Succession - Changing Forest Habitats

Section 4
FOREST INSIGHTS

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One of the differences between living and **nonliving things** is that living things grow and change in a predictable pattern. Communities of living things – **ecosystems** – also are dynamic and change.

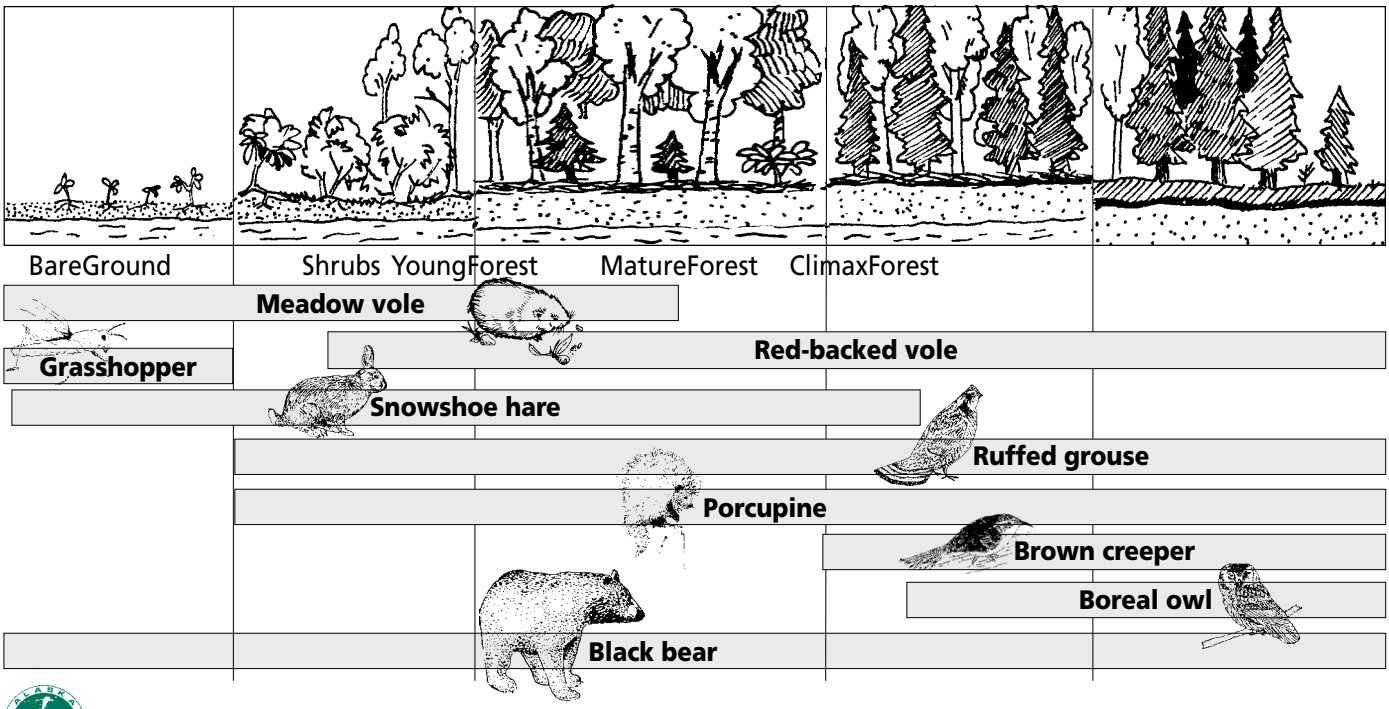
Succession describes the *patterns of change* in ecosystems when a new environment is formed or after an existing environment is disturbed. Succession occurs in all types of ecosystems, from oceans and wetlands to tundra, deserts, and forests.

Bare Rock to Deep Forest. If we could look back in time, we would see some currently forested lands that once showed no sign of trees or any other plants (*described in the following "Glacier Bay Time Machine*). Over time, a specific order of plants colonized the barren or disturbed site.

How Does It Happen? How a forest grows and which plants come first or second depends on
(1) competition,
(2) differences in the needs of plants, and
(3) the effects of the nonliving environment on plants and other living things.

Dynamic Wildlife Habitat. As the forest **habitat** changes, so does the list of wildlife that can call that stage of the forest their home.

Where Some Animals Fit in Boreal Forest Succession



Alaska's Very Own Time Machine

As glaciers recede (*melt*), they uncover a raw, new land – giving us a glimpse of how our continent looked thousands of years ago.

We can board the glacier "time machine" in Glacier Bay to see in minutes what took hundreds of years of natural forest growth.

GLACIER BAY:
View 200 *Years in a* FLASH

Historical records show that only 200 years ago in Glacier Bay there was no bay, no forest – just a huge glacier.

Now the main glacier has receded many miles, leaving a time-machine record of how forests develop.

Year 0: Nearest the glacier's toe, where the ice most recently melted, the land is barren rock and silt-laden runoff. No plants inhabit this area.

Year* 10:** A short distance outward, where the ice has been gone about 10 years, we see scattered patches of moss, fireweed, and dryas (*all* ***pioneer plants) among the gray rocks.

Year 30: We walk among alder, willows, and cottonwoods, stepping on grasses, dryas, and other herbs.

Year 50: Farther along the glacier's former path, the alders and cottonwoods are taller than we are. But we can step over small spruce that are just sprouting.

Year 200: Near Bartlett Cove, where 200 years ago local Natives and explorer George Vancouver encountered a wall of ice, we now see a dense spruce forest covering the land like a green glacier. Little light reaches the forest floor under the spruce **canopy** so there are few **understory** shrubs, and the **ground cover** is mainly moss. Scattered in the dark forest, small hemlock saplings strain upward to find sunlight.

Stages of Succession

Alaska's two forest types go through similar stages in succession. Although the stages are listed below as a linear order, succession is usually cyclical.

PRIMARY SUCCESSION

Primary succession occurs when **disturbances** (*such as glacial advances and retreats, volcanoes, earthquakes, landslides, scouring floods, or very hot-burning fires*) remove the soil and organisms from a site, leaving only bare rock, gravel, silt, or sand.

It is "primary" because soil – the foundation for everything else – starts here. Soil formation begins with slow breakdown of rocks by weathering. Dust, silt, and sand collect in these pockets of **mineral soil**. At the same time, **pioneer plants**, some animals, and other living things (*microscopic organisms*) colonize the site. As they grow, die, and decay, a layer of **organic soil** is formed.

The stages of primary succession are as follows. *Each stage is also called a* ***sere*** *by foresters.*

Pioneer
Tall Shrub
Young Forest
Mature Forest
Climax (or Old-Growth) Forest

If no new disturbance occurs, the site passes through the stages until a climax forest is formed. Each stage is characterized by a different **community** or mixture of plants. Each stage is distinguishable, but the change from one stage to another is gradual.

SECONDARY SUCCESSION

Secondary succession starts when a disturbance (*such as wind storms, insect outbreaks, logging, avalanches, bulldozers, or fire*) leaves the soil intact. Seeds, spores, and roots usually remain as well.

Sites that begin with secondary succession reach the next stage more quickly than during primary succession. Plants are often more crowded because the soil is deeper and more uniform. The crowding leads to intense **competition** for soil nutrients and light. This makes it difficult for new species to invade.

The stages of secondary succession are as follows.

COASTAL RAINFOREST
Regrowth Stage
Second-Growth Forest
Old-Growth Forest

BOREAL FOREST
Regrowth Herb Stage
Regrowth Shrub Thicket
Regrowth Young Forest
Mature Forest
Climax Forest

Fire as a Catalyst. Despite Smokey Bear's admonition to prevent them, fire is a natural component of many forest ecosystems including Alaska's boreal forest. Fire does indeed design the boreal forest by restarting succession at various stages (*see following*).

Note: While the term "secondary" suggests that it occurs after primary succession, the two do not form a sequence.

FIRE DESIGNS BOREAL FOREST

Fire is often succession's driving force, especially in Alaska's boreal forest ecosystem. The dry climate, long days and hot summer temperatures create perfect conditions for fires to spread.

"Stump" the Scientists

In Interior Alaska, the pattern of succession is unclear to scientists, even now. There are few mature spruce forests with trees older than 200 years even though white spruce are long-lived trees.

Born of Fire. In Interior Alaska up to 2 million acres of forest burn every year due mainly to lightning strikes. Foresters at the University of Alaska estimate that almost every part of the boreal forest burns at least once every 200 years.

Patchwork Quilt

Fires in Alaska's boreal forests leap and dance across the land, burning everything to charcoal in one spot, barely singeing tree branches in another. Succession begins whenever fire passes.

- If fire kills trees and removes all the surface organic matter, **primary** succession begins with soil building. **Pioneer plants** in the boreal forest are liverworts and mosses followed by plants with windblown seeds such as fireweed, grasses, willows, and cottonwoods.

- In places where fire has burned less hotly and soil remains intact, **secondary** succession begins using remnant seeds or any blown in from surrounding areas. Plants that grow the fastest and tallest shade out competitors to become dominant.

Evidence suggests that as the mossy carpet on the forest floor grows thicker, it insulates the ground and allows **permafrost** to rise closer to the surface. Ultimately, all boreal forests might become black spruce and tamarack, two species that tolerate permafrost.

In most boreal forest areas, succession never reaches "climax" stage because a disturbance stops the clock and starts the process over again.

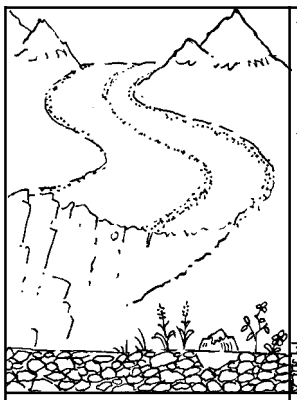
Fire Thrives in Mature Forests

As the boreal forest grows, so too, does its **fuel** for wildfires. A patch of pioneering willows on a sandbar is meager food for a lightning strike. But a strike within a mature coniferous forest can start a fire that gets hotter and hotter as it consumes trees, shrubs, grasses, and all the natural **litter** left by slow decay in cold climates.

Mosaic of Succession. The longer a forest has been without a fire, the more fuel it will have – and the hotter it will burn. Where fires are frequent, the forest is usually a mosaic of successional stages.

Primary Succession in the Coastal Rainforest

Areas where **glaciers** have retreated provide a living laboratory for the study of primary succession. The chart below illustrates the pattern of change after glaciers retreat. Primary succession also occurs on new lands created by **rivers**, **earthquakes**, **landslides**, or **volcanoes**. The patterns on these sites are similar, but pioneer plants may differ.

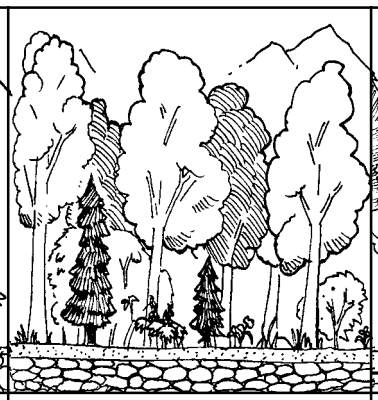


PIONEER STAGE:

Common **pioneer plants** include dryas, fireweed, willow, alder, and soapberry. Alder and dryas have symbiotic bacteria in their roots which take nitrogen from the air. This allows these plants to grow on soil that lacks an organic nitrogen-rich layer. The leaves of these plants, once decayed, form an important part of the **organic soil** layer. Several feet of snow may accumulate on the ground in protected sites in winter. Strong winds will keep most other areas snow-free.

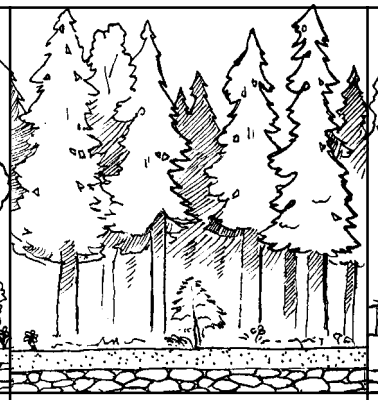
TALL SHRUB STAGE:

Within **5 to 20 years** after the retreat of a glacier, a layer of **organic soil** has developed on some sites. The **pioneer** willow, alder, and soapberry continue to grow taller. Cottonwood, Sitka spruce, and other plants begin to invade the site. Most of the shrubs and saplings are deciduous and do not trap much snow in winter. The leafless shrubs slow the winds, however, so several feet of snow may accumulate on the ground.



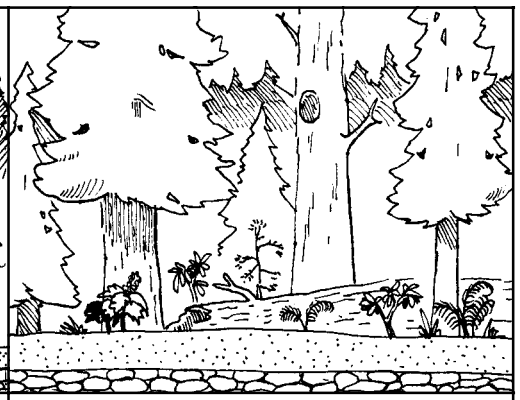
YOUNG FOREST:

70 to 100 years after glacial retreat, cottonwoods, red alder, and some willows have reached tree height. A few tall spruce are present and many spruce saplings grow beneath the broadleaf **canopy**. Strawberry, lupine, club mosses, and others form the **ground cover**. Because many of the trees are deciduous, the winter snows reach the ground and accumulate.



MATURE FOREST:

150 to 200 years after glacial retreat, Sitka spruce trees form the forest **canopy**. Because cottonwood and alder trees only live 70 to 100 years and their seedlings can not survive in the shade of conifers, few broadleafs remain. Hemlock seedlings are tolerant of the shade and some grow beneath the spruce. The needles of spruce are slow to decay, so many litter the forest floor. Relatively few **ground cover** plant species can grow amid these needles and in the shade. Mosses, huckleberry, and wintergreen are often present. The dense tree **canopy** intercepts most of the snow that falls, so that relatively little snow accumulates on the ground.



CLIMAX FOREST (*or Old-Growth*):

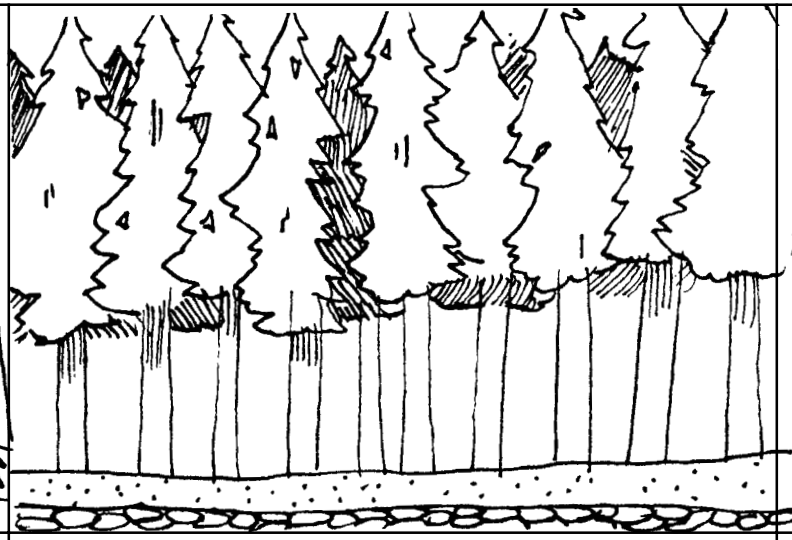
The length of time required varies, but some scientists estimate **250 to 600 years**. On well-drained sites the **canopy** trees are hemlock and Sitka spruce. Many large old conifers have died and fallen. Sunlight reaches the forest floor. Trees of all ages (seedlings, saplings, young trees, and old giants) are present. This forest will replace itself. Shrubs and herbs grow in the filtered sunlight including alder, salmonberry, devil's club, elderberry, huckleberry, skunk cabbage, false lily-of-the-valley, trailing bramble, ferns, and mosses. Trees branches are covered with lichens and mosses. **Snags** are riddled with woodpecker holes. Large branches of old trees catch much of the winter snow, so relatively little snow accumulates on the ground.

Secondary Succession in the Coastal Rainforest

Avalanches, **severe wind storms**, **outbreaks of insects** and **tree diseases**, and **human activities such as timber harvest** are the main events triggering secondary succession in the coastal rainforest. These events can disturb small or large areas. The pattern of regrowth shown in the chart below occurs if the site is not disturbed again. Repeated disturbances of a site can restart the process, setting back the clock to an earlier stage.

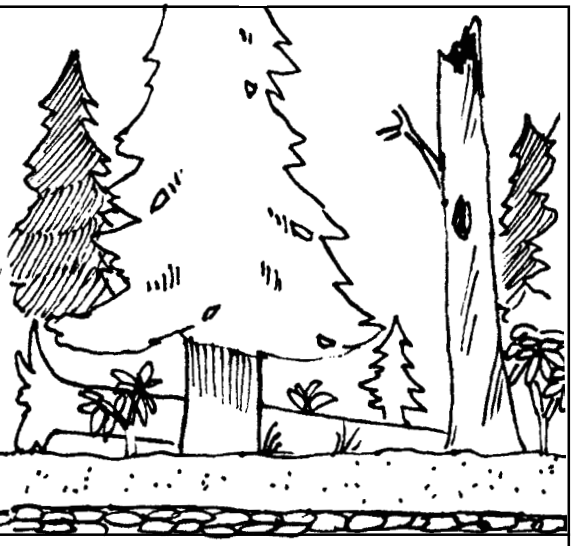
REGROWTH STAGE:

Alder, devil's club, elderberry, huckleberry, seedling spruce, and hemlock flourish within a few years if the **organic soil** layer remains. Many sprout from seeds or roots buried in the soil, while others sprout from seeds carried in by the wind or animals. Downed trees and branches cover much of the ground, making walking difficult. Large standing dead trees – **snags** – may be present if outbreaks of insects or disease started the succession. Snags may or may not be left during timber harvest. Several feet of snow usually accumulate on the ground in winter.



SECOND-GROWTH FOREST:

Within **25 to 35 years** conifers, particularly western hemlock, crowd the site. They are near the same size and age, giving this forest the name "even-aged forest." Few plants can grow in the deep shade and thick layer of needles from the hemlocks. Shrubs are few. Mosses and liverworts are the primary **ground cover**. The **snags** are too small for use by animals. In winter the dense **canopy** of conifers catches most snow, so little accumulates on the ground. (*This stage of succession is similar to the young and mature forest stages of primary succession, but here conifer trees are more numerous and more closely-spaced.*)

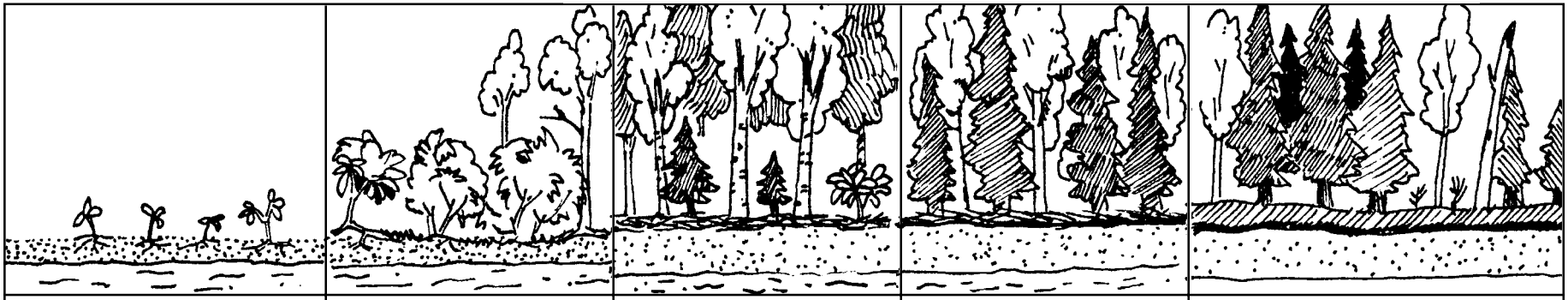


OLD-GROWTH FOREST:

After **200 or more years** the **canopy** trees are hemlock and Sitka spruce. Trees of all ages (seedlings, saplings, young trees, and old giants) are present. This forest will replace itself. Many large old conifers have died and fallen, opening the canopy. Sunlight reaches the forest floor. Shrubs and herbs grow in this light and include alder, salmonberry, devil's club, elderberry, huckleberry, skunk cabbage, false lily-of-the-valley, trailing bramble, ferns, and mosses. Tree branches are covered with lichens and mosses. Many **snags** contain nesting holes. Large branches of old trees catch much of winter's snow. Little snow accumulates on the ground beneath the trees, but may accumulate in the larger openings.

Primary Succession in the Boreal Forest

In Alaska's boreal forest, **rivers** often abandon old banks and sandbars to carve new channels. The chart below illustrates the pattern of change on abandoned river sites. Patterns of change would be somewhat similar on new lands created by **glaciers**, **landslides**, **earthquakes**, **volcanoes**, and **severe forest fires** that burn all organic soil. Pioneer plants invading each site may differ.



PIONEER STAGE:

Only hardy **pioneer plants** (willow and alder) take root in floodplains. The rocky base is usually covered with mineral salts. During high water, the site may flood. Roots of the willows and alders help to hold sand and trap more silt from the river. Silt combines with decayed leaf litter to eventually form **soil**. Symbiotic bacteria in the roots of the alder take nitrogen from the air and make it available to the roots. This allows these plants to grow on soil that lacks an organic, nitrogen-rich layer.

SHRUB STAGE:

In **10 to 30 years**, willow and alder grow into tall shrubs. Newly created soil and frequent deposits of silt raise the land level so it floods less often. Now other plants can invade including poplar, birch, rose, high-bush cranberry, and a variety of grasses and herbs.

YOUNG FOREST:

In **30 to 100 years**, poplars and birch have reached tree height, casting too much shade for sun-loving pioneer willows and alders. The better-developed soil layer and rarity of flooding allow white spruce to colonize the site. Rose and high-bush cranberry shrubs become more common.

MATURE FOREST:

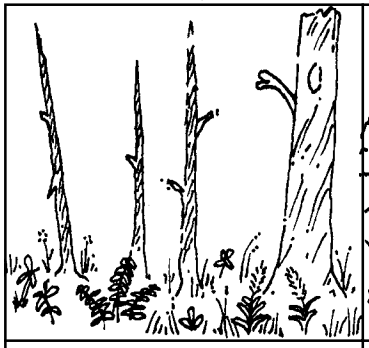
In **100 to 200 years**, the **canopy** is a mixture of balsam poplar and smaller white spruce. Rose, high- bush cranberry, and other shrubs form the **understory**. Fireweed, horsetails, and grasses occur in the **ground cover**. When spruce trees dominate the canopy, shade-tolerant mosses take over the forest floor.

CLIMAX FOREST (*or Old-Growth*):

Few forests in Interior Alaska survive to this stage; fire or flood usually turns back the clock. After **200 years**, white spruce trees form the **canopy** and **understory**, spanning all ages from seedling to old giant. At this stage the forest becomes self-renewing. A few poplars and birch grow here but seldom live more than 100 years. Their seedlings cannot survive in the shade of the spruce. Dead broadleafs or white spruce fall, creating openings in the canopy and exposing bare soil. Sunlight reaches the forest floor and new spruce seedlings start on the exposed soil. The forest floor is covered by feather moss and some reindeer lichen. Shrubs and herbs that grow in the filtered sunlight include alder, rose, a willow, wintergreen, low- bush cranberry, twinflower, and bunchberry.

Secondary Succession in the Boreal Forest: Non-Permafrost Sites

Wild fire is succession's driving force here. The chart below illustrates the pattern of change after fire on a **well-drained site**. Regrowth following **flooding**, **insect outbreak**, **avalanche**, **timber harvest**, or **land clearing** would be somewhat similar. **Fire benefits the forest** in ways the other events do not. Fire (1) releases minerals stored in wood, ensuring a nutrient-rich soil for the next stage, and (2) leaves many standing dead trees – **snags** – so more animals can occupy the early regrowth stages.

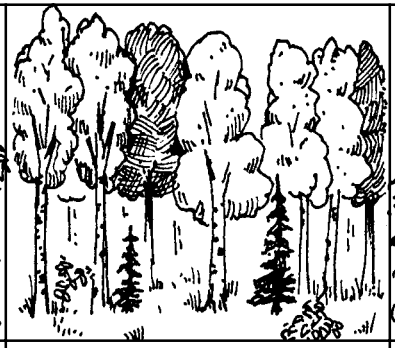


REGROWTH HERB STAGE:

Fire returns the **minerals** stored in trees to the soil, creating a nutrient-rich bed for plant growth. At least an inch of **organic soil** must remain for regrowth (rather than primary succession) to begin. Seeds and spores buried in the soil start to sprout. Other seeds blow in from surrounding areas. Some plants start from roots and stumps not killed by the fire. Common plants include fireweed, wild geranium, rock harlequin, horsetail, chiming bells, raspberry, rose, aspen, birch, willow, alder, and spruce. Mosses, liverworts, and lichens also grow on recent burn sites. Many **snags** will be present if regrowth starts from a mature or climax forest site.

REGROWTH SHRUB THICKET:

Within **3 to 25 years** after a fire, most sites are covered by a variety of shrub and sapling trees including willows, alder, raspberry, rose, birch, aspen, and poplar. A few white spruce seedlings start their slow growth. Fireweed, grasses, horsetails, chiming bells, and rock harlequin are the most common herbs. There are fallen trees and large **snags,** many with woodpecker holes.

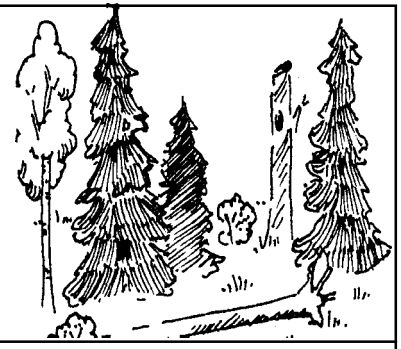


REGROWTH YOUNG FOREST:

From **25 to 45 years** after fire, the **organic soil** layer is at least 2 inches deep. Birches, aspens and/or poplars form a dense forest **canopy**. If present, the slow-growing spruce are smaller than the broadleafs. Seedlings of birch, aspen, and poplar cannot survive in the shade so they are absent. Few tall shrubs are present except for rose, alder, willows, and high-bush cranberry. Labrador tea, lingonberry, bunchberry, twinflower, and wintergreen are common **ground cover** plants. Feather mosses are abundant. Most fire-killed trees have fallen and are decaying into the soil. There are a few small **snags**.

MATURE FOREST:

From **45 to 150 years** after fire, **organic soil** is several inches thick. A mixture of broadleafs and white spruce form the forest **canopy**. The abundance of white spruce varies among sites. The canopy is more open, so some birch and aspen seedlings and saplings grow in the **understory**. High-bush cranberry and rose are the major tall shrubs; there are few willows. Low shrubs and **ground cover** plants thrive and include kinnikinnik, lingonberry, Labrador tea, twinflower, fireweed, horsetails, and timberberry. There are fallen dead trees and a few large **snags**.

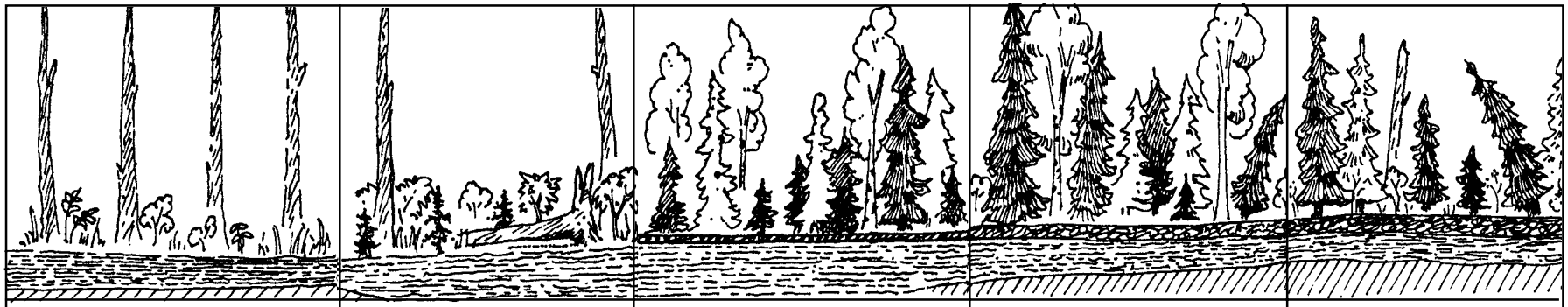


CLIMAX FOREST (*or Old-Growth*):

Some **150 to 300 years** after fire, if a site is not disturbed again, this **self-renewing** stage will be reached. **Organic soil** is about 5 inches thick. White spruce dominate the forest **canopy**, but some birch, aspen, and poplar may be present. The canopy is fairly open, so some sunlight reaches the forest floor. High-bush cranberry and rose are the main tall **understory**, though some alder may be present. Low shrubs and **ground cover** plants are mainly wintergreen, horsetails, and twinflower. Feather mosses, and sometimes lichens, are abundant. There are many fallen logs and **snags**, some with woodpecker holes.

Secondary Succession in the Boreal Forest: Permafrost Sites

Wild fire is succession's driving force here. The chart below illustrates the pattern of change after fire on a **poorly-drained site**. Regrowth following **flooding**, **insect outbreak**, **avalanche**, **timber harvest**, or **land clearing** would be similar. The old-growth stage may never be reached if fires and other disturbance events occur too frequently. **Fire benefits the forest** in ways the other events do not. Fire (1) ensures a nutrient-rich soil for the next stage by releasing minerals stored in wood, (2) releases seeds of black spruce, a common tree on permafrost sites, and (3) leaves many standing dead trees – **snags** – so more animals can occupy the early regrowth stages.



REGROWTH HERB:	REGROWTH SHRUB THICKET:	REGROWTH YOUNG FOREST:	MATURE FOREST:	CLIMAX FOREST:
Fire returns the **minerals** stored in trees to the soil, creating a nutrient-rich bed for plant growth. At least 3 inches of **organic soil** remains for regrowth (rather than primary succession). **Permafrost** may be 20 inches or more below the surface. Seeds and spores buried in the soil start to sprout. Willow, rose, grasses, blueberry, Labrador tea, mosses, and cloudberry sprout from existing roots. Wind and animals bring in more seeds: willow, lingonberry, resin birch, and spores of various liverworts and mosses. Fire and sun opened the cones of black spruce so their seedlings soon became numerous. Many **snags** will be present if regrowth starts from a mature or climax forest.	From **5 to 30 years** after a fire, the **organic soil** layer increases to about 7 inches. Most sites are covered by tall shrubs and sapling trees. Willows are most common, but aspen, birch, and black spruce seedlings and saplings are also abundant. Mosses, grasses, fireweed, blueberry, Labrador tea, and lingonberry are the most common **ground cover** plants. Some **snags** are drilled with woodpecker holes.	From **30 to 55 years** after fire, the **organic soil** layer remains about 7 inches thick, and **permafrost** has thawed to a least 30 inches or more below the surface. A dense stand of black spruce with some birch and aspen, or birch and aspen alone, form the **canopy**. Spruce seedlings crowd the ground. Seedlings of birch, aspen, and poplar cannot survive in the shade and are uncommon if spruce dominate the canopy. Few tall shrubs grow except for willow, resin birch, alder, and rose. Labrador tea, lingonberry, and blueberry are fairly common, but mosses and lichens cover much of the ground. Almost all of the trees killed by the fire have fallen and decayed, returning to the soil. This forest has many small **snags.**	From **55 to 90 years** after fire, **organic soil** thins as more mosses insulate the ground and permafrost rises to less than 23 inches below the surface. The **canopy** may be pure broadleafs, a mixture of broadleafs and black spruce, or nearly solid black spruce. The few tall shrubs include willows, rose, and alder. Lingonberry, blueberry, bunchberry, grasses, mosses, and many black spruce seedlings cover the ground. Some small **snags** are present, but few are large enough for nest holes. There are some fallen dead trees.	After **90 to 200 years**, if not disturbed again, this **self-renewing** stage is reached. The depth of **organic soil** and permafrost remain the same as in mature forest stands. Black spruce dominate the forest **canopy**, but some birch may be present. Alder and black spruce saplings form the **understory**. Low shrubs and **ground cover** plants are mainly Labrador tea, lingonberry, and timberberry. Feather mosses and sometimes reindeer lichens cover the ground and provide insulation that prevents the ground from thawing. There are many fallen trees and some **snags**, many with woodpecker holes.

Wildlife Follow the Habitat

All living things have **adaptations** or special traits that let them thrive in a particular environment. These adaptations may be structural (*body size and shape*), physiological (*diet, cold- or drought-tolerance*), or behavioral (*finding mates or defending territory*).

Some species (*such as brown bears*) have broad habitat requirements and wide ranges of tolerance for environmental conditions, so they occur in many different environments. But species with narrow ranges of tolerance and very specific **habitat** requirements occur only in specific environments.

The list of wildlife found in Alaska's two forest types changes as certain habitats become available during succession. Many animals, however, use more than one stage of succession as habitat, especially in different seasons.

To determine if an animal could live in a habitat created by a stage of succession, ask: Does it contain the food, shelter, water, and/or space needed by that animal?

Nonliving Elements Restrict Users. In early successional stages, for example, the environment is open and windy. Lots of sunlight reaches the ground. The temperatures can change quickly, and rain and snow have a great effect on the plants and animals. There are often daily and seasonal extremes of temperatures, wind, and moisture. Animals residents are restricted to those that can nest or hide near the ground.

Can I Reach My Food? The shrub thicket stage provides the dietary needs of moose and snowshoe hares. But as trees get older and taller, both moose and hare are at a disadvantage. They can no longer reach the new branches. Neither animal is adapted to use mature forests except for shelter.

Snag a Home. Birds such as woodpeckers, chickadees, and boreal owls nest in cavities in the decaying soft wood of **snags** (*standing dead trees*). Their adaptation for cavity-nesting works well in old-growth climax forests where snags are abundant. In turn, this adaptation limits their use of earlier successional stages that contain few snags.

Fish Need Forests Too. To hatch their eggs, salmon and other fish need (1) streams with a certain temperature range and amount of oxygen and (2) streambeds of gravel of a certain size. Forests provide cool and clean stream habitat.

Trees Protect Stream Habitat. Tree roots hold the soil, preventing erosion. Trees shade the streams, keeping the water temperature stable. The roots of live and dead trees that protrude into streams provide places for fish to rest and hide. The leaves and twigs that fall into streams feed the insects that fish eat.

The following text highlights some wildlife facts not covered in the preceding forest succession charts. For complete species reference, check the forest-coded ("F") *Alaska Ecology Card* for "Habitat" information.

Wildlife in the Coastal Rainforest

After **pioneer** plants start making the soil that allows other plants to follow, wildlife will be able to use the area. The plants produce food for **herbivores** such as insects and birds. Coyotes and ermine **(carnivores**) move in to feed on these herbivores.

In a true old-growth stand of coastal rainforest, spruce and hemlock trees may range in age from seedlings to 750 years old.

Detritivores Close the Cycle. The spores of **detritivores** (fungi and microscopic organisms) are blown in by the wind, and these begin the process of decay and mineral recycling. Thus an ecosystem is formed. It is not yet a forest ecosystem, and forest animals could not survive in it, but it is a step toward the establishment of a forest.