

Ecological site F043AX955MT

Subalpine Coniferous Cool Moist subalpine fir (*Abies lasiocarpa*)- Engelmann spruce (*Picea engelmannii*)

Last updated: 9/09/2023
Accessed: 05/02/2024

General information

Provisional. A provisional ecological site description has undergone quality control and quality assurance review. It contains a working state and transition model and enough information to identify the ecological site.

MLRA notes

Major Land Resource Area (MLRA): 043A–Northern Rocky Mountains

This MLRA is located in Montana (43 percent), Idaho (34 percent), and Washington (23 percent). It makes up about 31,435 square miles (81,460 square kilometers). It has no large cities or towns. It has many national forests, including the Okanogan, Colville, Kootenai, Lolo, Flathead, Coeur d'Alene, St. Joe, Clearwater, and Kaniksu National Forests.

This MLRA is in the Northern Rocky Mountains Province of the Rocky Mountain System. It is characterized by rugged, glaciated mountains; thrust- and block-faulted mountains; and hills and valleys. Steep-gradient rivers have cut deep canyons. Natural and manmade lakes are common.

The major Hydrologic Unit Areas (identified by four-digit numbers) that make up this MLRA are: Kootenai-Pend Oreille-Spokane (1701), 67 percent; Upper Columbia (1702), 18 percent; and Lower Snake (1706), 15 percent. Numerous rivers originate in or flow through this area, including the Sanpoil, Columbia, Pend Oreille, Kootenai, St. Joe, Thompson, and Flathead Rivers.

This area is underlain primarily by stacked slabs of layered sedimentary or metasedimentary bedrock. The bedrock formations range from Precambrian to Cretaceous in age. The rocks consist of shale, sandstone, siltstone, limestone, argillite, quartzite, gneiss, schist, dolomite, basalt, and granite. The formations have been faulted and stacked into a series of imbricate slabs by regional tectonic activity. Pleistocene glaciers carved a rugged landscape that includes sculpted hills and narrow valleys filled with till and outwash. Continental glaciation overrode the landscape in the northern half of the MLRA while glaciation in the southern half was confined to montane settings.

The average annual precipitation is 25 to 60 inches (635 to 1,525 millimeters) in most of this area, but it is as much as 113 inches (2,870 millimeters) in the mountains and is 10 to 15 inches (255 to 380 millimeters) in the western part of the area. Summers are dry. Most of the precipitation during fall, winter, and spring is snow. The average annual temperature is 32 to 51 degrees F (0 to 11 degrees C) in most of the area, decreasing with elevation. In most of the area, the freeze-free period averages 140 days and ranges from 65 to 215 days. It is longest in the low valleys of Washington, and it decreases in length with elevation. Freezing temperatures occur every month of the year on high mountains, and some peaks have a continuous cover of snow and ice.

The dominant soil orders in this MLRA are Andisols, Inceptisols, and Alfisols. Many of the soils are influenced by Mount Mazama ash deposits. The soils in the area have a frigid or cryic soil temperature regime; have an ustic, xeric, or udic soil moisture regime; and dominantly have mixed mineralogy. They are shallow to very deep, are very poorly drained to well drained, and have most of the soil texture classes. The soils at the lower elevations include Udivitrands, Vitrixerands and Haplustalfs. The soils at the higher elevations include Dystrocrypts, Eutrocrypts, Vitricryands, and Haplocryalfs. Cryorthents, Cryepts, and areas of rock outcrop are on ridges and peaks above timberline

This area is in the northern part of the Northern Rocky Mountains. Grand fir, Douglas-fir, western red cedar, western hemlock, western larch, lodgepole pine, subalpine fir, ponderosa pine, whitebark pine, and western white pine are the dominant overstory species, depending on precipitation, temperature, elevation, and landform aspect. The understory vegetation varies, also depending on climatic and landform factors. Some of the major wildlife species in this area are whitetailed deer, mule deer, elk, moose, black bear, grizzly bear, coyote, fox, and grouse. Fish, mostly in the trout and salmon families, are abundant in streams, rivers, and lakes.

More than one-half of this area is federally owned and administered by the U.S. Department of Agriculture, Forest Service. Much of the privately-owned land is controlled by large commercial timber companies. The forested areas are used for wildlife habitat, recreation, watershed, livestock grazing, and timber production. Meadows provide summer grazing for livestock and big game animals. Less than 3 percent of the area is cropland.

LRU notes

This ecological site resides in MLRA 43A in the Livingston-Lewis-Apgar Mountains which includes the bulk of Glacier National Park (GNP) and the lower western valley portions along the Flathead River. The landscape is mountains and landforms include glaciated mountains with associated features such as U-shaped valleys, mountain slopes, alpine ridges, cirques, valley floors and moraines. Glaciation of this area was in the form of alpine, icecaps and valley outlet glaciers. It also includes associated alluvium and outwash features. This area includes low valleys to tall mountains with elevation ranging 989-2,762 m (3,250-9,050 ft.). The climate is cold and wet with mean annual air temperature of 3 degrees Celsius (37 degrees F), mean frost free days of 65 days and mean annual precipitation of 1295 mm (51 in.) and relative effective annual precipitation is 169 cm (66 in.). The soil temperature regime is cryic and the soil moisture regime is udic. The geology of this area is dominated by metasedimentary rocks of the Belt Supergroup (Grinnell argillite and Siyeh limestone) with minor Tertiary sediments. Soils are generally weakly developed on mountain slopes within U-shaped valleys. Parent materials are commonly of colluvium, till, and residuum from metasedimentary rocks. Limestone bedrock within this part of the Belt Supergroup is not highly calcareous and due to high precipitation received in this area most carbonates at mid and upper elevations have been leached from the soil profiles. Bedrock depth varies greatly with location, landform and slope position. Volcanic ash is often found in the soil surface with various degrees of mixing. Thicker volcanic ash can be found on more stable positions on mid and upper elevation slopes that are protected from wind erosion. Volcanic ash is not typically found in low elevation areas on stream and outwash terraces associated with streams and rivers. There are numerous large lakes including St. Mary, Bowman, Kintla, Lake Sherburne, Logging, Upper Waterton and numerous creeks.

Classification relationships

This ecological site relates to the USFS Habitat Type ABLA/MEFE. This site relates to the USFS Habitat Type Group 7 and Fire Group 9. Both of these classification guides are specifically for the western Montana and northern Idaho region.

This ecological site relates to the NatureServe classification *Abies lasiocarpa-Picea engelmannii*/Menziesia ferruginea-Vaccinium scaprium Forest (CEGL005894) and *Abies lasiocarpa-Picea engelmannii*/Menziesia ferruginea/Xerophyllum tenax Forest (CEGL005895).

Ecological site concept

Ecological Site Concept

This site is found in cool, moist mid-elevations that span the lower subalpine. It is found on mountain slope and glacial valley wall landforms, on back, foot and toeslope positions on moderate to steep slopes (35-60%) at elevations ranging 1,300-2,000 meters with all aspects. Subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*) are the dominant overstory species with co-occurring Douglas-fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*). The main understory species are the medium-sized shrub rusty menziesia that is patchy or dense, the tall height shrub thinleaf alder and other medium-sized shrubs such as thinleaf huckleberry and grouse whortleberry with an understory of beargrass, broadleaf arnica, sidebells wintergreen, and darkwoods violet. The soils associated with this ecological site are very deep and well drained. The subsurface parent material of these soils is glacial till or colluvium. Depending on landform position, slope aspect and slope shape the soils have varying amounts of volcanic ash as a surface layer of the soil profile over the underlying parent material. Typically, south-facing convex slopes will have little or no volcanic ash. Conversely, more north-facing slope aspects on linear

to concave positions will have some amount of volcanic ash. Sites in concave accumulation zones in foot slope and toe slope positions often have the greatest thicknesses of volcanic ash. Although significant mixing of the ash with local soil materials can occur, subsoils below the volcanic ash tend to have a greater quantity of rock fragments than the volcanic ash surface layers. These soils are classified as Inceptisols or Andisols depending on the presence and thickness of volcanic ash in the profile. More specifically, they classify at the subgroup level of soil taxonomy as either Andic or Typic Humicrypts or Typic Haplocryands.

Associated sites

F043AX954MT	<p>Upper Subalpine Cold Coniferous subalpine fir (Engelmann spruce) /thinleaf huckleberry-rusty menziesia/ Hitchcock's smooth woodrush-beargrass/yellow avalanche lily.</p> <p>The 43A Upper Subalpine Cold Coniferous (ABLA/LUGLH) ecological site is found along the continental divide in cold, and moist to moderately dry, high elevations in the upper subalpine. It is primarily on cirque platform and headwall landforms, on backslope and shoulder positions at elevations ranging 1,700 to 2,600 meters (5,575-8,500 feet) with moderate to steep slopes ranging 10% to 80%.The 43A Upper Subalpine Cold Coniferous (ABLA/LUGLH) ecological site has a reference vegetation community of subalpine fir (and minor Engelmann spruce) with an understory of thinleaf huckleberry, rusty menziesia, Hitchcock's smooth woodrush-beargrass and yellow avalanche lily.</p>
R043AX968MT	<p>Montane Stable Colluvial Slope Saskatoon serviceberry-common snowberry/Sitka alder/ Rocky mountain maple/thimbleberry/mountain brome-Geyer's sedge</p> <p>The 43A Montane Stable Colluvial Slope ecological site is found on steep slopes (35-60 percent), on back, foot and toeslope positions on glacial valley wall landforms at elevations ranging from 1,150-2,100 meters (3,775-6,900 feet).The 43A Montane Steep Stable Colluvial Slope has soils that are very deep and well drained soils from till or colluvium from metasedimentary rock parent material. There is a high volume of fragments (50 to 67 percent by volume) within the soil profile. The predominant texture in the surface is very gravelly sandy loam and the subsurface is sandy skeletal. There are no redoximorphic features in the soil and there is rarely an argillic or mollic layer. There is a thin organic layer, usually less than 5 cm thick. The 43A Upper Subalpine Cold Coniferous (ABLA/LUGLH) has soils associated with this ecological site that are moderately deep, well drained and derived from glacial till or colluvium over residuum weathered from metasedimentary rock. Moderately deep depth class indicates that these soils are greater than 50 cm (20 inches) deep, but less than 100 cm (40 inches). These soils classify in the Inceptisols soil order and in the Typic Haplocrypts taxonomic subgroup. The 43A Montane Steep Stable Colluvial Slope ecological site is found on steep slopes with vegetation cover ranging from impenetrable shrubs to open canopy of medium statured shrubs with lush understory of grass and forb species. Steep sites on valley walls. The thick vegetative growth contributes to the dark surface horizon colors in these soils. The reference vegetation community is Saskatoon serviceberry (<i>Amelanchier alnifolia</i>), common snowberry (<i>Symphoricarpos albus</i>), Sitka alder (<i>Alnus viridis</i> ssp. <i>sinuata</i>), Rocky mountain maple (<i>Acer glabrum</i>), thimbleberry (<i>Rubus parviflorus</i>), mountain brome (<i>Bromus marginatus</i>) and Geyer's sedge (<i>Carex geyeri</i>).</p>
F043AX952MT	<p>Lower Subalpine Cool Moist Coniferous subalpine fir-Engelmann spruce/Rocky Mountain maple-thinleaf huckleberry/thimbleberry</p> <p>The 43A Lower Subalpine Coniferous Cool Moist Ashy Very Deep, (ABLA/CLUN2-ARNU2) is found in cool, moister mid-elevations that span the lower subalpine to subalpine. This ecological site is found on back, foot and toeslope positions, on glacial valley wall and moraine landforms, on all slopes, at elevations ranging 1,000 to 2,100 meters (3,300-6,900 feet). The 43A Lower Subalpine Coniferous Cool Moist Ashy Very Deep, (ABLA/CLUN2-ARNU2) has soils associated with this Ecological Site that are very deep, well drained or somewhat excessively drained and have subsoils with abundant rock fragments. The parent material is volcanic ash over glacial till from metasedimentary rock. In Soil Taxonomy, these soils classify primarily as Inceptisols soil order and more specifically as the Andic Haplocrypts taxonomic subgroup. The 43A Lower Subalpine Coniferous Cool Moist Ashy Very Deep, (ABLA/CLUN2-ARNU2) has a reference vegetation community of Subalpine fir-Engelmann spruce overstory and an understory of Rocky Mountain maple, thinleaf huckleberry, thimbleberry, wild Sarsaparilla, threelaf foamflower and queencup bead lily.</p>

Table 1. Dominant plant species

Tree	(1) <i>Abies lasiocarpa</i> (2) <i>Picea engelmannii</i>
Shrub	(1) <i>Vaccinium membranaceum</i> (2) <i>Menziesia ferruginea</i>

Herbaceous	(1) <i>Arnica latifolia</i> (2) <i>Xerophyllum tenax</i>
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Physiographic features

This site is found in cool, moist mid-elevations that span the lower subalpine to subalpine. It is found on mountain slope and glacial valley wall landforms, on back, foot and toeslope positions on moderate to steep slopes (35-60%) at elevations ranging 1,300-2,000 meters (4,275-6,550 feet) with all aspects.



Figure 1. Landscape views of this ecological site.



Figure 2. Landscape views of this ecological site.

Table 2. Representative physiographic features

Landforms	(1) Mountains > Glacial-valley wall (2) Mountains > Mountain slope (3) Mountains > Glacial-valley wall > Closed depression
Elevation	1,300–2,000 m
Slope	40–60%
Aspect	W, NW, N, NE, E, SE, S, SW

Table 3. Representative physiographic features (actual ranges)

Elevation	Not specified
Slope	35–65%

Climatic features

This ecological site is found in the cryic soil temperature regime and the udic soil moisture regime. Cryic soils have average annual temperature of less than 8 degrees C. (46 degrees F.), with less than 5 degrees C. (41 degrees F.) difference from winter to summer. The udic soil moisture regime denotes that the rooting zone is usually moist throughout the winter and the majority of summer. This site is found on the west side of the Continental Divide and has more maritime weather influences.

Climate Summary for West Glacier:

Mean Average Precipitation: 84-216cm 33-85 inches

Mean Average Annual Temperature: 0-6 degrees Celsius 32-43 degrees F

Frost-Free Days: 30-70

Relative Effective Precipitation: 127-254 cm 50-100 inches

SUMMARY TABLES ARE FOR AVAILABLE CLIMATE STATIONS WHICH ARE ALL LOCATED IN VALLEYS.

Table 4. Representative climatic features

Frost-free period (characteristic range)	17-57 days
Freeze-free period (characteristic range)	76-117 days
Precipitation total (characteristic range)	508-660 mm
Frost-free period (actual range)	6-68 days
Freeze-free period (actual range)	66-127 days
Precipitation total (actual range)	508-711 mm
Frost-free period (average)	37 days
Freeze-free period (average)	97 days
Precipitation total (average)	584 mm

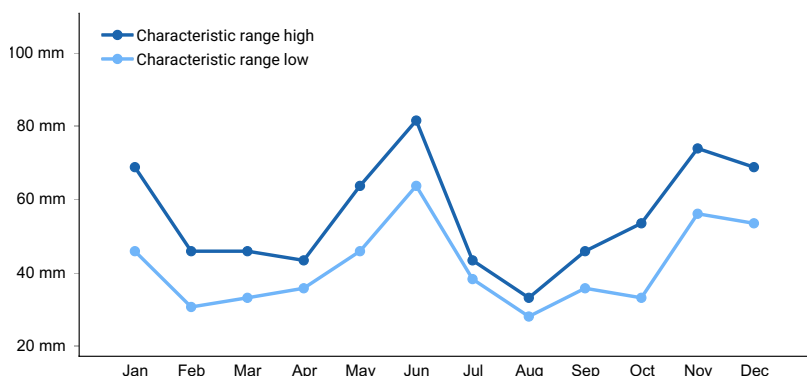


Figure 3. Monthly precipitation range

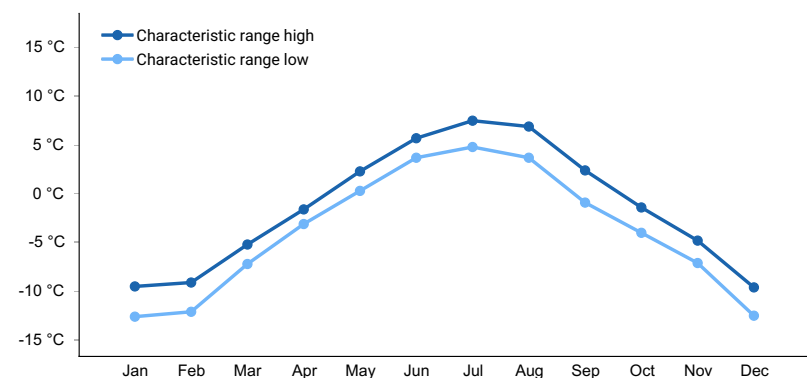


Figure 4. Monthly minimum temperature range

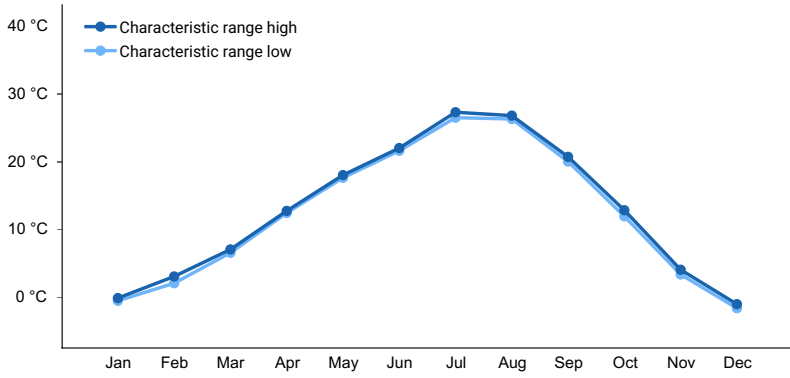


Figure 5. Monthly maximum temperature range

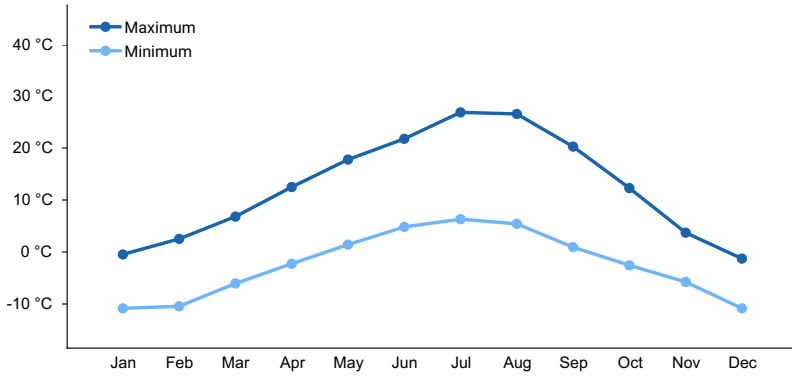


Figure 6. Monthly average minimum and maximum temperature

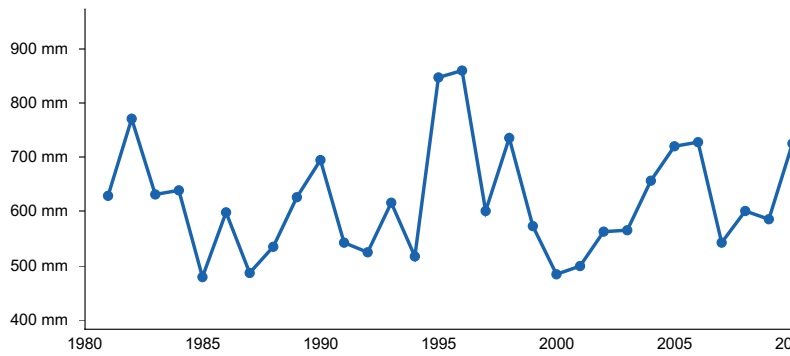


Figure 7. Annual precipitation pattern

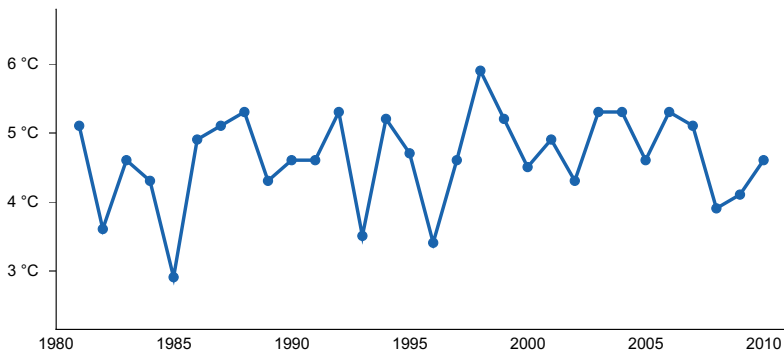


Figure 8. Annual average temperature pattern

Climate stations used

- (1) POLEBRIDGE 1 N [USC00246618], Essex, MT
- (2) POLEBRIDGE [USC00246615], Essex, MT
- (3) WEST GLACIER [USC00248809], Kalispell, MT

Influencing water features

Soil features

The soils associated with this ecological site are very deep and well drained. The subsurface parent material of these soils is glacial till or colluvium. Depending on landform position, slope aspect and slope shape the soils have varying amounts of volcanic ash as a surface layer in the soil profile over the underlying parent material. Typically, south-facing convex slopes will have little or no volcanic ash. Conversely, more north-facing slope aspects on linear to concave positions will have some amount of volcanic ash. Sites in concave accumulation zones in foot slope and toe slope positions often have the greatest thicknesses of volcanic ash. Although significant mixing of the ash with local soil materials can occur, subsoils below the volcanic ash tend to have a greater quantity of rock fragments than the volcanic ash surface layers. These soils are classified as Inceptisols or Andisols depending on the presence and thickness of volcanic ash in the profile. More specifically, they classify at the subgroup level of soil taxonomy as either Andic or Typic Humicryepts or Typic Haplocryands. Diagnostic features include an ochric or umbric epipedon, cambic horizon and andic soil properties if ash is present and has the required thickness to make the Andic subgroup (18 cm to 37 cm thick) or the Andisols soil order (greater than 37 cm thick) (Soil Survey Staff, 2015). Underneath a closed tree canopy these sites may have a surface layer of the organic material up to 7 cm in thickness.

For more information on soil taxonomy, please follow this

link:http://http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053580

CORRELATED SOIL SERIES & SOIL TAXONOMIC NAME

Garlet Loamy-skeletal, mixed, superactive Typic Haplocryepts

Goathaut Ashy-skeletal, amorphic Typic Haplocryands

Muddycreek Loamy-skeletal, isotic Andic Humicryepts

Table 5. Representative soil features

Parent material	(1) Volcanic ash–metasedimentary rock (2) Colluvium–metasedimentary rock (3) Till–metasedimentary rock
Surface texture	(1) Very gravelly, ashy loam (2) Gravelly, ashy loam (3) Very gravelly loam
Family particle size	(1) Loamy-skeletal (2) Ashy-skeletal
Drainage class	Well drained
Permeability class	Moderate to moderately rapid
Soil depth	152–254 cm
Surface fragment cover <=3"	0%
Surface fragment cover >3"	0%
Available water capacity (4.1-13.2cm)	Not specified
Soil reaction (1:1 water) (11.4-16.5cm)	Not specified

Ecological dynamics

Ecological Dynamics of the Site

This ecological site is found in cool, moist mid-elevations that span the lower subalpine through the subalpine zone. While primary data was collected in Glacier National Park (NP), this ecological site also occurs on the adjacent US Forest Service (USFS) Flathead National Forest (NF) land and in limited areas of the Kootenai NF. Associated sites to the 43A SUBALPINE COOL MOIST CONFEROUS ecological site include subalpine fir/queencup beadlily-rusty menziesia (ABLA/CLUN2-MEFE) at lower elevations, subalpine fir/Hitchcock's smooth woodrush (ABLA/LUGLH) at higher elevations, subalpine fir/beargrass (ABLA/XETE) in drier areas, and subalpine fir/bluejoint (ABLA/CACA4) in

very wet sites or wetland areas.

Management

Various management strategies can be employed for the 43A SUBALPINE COOL MOIST CONFEROUS ecological site, depending upon the ownership of the particular land and which value is prioritized. The management of the forest determines the composition of the stand and the amount of fuel loading. A stand will be managed differently and look differently if it is managed for timber or ecological services like water quality and quantity, old growth, or endangered species. If a stand is managed for timber, it may be missing certain attributes necessary for lynx habitat. If a stand is managed for lynx habitat, it may have increased fuels and therefore an increased risk of wildfires.

The USFS Habitat Type guide states that the basal area on the West side of the Continental Divide for ABLA/MEFE is 172 +/- ft² per acre and the site index at 50 years for *Picea* is 60 +/- 10 and for *Abies* 57 +/- 9. Timber production on these sites vary from moderate to high. Intensive management for timber production can have problems including partial cutting, which can increase shade-tolerant subalpine fir or lack of regeneration under the dense shrubs of rusty menziesia and Sitka alder. Site preparation by dozer scarification or prescribed burning on steep areas is essential. Prescribed burning can be accomplished only when fuels are dry on this rather moist site. Watershed values are high for this site. The management of USFS lands is encompassed in the management plan for each National Forest. The management plan for the Flathead NF also has an Appendix B that gives specific management guidelines for habitat types (which relate to our forested ecological sites) found on the forest in relation to current and historic data on forest conditions (Flathead NF Plan, 1998 amended 2001 and Appendix B). Another guiding USFS document is the Green et al. document, 1992 amended (2005) which defines "Old Growth" forest for the northern Rocky Mountains. This document provides an ecologically-based classification of old growth based on forest stand attributes including numbers of large trees, snags, downed logs, structural canopy layers, canopy cover, age, and basal area. While this document finds that the bulk of the pre-settlement upland old growth in the northern Rockies was in the lower elevation areas, ground fire-maintained ponderosa pine/western larch/Douglas-fir types (Losensky, 1992), it does not mean that other types were not common or not important. This could apply to some of the areas of this ecological site.

The USFS Habitat Type ABLA/MEFE is common on the Flathead NF, located just west of Glacier NP. The following is a personal communication with a silvicultural forester on management of subalpine fir/rusty menziesia (ABLA/MEFE) on the Flathead NF (Reichenberg, 1/2016):

This habitat type (HT) is common, but colder types dominate the Flathead NF This is managed to promote western larch and western white pine. These species are tolerant or resistant to root disease and insect outbreaks (much more so than subalpine fir, Engelmann spruce or Douglas-fir). Site preparation is key! Rapid and aggressive shrub response to sunlight. Planting is important to establish favored seral species before shrubs occupy site. Use large scalps (area of bare mineral soil created by the tree planter with hoedad) when planting to deter competing vegetation. This HT can grow some great picea species. I try to mix some in with the planting prescription. Currently, there is an uptick of western spruce budworm potentially brought on by the current drier weather conditions. Another reason to promote western white pine is that it is expected to be adaptable in the face of climate change and to restore this species to the landscape after the significant mortality caused by the introduction of white pine blister rust. The current generation of resistant western white pine seedling stock shows up to 60 percent survival against white pine blister rust. Historically, this habitat type was managed using traditional even age strategies on the FNF. Management also needed to employ intense methods to allow for scarification of the soil which is a regeneration requirement of western larch. These methods included harvesting using skid trails and prescribed burns for site preparation. These methods are constrained because of soil and air quality concerns. Therefore, planting of western larch is employed instead and there is competition by Canada thistle and grass. As well, management on this habitat type is further constrained by concerns for Lynx habitat. Unless a unit is classified as WUI or is managed for western white pine, there is no pre-commercial thinning allowed in this habitat type. This inability to thin stands could cause forest stand health issues with root disease or insect outbreaks if the stand has significant density of the vulnerable species of subalpine fir, Engelmann spruce or Douglas-fir. The inability to thin also greatly affects the diameter growth of individual trees. Traditional even-aged management on this type consists of pre-commercial thinning followed by commercial thinning to grow older larger western larch. A seed tree harvest leaving western larch and western white pine and large diameter Douglas fir and western larch snags for wildlife is used to regenerate a new stand. If a stand has sufficient subalpine fir, then it might trip the snowshoe hare screen for the Lynx Amendment and then left alone. Multi-story structure of a stand and minimum cutting unit size is important for lynx habitat. As well, if a unit is deemed old growth then it is left alone even if these conditions make it

susceptible to root rot or insect damage because these conditions are consistent with forest succession on this habitat type.

Associated Sites

43A Montane Steep Stable Colluvial Slope

43A Lower Subalpine Coniferous Cool Moist Ashy Very Deep, (ABLA/CLUN2-ARNU2)

43A Upper Subalpine Cold Coniferous, (ABLA/LUGLH)

The 43A Montane Steep Stable Colluvial Slope ecological site is found on steep slopes with vegetation cover ranging from impenetrable shrubs to open canopy of medium statured shrubs with lush understory of grass and forb species. Steep sites on valley walls. The thick vegetative growth contributes to the dark surface horizon colors in these soils. The reference vegetation community is Saskatoon serviceberry (*Amelanchier alnifolia*), common snowberry (*Symphoricarpos albus*), Sitka alder (*Alnus viridis* ssp. *sinuata*), Rocky mountain maple (*Acer glabrum*), thimbleberry (*Rubus parviflorus*), mountain brome (*Bromus marginatus*) and Geyer's sedge (*Carex geyeri*).

The 43A Lower Subalpine Coniferous Cool Moist Ashy Very Deep, (ABLA/CLUN2-ARNU2) has a reference vegetation community of Subalpine fir-Engelmann spruce overstory and an understory of Rocky Mountain maple, thinleaf huckleberry, thimbleberry, wild Sarsaparilla, threeleaf foamflower and queencup bead lily.

The 43A Upper Subalpine Cold Coniferous (ABLA/LUGLH) ecological site has a reference vegetation community of subalpine fir (and minor Engelmann spruce) with an understory of thinleaf huckleberry, rusty menziesia, Hitchcock's smooth woodrush-beargrass and yellow avalanche lily.

State 1.0

Western white pine (*Pinus monticola*)/(subalpine fir (*Abies lasiocarpa*)-Engelmann spruce (*Picea engelmannii*)/Sitka alder (*Alnus viridis* ssp. *sinuata*)/rusty menziesia (*Menziesia ferruginea*)-thinleaf huckleberry (*Vaccinium membranaceum*)/common beargrass (*Xerophyllum tenax*).

Historically western white pine would have been within Flathead County which encompasses the Flathead NF and in lower elevations, west of the Continental Divide in Glacier NP. The historic extent of western white pine in Glacier National Park was primarily along the western border. Originally, western white pine covered 5 million acres in the Inland Northwest. Western white pine is incredibly productive for timber with a very high growth rate, tall and deep rooted, and competes best on highly variable, high resource sites. As well, it is tolerant to the native root rot diseases and other native forest pests, susceptible to Armillaria root disease only when young, and to mountain pine beetle largely at advanced ages (over 140 years). It also has the capability to thrive in a wide variety of sites and environments, which means it has high ecological flexibility. It is a long-living seral species that tolerated intense timber harvesting practices and severe fire disturbance by its ability to regenerate heavily on mineral soil and full sunlight. Fire greatly influences the composition, structure, and function of vegetation across the landscape. Historically, the area had mixed severity fires in between severe stand-replacement fires. Western larch and western white pine are long-lived, fire-adapted, shade-intolerant tree species that thrived historically. Also present in significant amounts particularly in young stands, but declined through time due to effects of insects and pathogens, were shorter-lived, shade-intolerant, fire-adapted tree species such as Douglas-fir and lodgepole pine. Shade-tolerant, fire-intolerant tree species such as western cedar, western hemlock, grand fir, Engelmann spruce, and subalpine fir were present but rarely survived long enough to dominate stands, except where the interval between fires was unusually long and where root disease was not severe. Western white pine was a major component in forested ecosystems of the inland northwest U.S. prior to the 20th century, but has been greatly reduced in distribution and abundance by white pine blister rust, mountain pine beetles, and anthropogenic fire exclusion (Tomback and Achuff, 2010). Western white pine has been replaced by Douglas-fir, grand fir, and western hemlock. Douglas-fir and grand fir are susceptible to a greater variety of insect and disease problems, and hemlock is more sensitive to drought and decay. More stands have also progressed to the climax species-dominated phase, which previously were rarely achieved due to the fire rotations and susceptibility of these species to disease and forest pests. In a study of pathogens and insects effects on forests within the Inland Empire found that, excluding fire, there were more than 90 percent of sample stands changed to a different cover type, structure stage, or both during a 40-year period that was coincident with the blister rust epidemic and fire suppression policy. Root pathogens, white pine blister rust, and bark beetle were the cause of most changes, and this accelerated succession of western white pine, ponderosa pine, and lodgepole pine to later successional, more shade-tolerant species. Structure was reduced in stand density or prevented canopy closure. Grand fir, Douglas-fir, and subalpine fir were the predominant cover types at the end of the period and were highly susceptible to root diseases, bark beetles, fire, and drought. It is estimated that there will be greater accumulations occurring in low-density mature and younger pole-sized stands that result from root disease and bark beetle-caused mortality (Byler and Hagel, 2000). These stands are also less productive in terms of timber. They also are dominated by species with high nutrient demands,

in areas where nutrient storage and cycling rates are increasingly depressed. This will likely lead to ever-increasing stress and destabilization by pests and diseases. Drought can further exacerbate the situation by stressing trees. The Inland Empire Tree Improvement Cooperative and the USFS have a breeding program for blister-resistant western white pine. There has been a total of approximately 5 percent of the original acre range planted with rust-resistant stock. Currently, the modified stock shows about 60 percent resistance to blister rust. A study modeling the effects of climate change found that warming temperatures would favor increased abundance of western white pine over existing climax and shade-tolerant species in Glacier NP, mainly because warmer conditions potentiate fire dynamics, including increased wildfire frequency and extent, which facilitates regeneration (Loehman et al., 2011).

State 2: Subalpine fir (Douglas fir) /Greene's mountain ash/rusty menziesia-thinleaf huckleberry/beargrass. State 2 is different than State 1 in that western white pine no longer plays a significant role in the seral communities as it once did. Western white pine has been dramatically reduced in numbers and area by the epidemics of white pine blister rust, western spruce budworm, and dramatic fire suppression. Therefore, climax species have been able to fill the seral role that western white pine held. As well, more forests are progressing to the climax or Reference phase than historically when most forests were in the fire-maintained western white pine-dominated seral phase. Forests are now dominated by these shade-tolerant climax species subalpine fir and Engelmann spruce. While there is a tremendous effort to bolster the numbers of western white pine, it currently covers only 5 percent of its historic range.

Subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*) are the dominant overstory species with co-occurring Douglas-fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*). The main understory species are the medium-sized shrub rusty menziesia that is patchy or dense, the tall height shrub Greene's mountain ash and Utah honeysuckle, and other medium-sized shrubs such as thinleaf huckleberry with an understory of beargrass, sidebells wintergreen, threelobed foamflower and darkwoods violet. Subalpine fir, Engelmann spruce, western larch, Douglas-fir, western white pine, and lodgepole pine are present in order of decreasing abundance. The rusty menziesia (MEFE) indicated type specifically represents areas that are cold and moist. It is more common on cool northern and eastern exposures, and where rusty menziesia and broadleaf arnica (ARLA8) are abundant. Historically, this site would have had western white pine before this species was decimated by the white pine blister rust epidemic (McDonald et al., 2000).

This ecological site is described as having cool and moist site conditions and high species diversity in the overstory. Sites after stand-replacement fires can be dominated by lodgepole pine. Sites are too cool for western redcedar and western hemlock, and not cold enough for whitebark pine in any major way. The historic fire regime of these forests is one of low frequency (about 128 years) and high intensity, and therefore there is an increased chance of stand-replacement fire when it does occur due to moist site conditions and relatively high loadings of live and dead fuels, combined with periodic summer drought. Stand-replacement fires occur in patches of 200 to 2,000 hectares (McDonald et al., 2000). The general post-disturbance successional phases include the stand initiation phase dominated by herbaceous and shrub species and conifer seedlings, the competitive exclusion phase of dense pole-sized mixed conifer or single seral species, the maturing forest of overstory mixed conifer trees with or without patches of regeneration, and the Reference Phase dominated by subalpine fir and Engelmann spruce with small gap dynamics. Understory burns, which effect the understory shrub and herbaceous species and conifer regeneration the most, can occur and maintain any community phase. A stand-replacement fire in the mature forest or Reference Phase would result in the stand initiation phase, with species composition of seedlings varying with site conditions. Moderate fires (or mixed severity fires) in the competitive exclusion phase would favor the more fire-resistant Douglas-fir, western larch, or western white pine over lodgepole pine, Engelmann spruce, and subalpine fir. Therefore, these species would dominate the maturing forest phase for longer periods of time. After a stand-replacement fire at this stage with serotinous lodgepole present, these seedlings would dominate the seedling and competitive exclusion phases. Absence of fire will transition the competitive exclusion phase to a mature forest, dominated in the overstory by a mix of conifer species. Moderate or severe fire at this stage could remove much of the Douglas-fir, leaving the site to be regenerated by either serotinous lodgepole or remnant western larch. Severe fires that remove even western larch will return to the treeless stand initiation phase. If fire does not occur in the forest maturing phase, then this will continue into the Reference Phase. Significant fires that have occurred on the west side of the Continental Divide and affected this ecological site are the 1994 Starvation Creek fire, which burned 4,001 acres in Glacier NP and 7,202 in total, caused by lightning. The Wedge Canyon fire in 2003 burned 30,314 acres in Glacier NP, 53,359 total acres, and was caused by lightning. The 1988 Red Bench fire burned 27,500 acres in Glacier NP, and a total of 36,037 acres, also caused by lightning. In 2001, the Moose fire burned 27,194 acres in Glacier NP and 70,605 total acres, caused by lightning. The 2003 Robert fire burned 39,384 acres in Glacier NP, 52,747 total acres, and was caused by humans; while lightning caused the Harrison fire that same

year, burning 5,864 acres in Glacier NP and the Rampage fire, which burned 21,630 acres in Glacier NP.

Both subalpine fir and Engelmann spruce are subjected to a variety of diseases and insect pests including root rot, stem decay, bark beetles, and wood borers and defoliators. These can weaken and or kill trees and result in small openings scattered throughout the forest, or major mortality during an outbreak such as western spruce budworm (*Choristoneura occidentalis*). The patterns of damage from endemic populations of insects and disease creates small openings, whereas epidemic patterns are extensive throughout the landscape. Windthrow commonly can cause additional damage to stands following disease and pest disturbance. Subalpine fir is most commonly susceptible to *Armillaria* and *Annosus* root disease, pouch, Indian paint, and red belt fungi which cause stem decay, metallic, roundheaded, and Western balsam bark beetle, fir canker, and defoliators such as *Delphinella* shoot blight, black mildew, brown felt blight, fir needlecast, snow blight, and fir-blueberry rust. Engelmann spruce is most commonly susceptible to *Annosus* and *Schweinitzii* root disease and butt rot, pini rot, stem decays by red belt fungus, metallic and roundheaded borers, spruce beetle, blue stain of sapwood, spruce broom rust, spruce canker, and brown felt blight.

Aerial photography is a good tool to use to discern the level of insect and disease and the damage patterns and whether these are at endemic or epidemic levels. These maps capture only moments in time, and infestations grow and move from location to location following their preferred habitat, so repeated photography can be necessary. Specifically for the northern region, the USFS Stand Health map shows that the major impact is defoliation by western spruce budworm. The defoliation was categorized as mostly low severity (equal to or less than 50 percent defoliation) and some as high (with greater than 50 percent defoliation) on *Abies* species, and the damage is contiguous or nearly continuous. The forest type was categorized as western Fir-Spruce type. There was also defoliation by Western Spruce budworm on Douglas-fir, but to a much lesser degree. Larch casebearer, a defoliator of western larch, and generalized needlecast of larch was also found to a much lesser degree. Scattered small areas were found throughout the region including mortality from mountain pine beetle on lodgepole pine, Douglas-fir beetle on Douglas-fir, spruce beetle on Engelmann spruce, fir engravers and woolly adelgid on *Abies* species, and general *Abies* species mortality. All of these would affect this ecological site and field notes corroborate these findings.

Community Phase 2.1

Structure: multistory with small gap dynamics

The overstory is dominated by subalpine fir and Engelmann spruce, with small gap dynamics in which small numbers of trees are dead and conifer regeneration is infilling. The canopy cover ranges from 40-60 percent. The understory is dominated by a shrub layer in which the indicator species, rusty menziesia, is present and may be dominant. Species with high frequency of occurrence in 7 canopy cover sites include: thinleaf huckleberry, beargrass, Greene's mountain ash and rusty menziesia. Foliar cover (taken at three sites) is high at this community phase, and the ground cover predominantly consists of very high cover of duff (86%) with a low amount (<5%) of moss, bare soil, and stones. The vegetation structure at this community phase is that of tall trees (700 inches on average) with a tall shrub layer of *Menziesia ferruginea* at 90 inches, and a lower layer of shrubs and forbs at 20 inches including beargrass, white spirea, fireweed, thinleaf huckleberry, and Oregon boxleaf. At these higher elevations both tree species are slow-growing and infill can take several decades, sustaining the multistory structure of this community. The presence of root rot pockets can shift the composition of this community away from its host species. The understory of this community is defined by the medium-sized shrub rusty menziesia in either clumps or dense thicket. The tall shrub Greene's mountain ash and the medium-sized thinleaf huckleberry is also prevalent. The understory has beargrass and moss. This ecological site must have a presence of rusty menziesia and sometimes this is dominant. At this phase, *Armillaria* root rot and defoliation by western spruce budworm can be a threat.

Community Phase Pathway 2.1A

This pathway represents a larger disturbance, such as an insect infestation, wind storm, or rot pocket that would create this forest structure. Areas of regeneration would range from approximately 2 to 5 acres.

Community Phase Pathway 2.1B

This pathway represents a major stand-replacement fire disturbance such as a high-intensity fire, large-scale wind event, or major insect infestation.

Forest Overstory

Forest canopy: Canopy cover ranges from 40-60 percent

Average basal area: Total 260 ft²/acre

Site Index at 100 yrs.: ABLA ranges from 30-57

CMAI ABLA 26@130yrs. 45@125yrs.

Community Phase 2.2

Structure: mosaic of mature overstory and regenerating openings

Community Phase 2.2 retains some areas that resemble Community Phase 2.1, but also contains moderate-sized (2-5 acres) openings. Subalpine fir and Engelmann spruce are both host to organisms causing root rot and heart rot, and with windthrow can cause large pockets of overstory mortality. These areas may take decades to become reforested, resulting in either patches of shrubs or seral species such as western larch and Douglas-fir. As the organisms slowly die off due to a lack of host trees, subalpine fir, and Engelmann spruce will re-colonize these areas. This community can be prone to *Armillaria* root rot and western spruce budworm on fir.

Community Phase Pathway 2.2A

This pathway represents growth over time with no further significant disturbance. The areas of regeneration pass through the typical stand phases-competitive exclusion, maturation, and understory reinitiation until they resemble the old-growth structure of the Reference Community.

Community Phase Pathway 2.2B

This pathway represents a major stand-replacement fire disturbance, such as a major insect outbreak, or major fire event, which leads to the stand initiation phase of forest development.

Community Phase 2.3

Structure: patchy clumps of regeneration-single story

Community Phase 2.3 is a forest in the stand initiation phase, possibly with scattered remnant mature trees; the composition of the seedlings depends on the natural seed sources available. The canopy cover is generally less than 10 percent as a mixture of conifers including Douglas-fir, lodgepole pine, western larch, Engelmann spruce, and subalpine fir. If serotinous lodgepole seedbank is present, it will dominate the area.

Community Phase Pathway 2.3A

This pathway represents continued growth over time with no further major disturbance.

Community Phase 2.4

Structure: dense single story

Community Phase 2.4 is a forest in the competitive exclusion phase, possibly with scattered remnant mature trees; individual trees compete for the available water and nutrients. The canopy cover ranges from 50-80 percent. Canopy closure is very high within the areas successfully reforested, leading eventually to a diminished graminoid community, but also providing protection for those species which do well in the shade, such as prince's pine. This community is more tolerant of *Armillaria* root rot due to forest stand composition, but is vulnerable to defoliation by western spruce budworm on fir. The understory at this community phase of this ecological site has a thick shrub layer, including rusty menziesia and grouse whortleberry and thinleaf huckleberry and forbs sidebells wintergreen and beargrass.

Community Phase Pathway 2.4A

This pathway represents continued growth over time with no further major disturbance.

Community Phase Pathway 2.4B

This pathway represents a major stand-replacement fire disturbance, such as a major insect outbreak, or major fire event which leads to the stand initiation phase of forest development.

Community Phase 2.5

Structure: single story with few small openings

Community Phase 2.5 is a maturing forest which is starting to differentiate vertically. The canopy cover ranges from 30-80 percent, and is a mixed conifer overstory including subalpine fir, Engelmann spruce, Douglas fir, and lodgepole pine. The understory is dominated by the medium-statured shrubs rusty menziesia, thinleaf huckleberry, and beargrass can have high cover. Other species that occur frequently include Utah honeysuckle, sidebells wintergreen, threeleaf foamflower, darkwood violet. Individual trees are dying (whether due to insects, disease, competition, or windthrow), allowing some sunlight to reach the forest floor. This allows for an increase in the understory as well as some pockets of overstory tree species regeneration. This community is prone to *Armillaria* root rot and western spruce budworm on fir.

Community Phase Pathway 2.5A

This pathway represents no further major disturbance. Continued growth over time, as well as ongoing mortality, leads to continued vertical diversification. The community begins to resemble the structure of the Reference Community, with small pockets of regeneration and a more diversified understory.

Community Phase Pathway 2.5B

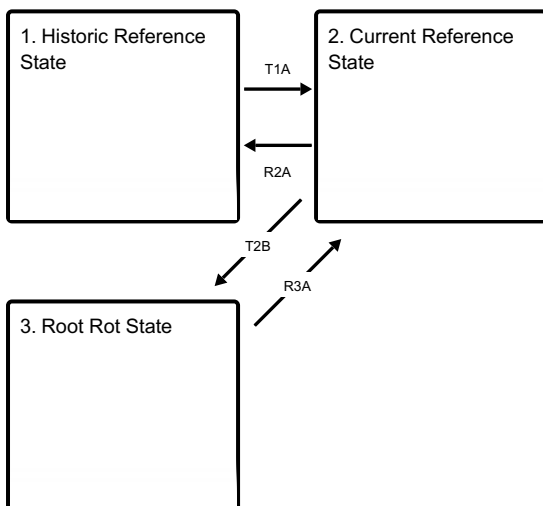
This pathway represents a major stand-replacement fire disturbance, leading to the stand initiation phase of forest development.

State 3.0

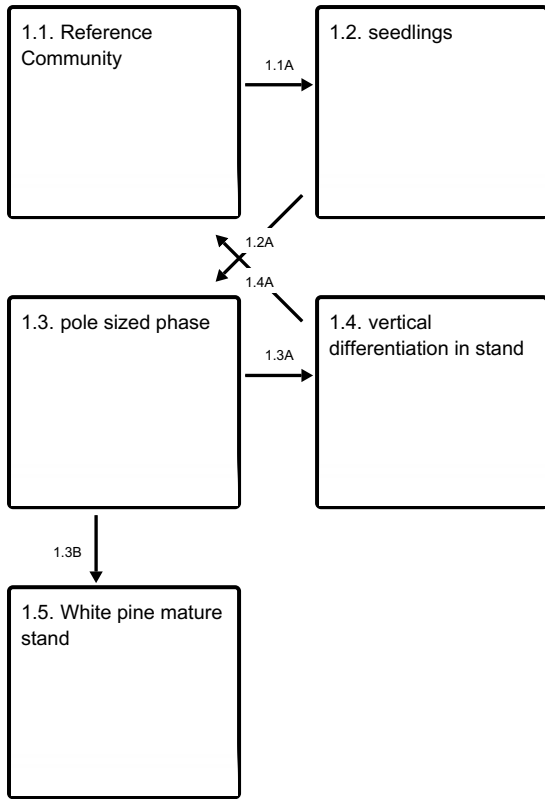
Another disease affecting the 43A SUBALPINE COOL MOIST CONIFEROUS ecological site is root rot. *Armillaria* root disease is the most common root disease fungus in this region, especially prevalent west of the Continental Divide. It may be difficult to detect until it has killed enough trees to create large root disease pockets or centers, ranging in size from a fraction of an acre to hundreds of acres. The root disease spreads from an affected tree to its surrounding neighbors through root contact. The root disease affects the most susceptible tree species first, leaving less susceptible tree species that mask its presence. When root rot is severe, the pocket has abundant regeneration or dense brush growth in the center. In western Montana and northern Idaho, *Armillaria* is present in most stands with diffuse mortality and large and small root disease centers. The disease pattern is one of multiple clones merging to form essentially continuous coverage of sites. Grouped as well as dispersed mortality can occur throughout the stand. A mosaic of brushy openings, patches of dying trees, and apparently unaffected trees may cover large areas. There can be highly significant losses, usually requiring species conversion in the active management approach. Management tactics include to identify the type of *Armillaria* root disease present and manage for pines and larch. Pre-commercial thinning may improve growth and survival of pines and larch. Avoid harvests that leave susceptible species (usually Douglas-fir or true firs) as crop trees (Hagle, 2010). A link has been determined between parent material and susceptibility to root disease, and metasedimentary parent material is thought to increase the risk of root disease. Glacier NP is dominated by metasedimentary parent material, and therefore may be more at risk than other areas to root disease (Kimsey et al., 2012). If a stand sustains very high levels of root disease mortality, then a coniferous stand could cross a threshold and become a shrubland, once all conifers are gone (Kimsey et al., 2012).

State and transition model

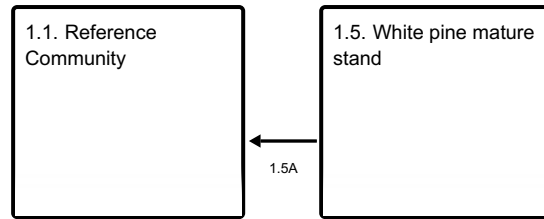
Ecosystem states



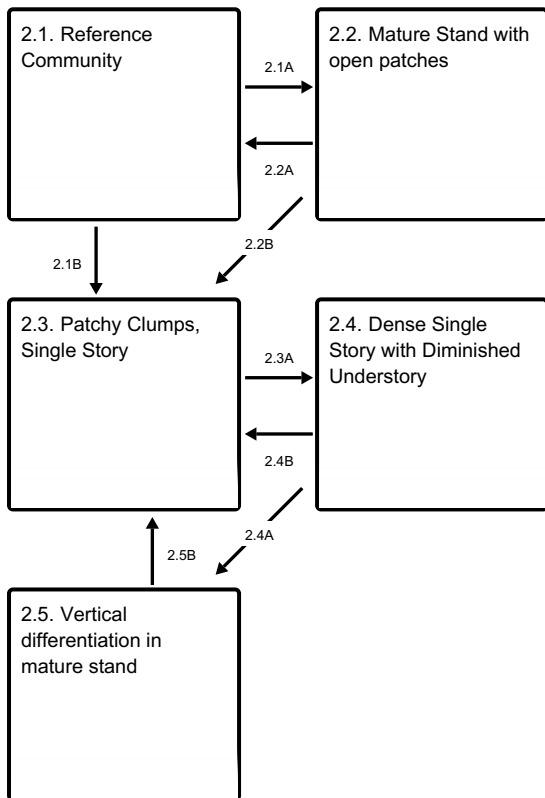
State 1 submodel, plant communities



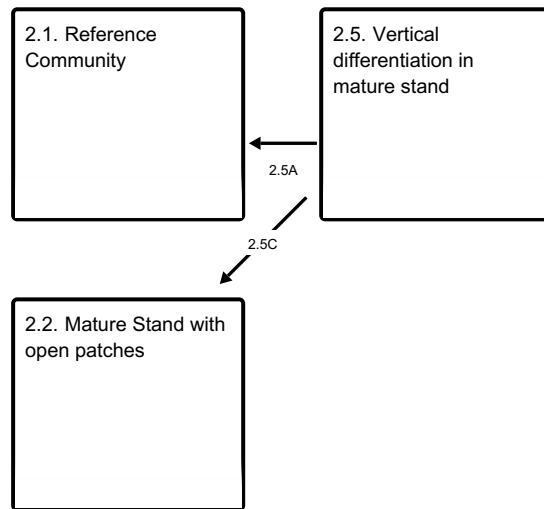
Communities 1 and 5 (additional pathways)



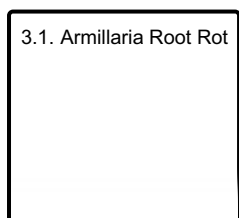
State 2 submodel, plant communities



Communities 1, 5 and 2 (additional pathways)



State 3 submodel, plant communities



State 1

Historic Reference State

State 1.0 Western white pine (*Pinus monticola*)/(subalpine fir (*Abies lasiocarpa*)-Engelmann spruce (*Picea engelmannii*)/Sitka alder (*Alnus viridis* ssp. *sinuata*)/rusty menziesia (*Menziesia ferruginea*)-thinleaf huckleberry (*Vaccinium membranaceum*)/common beargrass (*Xerophyllum tenax*).

Community 1.1

Reference Community

Subalpine fir-Engelmann spruce overstory Minor white pine-western larch Structure: Multistory with small gap dynamics Rare phase due to disturbance rotations

Community 1.2

seedlings

White pine-western larch-(lodgepole pine) seedlings. Structure: patchy clumps, single story. Time spent in this phase: 1-50 years

Community 1.3

pole sized phase

White pine-western larch-(subalpine fir-Engelmann spruce-Douglas fir) Structure: dense single story with diminished understory. Time spent in this phase: 50-140 years

Community 1.4

vertical differentiation in stand

White pine-(western larch-subalpine fir-Engelmann spruce-Douglas fir). Structure: some vertical differentiation in stand. Time spent in this phase: 140 years- centuries

Community 1.5

White pine mature stand

White pine-(western larch-Douglas fir-subalpine fir-PIEN). Structure: Mature stand with patches. Time spent in this phase: 140 years- centuries

Pathway 1.1A

Community 1.1 to 1.2

A major stand-replacement fire disturbance such as a high-intensity fire, large-scale wind event, or major insect infestation.

Pathway 1.2A

Community 1.2 to 1.3

Growth over time with no further significant disturbance.

Pathway 1.3A

Community 1.3 to 1.4

No further major disturbance. Continued growth over time, as well as ongoing mortality, leads to continued vertical diversification.

Pathway 1.3B

Community 1.3 to 1.5

A larger disturbance, such as an insect infestation, wind storm, or rot pocket that would create this forest structure.

Pathway 1.4A

Community 1.4 to 1.1

Growth over time with no further significant disturbance, leading to the reference phase.

Pathway 1.5A

Community 1.5 to 1.1

Growth over time with no further significant disturbance, leading to the reference phase.

State 2

Current Reference State

State 2: Subalpine fir (Douglas fir) /Greene's mountain ash/rusty menziesia-thinleaf huckleberry/beargrass. State 2 is different than State 1 in that western white pine no longer plays a significant role in the seral communities as it once did. Western white pine has been dramatically reduced in numbers and area by the epidemics of white pine blister rust, western spruce budworm, and dramatic fire suppression. Therefore, climax species have been able to fill the seral role that western white pine held. As well, more forests are progressing to the climax or Reference phase than historically when most forests were in the fire-maintained western white pine-dominated seral phase. Forests are now dominated by these shade-tolerant climax species subalpine fir and Engelmann spruce. While there is a tremendous effort to bolster the numbers of western white pine, it currently covers only 5 percent of its historic range.

Community 2.1

Reference Community





Plant Community 2.1 Reference Community Subalpine fir (Engelmann spruce) /Greene's mountain ash/rusty menziesia-thinleaf huckleberry/beargrass/moss. Structure: Multistory with small gap dynamics Tree Age: 150+ years

Community 2.2 Mature Stand with open patches

Plant Community 2.2 Subalpine fir-Engelmann spruce(Lodgepole pine)/ Rusty menziesia-thinleaf huckleberry/beargrass. Structure: Mature stand with patches. Tree Age: 0-10 and 150+ years.

Community 2.3 Patchy Clumps, Single Story

Plant Community 2.3 Structure: patchy clumps, single story. Time spent in this phase: 20-40 years.

Community 2.4 Dense Single Story with Diminished Understory





Plant Community 2.4 Structure: dense single story with diminished understory. Time spent in this phase: 25-60 years

Community 2.5 **Vertical differentiation in mature stand**



Plant Community 2.5 Subalpine fir-Engelmann spruce(Lodgepole pine)/ Rusty menziesia-thinleaf huckleberry/beargrass. Structure: some vertical differentiation in stand. Time spent in this phase: 20-50 years.

Pathway 2.1A **Community 2.1 to 2.2**

This pathway represents a larger disturbance, such as an insect infestation, wind storm, or rot pocket that would create this forest structure. Areas of regeneration would range from approximately 2 to 5 acres.

Pathway 2.1B **Community 2.1 to 2.3**

This pathway represents a major stand-replacement fire disturbance such as a high-intensity fire, large-scale wind event, or major insect infestation.

Pathway 2.2A **Community 2.2 to 2.1**

This pathway represents growth over time with no further significant disturbance. The areas of regeneration pass through the typical stand phases-competitive exclusion, maturation, and understory reinitiation until they resemble the old-growth structure of the Reference Community.

Pathway 2.2B

Community 2.2 to 2.3

This pathway represents a major stand-replacement fire disturbance such as a high-intensity fire, large-scale wind event, or major insect infestation.

Pathway 2.3A

Community 2.3 to 2.4

This pathway represents continued growth over time with no further major disturbance.

Pathway 2.4B

Community 2.4 to 2.3

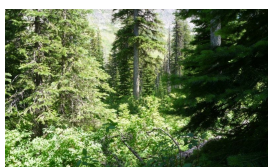
This pathway represents a major stand-replacement fire disturbance, such as a major insect outbreak, or major fire event which leads to the stand initiation phase of forest development.

Pathway 2.4A

Community 2.4 to 2.5



Dense Single Story with Diminished Understory

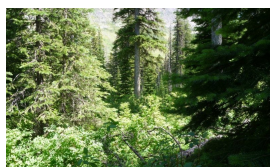


Vertical differentiation in mature stand

This pathway represents no further major disturbance. Continued growth over time

Pathway 2.5A

Community 2.5 to 2.1



Vertical differentiation in mature stand



Reference Community

This pathway represents no further major disturbance. Continued growth over time, as well as ongoing mortality, leads to continued vertical diversification. The community begins to resemble the structure of the Reference Community, with small pockets of regeneration and a more diversified understory.

Pathway 2.5C

Community 2.5 to 2.2

This pathway represents no further major disturbance. Continued growth over time,

Pathway 2.5B

Community 2.5 to 2.3

This pathway represents a major stand-replacement fire disturbance, leading to the stand initiation phase of forest development.

State 3

Root Rot State

Another disease affecting the 43A SUBALPINE COOL MOIST CONFEROUS ecological site is root rot. Armillaria root disease is the most common root disease fungus in this region, especially prevalent west of the Continental Divide. It may be difficult to detect until it has killed enough trees to create large root disease pockets or centers, ranging in size from a fraction of an acre to hundreds of acres. The root disease spreads from an affected tree to its surrounding neighbors through root contact. The root disease affects the most susceptible tree species first, leaving less susceptible tree species that mask its presence. When root rot is severe, the pocket has abundant regeneration or dense brush growth in the center. In western Montana and northern Idaho, Armillaria is present in most stands with diffuse mortality and large and small root disease centers. The disease pattern is one of multiple clones merging to form essentially continuous coverage of sites. Grouped as well as dispersed mortality can occur throughout the stand. A mosaic of brushy openings, patches of dying trees, and apparently unaffected trees may cover large areas. There can be highly significant losses, usually requiring species conversion in the active management approach. Management tactics include to identify the type of Armillaria root disease present and manage for pines and larch. Pre-commercial thinning may improve growth and survival of pines and larch. Avoid harvests that leave susceptible species (usually Douglas-fir or true firs) as crop trees (Hagle, 2010). A link has been determined between parent material and susceptibility to root disease, and metasedimentary parent material is thought to increase the risk of root disease. Glacier NP is dominated by metasedimentary parent material, and therefore may be more at risk than other areas to root disease (Kimsey et al., 2012). If a stand sustains very high levels of root disease mortality, then a coniferous stand could cross a threshold and become a shrubland, once all conifers are gone (Kimsey et al., 2012).

Community 3.1 Armillaria Root Rot

Community- Metasedimentary and quartzite parent material (vitrandic soils on south and west aspects). Shrubland with no trees. Time=50 years

Transition T1A State 1 to 2

Epidemics of white pine blister rust, western spruce budworm, and dramatic fire suppression.

Restoration pathway R2A State 2 to 1

Infilling of shrubland with conifer seedlings, usually root rot resistant species.

Transition T2B State 2 to 3

High density fir becomes infected.

Restoration pathway R3A State 3 to 2

Active management and seedling of true pine and larch species.

Additional community tables

Table 6. Community 2.1 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
mountain brome	BRMA4	<i>Bromus marginatus</i>	–	–	3
Forb/Herb					
common beargrass	XETE	<i>Xerophyllum tenax</i>	–	–	3–37.5
western meadow-rue	THOC	<i>Thalictrum occidentale</i>	–	–	15
heartleaf arnica	ARCO9	<i>Arnica cordifolia</i>	–	–	3–15
aster	ASTER	<i>Aster</i>	–	–	3
common cowparsnip	HEMA80	<i>Heracleum maximum</i>	–	–	3
fireweed	CHAN9	<i>Chamerion angustifolium</i>	–	–	3
pipsissewa	CHUM	<i>Chimaphila umbellata</i>	–	–	3
Brewer's miterwort	MIBR6	<i>Mitella breweri</i>	–	–	3
sidebells wintergreen	ORSE	<i>Orthilia secunda</i>	–	–	0.5–3
arrowleaf ragwort	SETR	<i>Senecio triangularis</i>	–	–	3
alpine leafybract aster	SYFO2	<i>Symphotrichum foliaceum</i>	–	–	3
claspleaf twistedstalk	STAM2	<i>Streptopus amplexifolius</i>	–	–	0.5
scentbottle	PLDI3	<i>Platanthera dilatata</i>	–	–	0.5
northwestern twayblade	LICA10	<i>Listera caurina</i>	–	–	0.5
fragrant bedstraw	GATR3	<i>Galium triflorum</i>	–	–	0.5
western rattlesnake plantain	GOOB2	<i>Goodyera oblongifolia</i>	–	–	0.5
Fern/fern ally					
common ladyfern	ATFI	<i>Athyrium filix-femina</i>	–	–	3
Shrub/Subshrub					
rusty menziesia	MEFE	<i>Menziesia ferruginea</i>	–	–	15–62.5
thinleaf huckleberry	VAME	<i>Vaccinium membranaceum</i>	–	–	3–37.5
grouse whortleberry	VASC	<i>Vaccinium scoparium</i>	–	–	15
thimbleberry	RUPA	<i>Rubus parviflorus</i>	–	–	15
rose meadowsweet	SPSP2	<i>Spiraea splendens</i>	–	–	15
Sitka alder	ALVIS	<i>Alnus viridis ssp. sinuata</i>	–	–	0.5–15
Oregon boxleaf	PAMY	<i>Paxistima myrsinites</i>	–	–	3–15
Utah honeysuckle	LOUT2	<i>Lonicera utahensis</i>	–	–	3
alderleaf buckthorn	RHAL	<i>Rhamnus alnifolia</i>	–	–	3
Greene's mountain ash	SOSC2	<i>Sorbus scopulina</i>	–	–	0.5–3
white spirea	SPBE2	<i>Spiraea betulifolia</i>	–	–	0.5
Nonvascular					
Moss	2MOSS	<i>Moss</i>	–	–	3–37.5

Table 7. Community 2.4 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
mountain brome	BRMA4	<i>Bromus marginatus</i>	–	–	3
sedge	CAREX	<i>Carex</i>	–	–	0.5
Forb/Herb					
common beargrass	XETE	<i>Xerophyllum tenax</i>	–	–	15–62.5
sidebells wintergreen	ORSE	<i>Orthilia secunda</i>	–	–	0.5–15
sweetcicely	OSBE	<i>Osmorhiza berteroi</i>	–	–	3
heartleaf arnica	ARCO9	<i>Arnica cordifolia</i>	–	–	3
pipsissewa	CHUM	<i>Chimaphila umbellata</i>	–	–	0.5–3
western rattlesnake plantain	GOOB2	<i>Goodyera oblongifolia</i>	–	–	0.5–3
white hawkweed	HIAL2	<i>Hieracium albiflorum</i>	–	–	3
darkwoods violet	VIOR	<i>Viola orbiculata</i>	–	–	0.5–3
threeleaf foamflower	TITR	<i>Tiarella trifoliata</i>	–	–	0.5–3
wormleaf stonecrop	SEST2	<i>Sedum stenopetalum</i>	–	–	3
arrowleaf ragwort	SETR	<i>Senecio triangularis</i>	–	–	0.5–3
western meadow-rue	THOC	<i>Thalictrum occidentale</i>	–	–	0.5
narrowleaf hawkweed	HIUM	<i>Hieracium umbellatum</i>	–	–	0.5
northwestern twayblade	LICA10	<i>Listera caurina</i>	–	–	0.5
heartleaf twayblade	LICO6	<i>Listera cordata</i>	–	–	0.5
broadleaf arnica	ARLA8	<i>Arnica latifolia</i>	–	–	0.5
Shrub/Subshrub					
grouse whortleberry	VASC	<i>Vaccinium scoparium</i>	–	–	0.5–37.5
rusty menziesia	MEFE	<i>Menziesia ferruginea</i>	–	–	3–15
thimbleberry	RUPA	<i>Rubus parviflorus</i>	–	–	15
Oregon boxleaf	PAMY	<i>Paxistima myrsinites</i>	–	–	3–15
sticky currant	RIVI3	<i>Ribes viscosissimum</i>	–	–	3
Utah honeysuckle	LOUT2	<i>Lonicera utahensis</i>	–	–	3
Greene's mountain ash	SOSC2	<i>Sorbus scopulina</i>	–	–	0.5–3
white spirea	SPBE2	<i>Spiraea betulifolia</i>	–	–	3
common snowberry	SYAL	<i>Symphoricarpos albus</i>	–	–	0.5–3
thinleaf huckleberry	VAME	<i>Vaccinium membranaceum</i>	–	–	3
whortleberry	VAMY2	<i>Vaccinium myrtillus</i>	–	–	3
red elderberry	SARA2	<i>Sambucus racemosa</i>	–	–	0.5
Tree					
Saskatoon serviceberry	AMAL2	<i>Amelanchier alnifolia</i>	–	–	3
Rocky Mountain maple	ACGL	<i>Acer glabrum</i>	–	–	0.5
Nonvascular					
Moss	2MOSS	<i>Moss</i>	–	–	3–15

Table 8. Community 2.5 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
mountain brome	BRMA4	<i>Bromus marginatus</i>	–	–	3
Geyer's sedge	CAGE2	<i>Carex geyeri</i>	–	–	3
Forb/Herb					
common beargrass	XETE	<i>Xerophyllum tenax</i>	–	–	0.5–37.5
green false hellebore	VEVI	<i>Veratrum viride</i>	–	–	15
western meadow-rue	THOC	<i>Thalictrum occidentale</i>	–	–	3–15
threeleaf foamflower	TITR	<i>Tiarella trifoliata</i>	–	–	0.5–3
fireweed	CHAN9	<i>Chamerion angustifolium</i>	–	–	3
pipsissewa	CHUM	<i>Chimaphila umbellata</i>	–	–	3
heartleaf arnica	ARCO9	<i>Arnica cordifolia</i>	–	–	3
common cowparsnip	HEMA80	<i>Heracleum maximum</i>	–	–	3
sidebells wintergreen	ORSE	<i>Orthilia secunda</i>	–	–	0.5–3
liverleaf wintergreen	PYAS	<i>Pyrola asarifolia</i>	–	–	0.5–3
arrowleaf ragwort	SETR	<i>Senecio triangularis</i>	–	–	0.5
narrowleaf hawkweed	HIUM	<i>Hieracium umbellatum</i>	–	–	0.5
fragrant bedstraw	GATR3	<i>Galium triflorum</i>	–	–	0.5
western rattlesnake plantain	GOOB2	<i>Goodyera oblongifolia</i>	–	–	0.5
darkwoods violet	VIOR	<i>Viola orbiculata</i>	–	–	0.5
Fern/fern ally					
Pacific oakfern	GYDI2	<i>Gymnocarpium disjunctum</i>	–	–	3
common ladyfern	ATFI	<i>Athyrium filix-femina</i>	–	–	3
Shrub/Subshrub					
rusty menziesia	MEFE	<i>Menziesia ferruginea</i>	–	–	0.5–62.5
thinleaf huckleberry	VAME	<i>Vaccinium membranaceum</i>	–	–	0.5–37.5
Utah honeysuckle	LOUT2	<i>Lonicera utahensis</i>	–	–	3–15
Oregon boxleaf	PAMY	<i>Paxistima myrsinites</i>	–	–	3
Greene's mountain ash	SOSC2	<i>Sorbus scopulina</i>	–	–	0.5–3
sumac	RHUS	<i>Rhus</i>	–	–	3
prickly currant	RILA	<i>Ribes lacustre</i>	–	–	3
velvetleaf huckleberry	VAMY	<i>Vaccinium myrtilloides</i>	–	–	3
Nonvascular					
Moss	2MOSS	<i>Moss</i>	–	–	3–15

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Approval

Kirt Walstad, 9/09/2023

Rangeland health reference sheet

Interpreting Indicators of Rangeland Health is a qualitative assessment protocol used to determine ecosystem condition based on benchmark characteristics described in the Reference Sheet. A suite of 17 (or more) indicators

are typically considered in an assessment. The ecological site(s) representative of an assessment location must be known prior to applying the protocol and must be verified based on soils and climate. Current plant community cannot be used to identify the ecological site.

Author(s)/participant(s)	
Contact for lead author	
Date	12/18/2020
Approved by	Kirt Walstad
Approval date	
Composition (Indicators 10 and 12) based on	Annual Production

Indicators

1. **Number and extent of rills:**

2. **Presence of water flow patterns:**

3. **Number and height of erosional pedestals or terracettes:**

4. **Bare ground from Ecological Site Description or other studies (rock, litter, lichen, moss, plant canopy are not bare ground):**

5. **Number of gullies and erosion associated with gullies:**

6. **Extent of wind scoured, blowouts and/or depositional areas:**

7. **Amount of litter movement (describe size and distance expected to travel):**

8. **Soil surface (top few mm) resistance to erosion (stability values are averages - most sites will show a range of values):**

9. **Soil surface structure and SOM content (include type of structure and A-horizon color and thickness):**

10. **Effect of community phase composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:**

11. **Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site):**

12. **Functional/Structural Groups (list in order of descending dominance by above-ground annual-production or live foliar cover using symbols: >>, >, = to indicate much greater than, greater than, and equal to):**

Dominant:

Sub-dominant:

Other:

Additional:

13. **Amount of plant mortality and decadence (include which functional groups are expected to show mortality or decadence):**

14. **Average percent litter cover (%) and depth (in):**

15. **Expected annual annual-production (this is TOTAL above-ground annual-production, not just forage annual-production):**

16. **Potential invasive (including noxious) species (native and non-native). List species which BOTH characterize degraded states and have the potential to become a dominant or co-dominant species on the ecological site if their future establishment and growth is not actively controlled by management interventions. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants. Note that unlike other indicators, we are describing what is NOT expected in the reference state for the ecological site:**

17. **Perennial plant reproductive capability:**
