wildlife. These cannot find homes in recently burned areas and are forced to move to other areas or die. But other kinds of wildlife move into and use burn sites. The species and numbers of animals that move into a burned area depend largely upon the kinds of plants that become re-established and the rate at which these plants grow. In general, as plants re-invade a burned area and succession proceeds, wildlife also reappears and some species flourish. The “Effects of Fire on Wildlife” provides more information on the effects of fire on specific species of wildlife.

HOW DO FIRES IN THE BOREAL FOREST AFFECT WILDLIFE POPULATIONS?

The general patterns of wildlife use during post-fire succession in the boreal forest are discussed below.

Wildlife Use of Recent Burns

A few wildlife species find food and cover in a burn site immediately after a forest fire. Bark beetles have built-in smoke detectors and heat sensors to help them locate burned areas.

These wood-boring beetles fly through the smoke and flames in search of burned trees. They feed on the inner bark (cambium) and wood of trees. Trees injured or killed by fire are unable to resist the attacks of these insects, so the beetles find an abundant food supply in burned areas. As growing numbers of beetles attack the burned trees, their predators, three-toed and black-backed woodpeckers, congregate in the burned areas to feed. Other predators such as foxes, coyotes, hawks, and owls often hunt in recent burns, probably because the voles and other small mammals that remain have little cover and are easy prey. This initial wave of animal invaders takes advantage of short-lived conditions. The predators soon clean up the small mammals that lost their homes in the fire. Within three to four years the beetles run out of injured trees to attack. Soon after, the numbers of beetles and woodpeckers in the burn area decline. In the meantime, plant succession is proceeding. Soils enriched by ashes provide the nutrients needed for a flush of plant growth. Grasses, herbs, and seedling shrubs and trees provide a rich source of food for insects and seed-eating birds and mammals. Far from devoid of life, a young burn is often alive with a wide variety of insects, along with hares, voles, shrews, sparrows, and flycatchers. These animals attract predators like foxes, coyotes, red-tailed hawks, northern hawk-owls, and American kestrels.

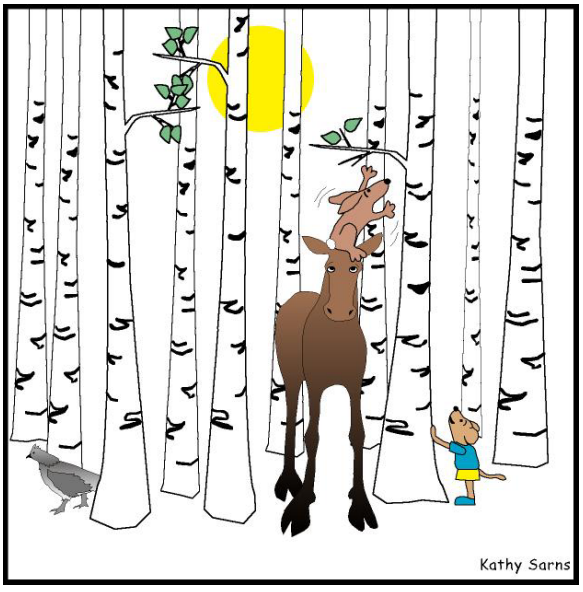
Wildlife Use of The Shrub Stage

Wildlife begins to flourish as the plant communities develop. Young trees and tall shrubs provide new nesting and feeding sites for birds. New species, including some warblers, sparrows, thrushes, and sharp-tailed grouse, may begin using the burn site at this stage. Due to abundant herbs, grasses, shrubs, and cover provided by fallen trees, the shrub stage of succession may provide habitat for larger numbers of small mammals and certain ground-nesting birds than any other successional stage. This abundance of prey supports similarly high numbers of predators, including foxes, weasels, and marten. In general, these species of predators are more abundant in this early stage forest than in any other stage.

If hardwood trees and shrubs are abundant, moose and snowshoe hares may also find an abundant and nutritious food supply in this successional stage. As their numbers increase, predators such as wolves and lynx may also move into the burn area.

Wildlife Use of The Young Forest And Mature Forest Stages

Once the saplings have grown into trees, they shade out smaller shrubs, other saplings, and many ground cover plants like fireweed and grasses. Animals that needed these plants die out or are forced to move to other areas in search of appropriate food and cover. Among the affected species are moose and hares when tree branches have grown out of their reach. Many of the seed-eating and shrub-nesting birds are also displaced, including most sparrows. But other species of wildlife, including ruffed grouse, Swainson's thrushes, yellow-rumped warblers, and sharp-shinned hawks, find ideal habitat in this forest stage.



Wildlife Use of The Aging Stage

As hardwood trees are replaced by spruce, wildlife that prefers spruce trees replace those that need hardwood forests. Porcupines, red squirrels, northern flying squirrels, caribou, white-winged crossbills, brown creepers, spruce grouse, boreal chickadees, goshawks, Swainson's thrushes, and Townsend's warblers are among the wildlife typical of old stands of spruce trees.

Fires rarely burn evenly. They burn in patches, completely burning some parts of the forest or tundra and leaving other parts untouched. This patchy burning pattern helps maintain a mosaic of different successional stages. The areas of the mosaic where different habitat types meet are called edges. Because many species of wildlife require more than one habitat type to provide their needs, edges offer the opportunity for the greatest diversity of wildlife. Many wildlife species prefer the edges found between vegetation types, using these areas for feeding and travel. Many species that feed in earlier successional stages seek cover in old

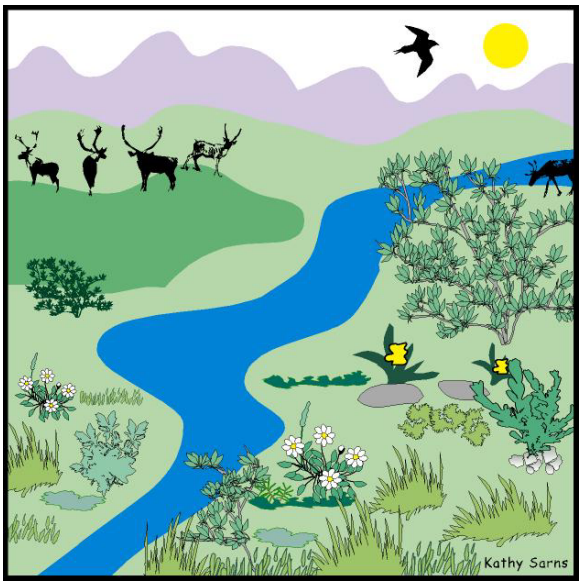
forests, particularly during winter. These include snowshoe hares, lynx, bear, marten, moose, and resident birds.

In summary, many of the wildlife of the boreal forest depend upon repeated and sporadic fires to create and maintain the forest mosaic. Just as plant populations change throughout succession, so do those of wildlife. Some boreal forest wildlife find the best habitat in recent burns or the shrub-sapling stage of succession, while others find their habitat needs met by old forests (see "Effects of Fire on Wildlife Handout") Some species apparently require both early and later stages of succession. The abundance of wildlife in the boreal forest is largely a result of the variety of habitats and edges provided by the forest mosaic.

HOW DO TUNDRA FIRES AFFECT WILDLIFE POPULATIONS?

The effects of tundra fires on wildlife are often short-lived. The lush plant growth that occurs in the years immediately following a fire (due to the soil changes discussed above) can lead to higher populations of plant-eating organisms and their predators. Lemming and vole populations may increase a few years after a fire, providing abundant food for foxes, weasels, and jaegers. In areas where tundra fires lead to formation or maintenance of wetlands and ponds, waterfowl and other aquatic animals such as beavers and muskrat may benefit. In general, as plants re-invade a burned area and succession proceeds, wildlife also reappear and some species flourish.

The long-term effects of tundra fires on wildlife have not been fully studied. Since the effects of fire on tundra plant communities are fairly short-lived, it seems likely that tundra fires cause few long-term changes in wildlife populations. However, scientists disagree about the effects of fires on caribou. Since these animals eat lichens for winter food, some scientists are concerned that fires may reduce the amount of winter habitat for them. However, research into the effects of fire on the size of various caribou herds has not shown any clear pattern.



Some herds have increased following large fires, while others have declined. At present, most caribou biologists think that fire is less important than other factors in determining the size and health of caribou populations.