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Coram Experimental Forest: 50 Years of Research in a Western Larch Forest

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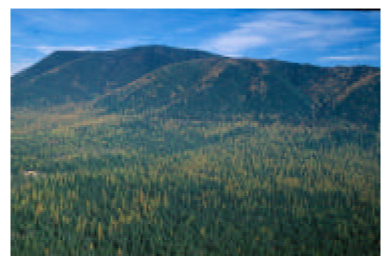

Abstract

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This publication will enrich public understanding about the important contributions to science made at this and other outdoor laboratories.

Coram, and other long-range research sites, provide scientific knowledge to assist resource professionals with the development of sound land management principles. This knowledge ensures healthy, sustainable, and productive ecosystems while meeting social and economic needs.

Major research at Coram includes the regeneration of young forests and the interaction of flora, fauna, and water to a wide range of forest treatments.

Ongoing studies include:

- cone and seed development and dispersal
- natural and artificial regeneration after harvest cuttings
- effects of stand culture treatment on forest development
- insect and disease interactions
- effects of the amount of wood harvest on site productivity
- influence of silvicultural practices on watershed, esthetics, and wildlife values

The Coram Experimental Forest is used cooperatively by Federal, university, and private scientists. About 340 ha of the forest are designated as the Coram Research Natural Area where virgin conditions are permanently maintained for research and monitoring.

Coram, designated a Biosphere Reserve in 1976, is part of an international network that is devoted to the conservation of nature and scientific research in the service of humans. Continuing research at Coram will help people gain a better understanding of how they can live in harmony with the landscape and assist with the protection of forest and range ecosystems.

Keywords: even-aged harvest methods, site preparation, regeneration, cone production, seed dispersal, stand culture, natural area, biosphere reserve

The Authors

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Madelyn M. Kempf was a Public Affairs Specialist with the USDA Forest Service from 1985 to 1995. Kempf now contracts her services for publication design and writing/editing assignments. Kempf also writes for national publications and serves as a writer/editor for non-profit organizations.

Cover Photographs: In 1933, Coram Experimental Forest was established to study the ecology and management of western larch, a deciduous and valuable conifer (large photo) that grows only in the upper Columbia River basin. **Upper left**: A 1935 aerial photo shows Belton Point and the 1929 wildfire boundary, mostly off the north end of the experimental forest. **Upper right**: An October 1997 photo shows Belton Point and distribution of larch (yellow foliage) on west-facing slopes at Coram and on bordering privately-owned land. **Center left**: A fire scar on a western larch damaged by a prescribed fire in 1975. **Lower left**: Two-year-old larch seedlings growing on a burned surface. **Lower center**: Logs are brought downhill by cable from a shelterwood cutting to Road 590B in 1974. **Lower right**: Man and the Biosphere plaque designating Coram Experimental Forest as a Biosphere Reserve in 1976 located at the Abbot Basin vista. **Center right:** A 27-year-old larch natural regeneration (bottom of photo) established at the edge of the 12 ha clearcut, bordering old-growth forest, and the vista overlooking Abbot Basin (top of photo).

Acknowledgments

Many dedicated and competent Forest Service research and management personnel have contributed to 50 years of research on the Coram Experimental Forest. Recognition and thanks are extended to Charles A. Wellner, Russell K. LeBarron, Arthur L. Roe, Kenneth N. Boe, Anthony E. Squillace, Robert D. Pfister, Clinton E. Carlson, and Wyman C. Schmidt for providing direction and leadership during 50 years of research. Since the late 1960s, Jack A. Schmidt has been instrumental in the establishment, measurement, and maintenance of many study plots. He converted mechanical monitoring equipment to electronic recorders that report climatic and hydrologic events on the experimental forest.

The cooperation and support of personnel on the Flathead National Forest—especially the District Rangers and other employees on the Coram and Hungry Horse Ranger Districts—is recognized and appreciated. These dedicated individuals accomplished many details that permitted research objectives to be met. Outstanding service to research was also provided by temporary employees, volunteers, and interested neighbors.

Special acknowledgment goes to E. Donald Kiehn and L. Lynne Dixon (Forest Service volunteers) and Silja Meier (Clemson University intern) who used research data to develop curricula being used in nearby schools and helped establish the Coram Experimental Forest as an outdoor classroom for teachers and students.

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Introduction

The Coram Experimental Forest (figure 1) leads the way in *Larix occidentalis* (western larch) ecosystem research and is the focal point of larch studies throughout the spectacular mountain country of the northwest United States and southwestern Canada. Great unbroken reaches of alpine meadows, towering peaks, turbulent rivers, and sparkling lakes provide a habitat for western larch forests. Larch forests range from slow-growing, old growth to fast-growing young stands regenerated following natural disturbance and many management treatments. The Coram Experimental Forest also features one of the most comprehensive research program of any area in the world studying any of the 10 species of *Larix*.

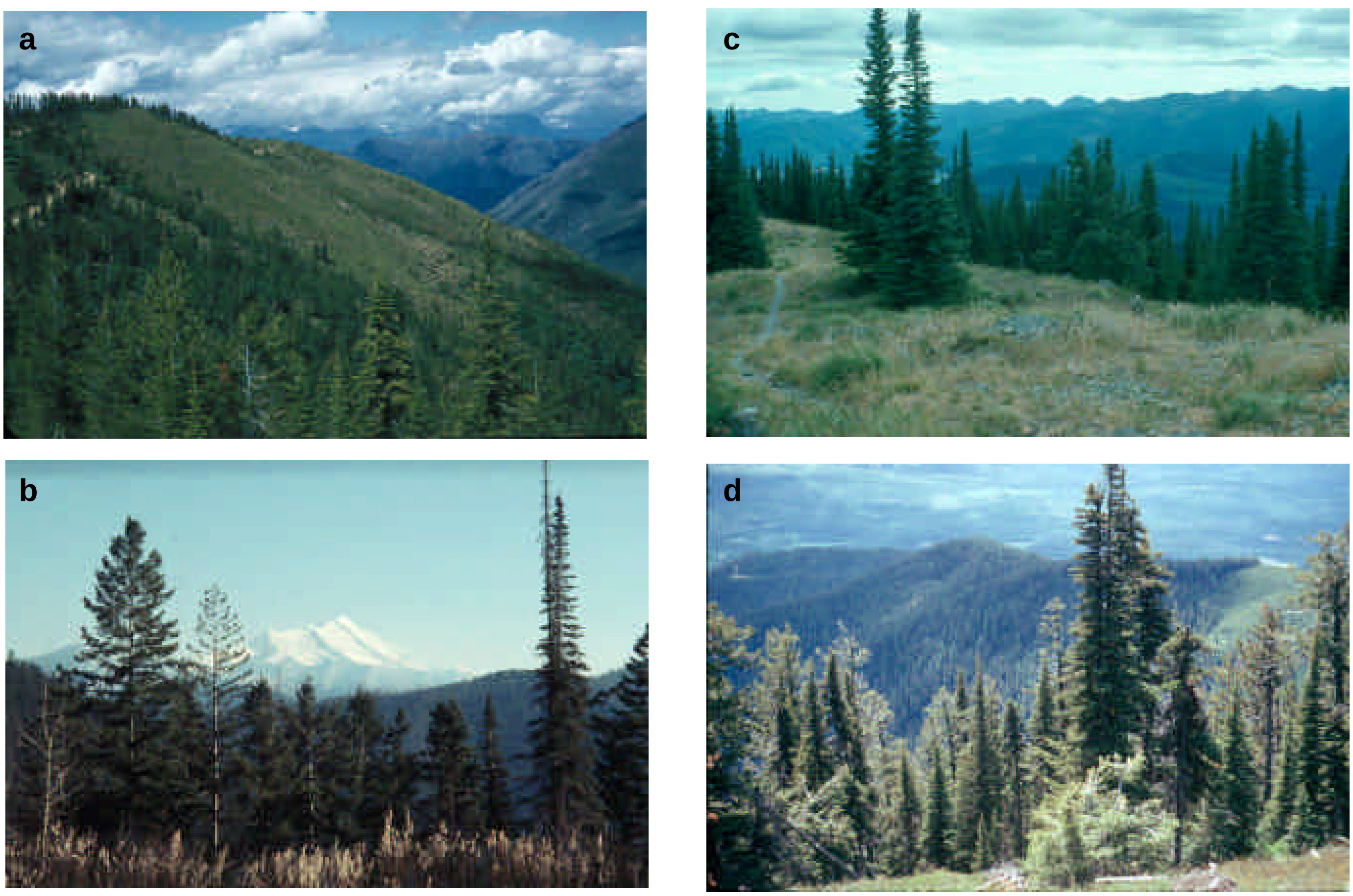

Figure 1. Within the rugged vastness of northwest Montana, lies the Coram Experimental Forest, which is cradled between Glacier National Park and the Great Bear Wilderness and is a "green Jewel" in the Crown of the Continent Biosphere Reserves. These views are from Desert Mountain, 1,942 m in elevation, on the northeast corner of the experimental forest. (a) Desert Ridge to Belton Point and east facing slope burned by wildfire in August 1929; peak in Glacier National Park in background. (b) Great Northern Mountain in the Great Bear Wilderness, 1994. (c) Abbot Basin, Hungry Horse Reservoir and the Swan Range in background, 1959. (d) Head of Abbot Basin, 1973. (Photos by Ray Shearer)

Western larch, an important and common conifer growing within many forests of the upper Columbia River Basin, is the largest of 10 species of larch worldwide (Boe 1958). Larch is 1 of only 4 conifer genera that loses its needles in the fall (figure 2). In autumn, the light green needles change to a bright yellow adding a golden hue to the otherwise evergreen forests. Larch, the most shade-intolerant conifer in the Northern Rockies, readily regenerates in sunlight following fire (LeBarron 1948). Seedlings grow rapidly during the first hundred years enabling them to survive competition from other vegetation in the developing forests.

Mature and old growth western larch, the most fire-resistant trees within their natural range, have thick bark of low resin content that protects the cambium layer from all but the most severe ground fires, which often kill other tree species (Schmidt and others 1976). Seeds within singed, maturing cones often persist on fire-killed or surviving trees, then fall on the freshly burned surfaces after the cones open. Old growth western larch, one of the few conifers that often develop hollow centers, are favorite habitats for a wide range of mammals and birds (Richardson 1997)—*Ursus americanus cinnamomum* (black bear), *Dryocopus pileatus* (pileated woodpecker), *Chaetura vauxi* (Vaux's swift), *Martes americana* (American marten), *Glaucomys sabrinus* (flying squirrel), bats, and *Neotoma cinerea* (bushy-tailed woodrats). In the spring, black bears may strip bark from young trees to feast on the sap that is high in wood sugar (Schmidt and Gourley 1992). Many people prefer larch for firewood and other commercial lumber products. Coram's unique 3,019 ha landscape, where larch is the major component (figure 3), is a thriving field laboratory where scientific information increases human understanding of forest function.

Figure 2. Western larch is the focus of research on the Coram Experimental Forest. (Photo by Steve Wirt)

LeBarron (1948) suggested projects requiring investigation for western larch 50 y ago. Research at Coram focused on the ecology and silviculture of western larch and has filled gaps in knowledge noted by LeBarron. Although near the eastern limit of its natural range, western larch growth at Coram is similar to elsewhere in the inland mountain west. Studies at Coram and elsewhere provide a scientific basis for management to help sustain productive western larch forests and to predict the effects of management activities on these ecosystems.

Research scientists are working to:

- delineate the biological and economic effects of wood-use practices;
- understand how to improve forest health through silvicultural treatments;
- determine the development of young to intermediate age larch forests under different management practices;
- define the interaction of young larch forests and their wood properties with insects, diseases, animals, and other factors under intensive management;
- describe changes in vegetation structure, species, and conifer seed production in the Coram Research Natural Area;
- identify habitat requirements for mammals and birds;
- determine characteristics of watersheds in Abbot Basin, and the influence of silviculture treatments on water flow and quality; and
- integrate data into a computer software system that simulates changes in vegetation patterns as a result of insect, disease, fire, and management activities.

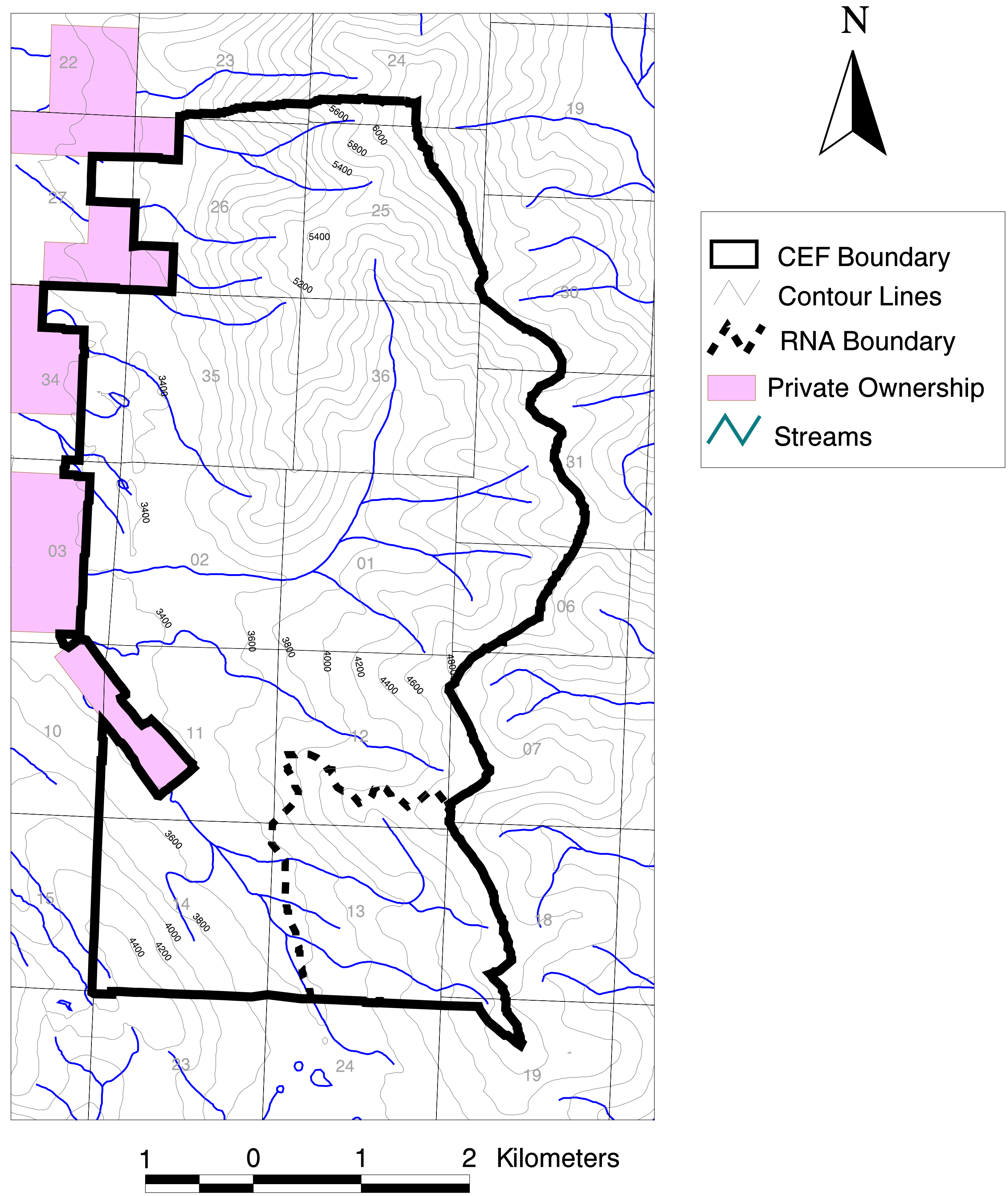

Figure 3. Geographic Information Systems map of the Coram Experimental Forest, 1998, showing topography.

Area Description

Geology

The Rocky Mountains were formed 70 to 90 million y ago by cataclysmic convulsions deep within the core of the earth. Intense pressure caused the planet's surface to bulge, stripping large rock layers away from the surface and shifting them eastward. As these layers piled up, they formed the beginning of the jagged mountains on the east side of the Flathead Valley.

Bedrock of the Coram Experimental Forest is mapped as Missoula group and Belt subgroup and is composed of late Precambrian sedimentary rocks—red, maroon, and purple argillite, sandy or quartzitic argillite, and quartzite (Klages and others 1976). At lower elevations, in the west and southwestern parts of the Coram Experimental Forest, bedrock consists of siltstone, silty sandstone, local carbonaceous shale, indurated conglomerate and reddish shale.

At the beginning of the ice age, about 25 million y ago, giant glaciers covered the land, completely filling northern valleys to a depth of over 1.6 km in some places. As the glaciers began moving, they scoured the high ridges scraping and depositing glacial till, soil, sand, and gravel, into the valleys creating much of Coram's landscape. Prominent U-shaped valleys throughout this area are evidence of heavy glaciation, as are the moraine deposits and pot-hole lakes found at the base of the mountains. Glacial till and pot holes occur inside and to the west of what is now the Coram Experimental Forest.

Slopes along Abbot Creek, and its south bank up to about 1,250 m in elevation, include glacial drift, moraine, and outwash deposits of mountain glaciers of the Middle and South Fork Flathead Rivers. Steep mountain slopes north of Abbot Creek and at high elevations on the east side of the area were probably glaciated.

Soils

When the last major ice age ended, about 10,000 y ago, the glacial till that remained in the Flathead Valley had a very high rock content, which is not conducive to vegetation growth. However, other natural occurrences contributed to a change in soil conditions in the area. About 6,800 y ago Mt. Mazama located at the site of the present day Crater Lake in Oregon, violently erupted spewing clouds of volcanic ash into the atmosphere. Winds carried the ash to the northeast where it fell, 0.6 to 1.2 m deep in some locations in northwest Montana. At Coram, a thin layer of volcanic ash covers about half of the experimental forest. The ash has partially mixed with the surface horizons on the remainder of the area (Klages 1974). Clays within all horizons, except the surface of ash-covered soils, contain from 50% to 60% mica. Ash-covered soils average only 20% mica and 60% allophane in the A horizon. Soils without ash covering average only 20% allophane in the A horizon.

Soils on the Coram Experimental Forest are a mix of Precambrian sedimentary rocks and glacial till, with a surface mantle containing volcanic ash. This mix results in a rich, loamy soil ranging in depths from a few centimeters on steep, upper slopes, to over 3 m on the gentle, lower terrain (Klages and others 1976). Soils at Coram were classified and mapped (figure 4) between 1960 and 1965 from 31 pits that were 1 to 2 m deep (figure 5).

Six soils were identified (Klages and others 1976):

I. loamy-skeletal soils on materials weathered from impure limestone and argillite
II. loamy-sleletal soils on argillite, siltite, and quartzite
III. loamy-skeletal soils on glacial till
IV. loamy-skeletal soils on both alluvium, and glacial outwash
V. loamy-skeletal soils on glacial outwash
VI. fine and fine-loamy soils on lacustrine deposits

Climate

Wide ranges in moisture and temperature over the millennia have promoted varying zones of plant life in what is now the Coram Experimental Forest. Western larch is present throughout the landscape and blends with other tree species, sometimes as lush groves of mostly moss-covered *Thuja plicata* (western redcedar) on warmer, moister sites, or as scattered trees mixed with rapidly declining stands of *Pinus albicaulis* (whitebark pine) infected with the introduced disease *Cronartium ribicola* (white pine blister rust) along the subalpine Desert Ridge.

Climate within the Coram Experimental Forest is classified as a modified Pacific maritime-type (State Engineers Office 1985). Occasionally, in the winter, continental-type polar air spills westward over the Continental Divide dropping temperatures substantially for a few days. Finklin (1986) broadly characterized seasons within Glacier National Park, including the nearby Coram Experimental Forest, as: winter, November through March; spring, April through June; summer, July and August; and autumn, September and October. During winter, it is cloudy about 75% of the time and most of the annual precipitation occurs then. Summer tends to be dry and warm. Hungerford and Schlieter (1984) summarized climatic data for Coram Experimental Forest. Selected climatic factors continue to be measured at several locations to determine how they vary within this research area. Streamflow is monitored on Abbot Creek near its source and on Lunch Fork of Abbot Creek.

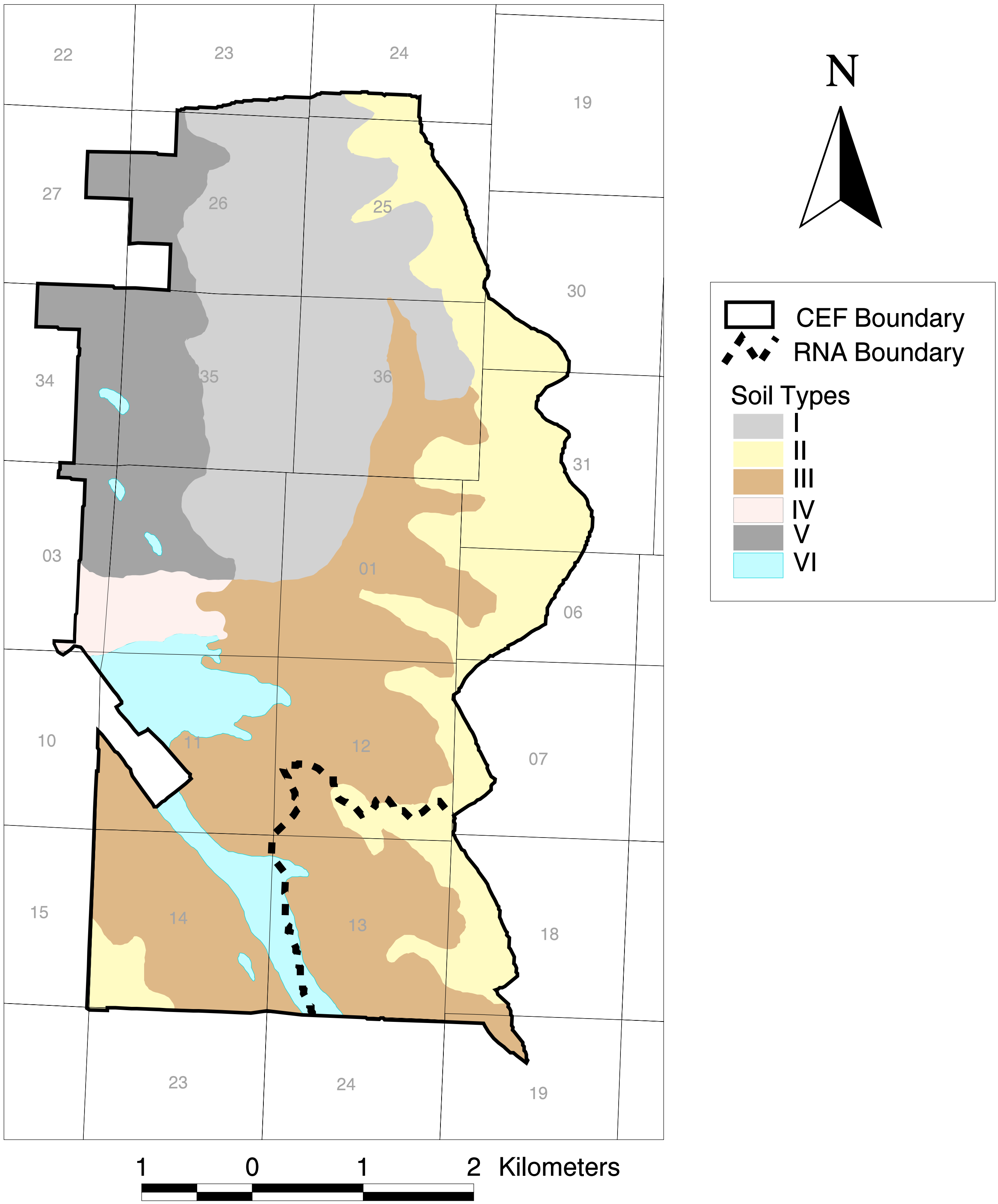

Figure 4. Geographic Information System map from a 1965 soils map of the Coram Experimental Forest, 1998.

Figure 5. Soil pit #25 on the Coram Experimental Forest, September 1965. (Photo by Ray Shearer)

Precipitation

Mean annual precipitation (figure 6) at Coram ranges from 890 mm at lower elevations, to 1,270 mm at Desert Mountain (Farnes and others 1995a, 1995b). Snow provides most of the moisture from November through March. May and June rainfall is substantially greater than other months. Rainfall is usually light, but it can be heavy. For example, within a 19 h period on June 7 and 8, 1964 (figure 7) about 87 mm fell on Abbot Flat, elevation 1,067 m, and about 108 mm fell in Abbot Basin, elevation 1,295 m. Serious surface runoff from cutover and old growth stands caused debris to plug culverts and resulted in serious road damage. Rain from this storm combined with rapid high elevation snow melt caused devastating floods in Montana, east and west of the Continental Divide (USDC 1964).

Although snow usually accumulates from November through March, it can fall in any month. Heavy snowfall in late spring soon after foliage develops on deciduous trees, such as western larch, can be a serious problem. On June 4, 1966, 152 to 203 mm of very heavy snow (USDC 1966) fell bending 13 y-old larch and other forest vegetation nearly to the ground (Schmidt and Schmidt 1979). Most of the young trees recovered and straightened, a process that can take many years. Some trees still show crooks in their trunks, evidence of severe snow bend. Thirty years later, a similar snowfall occurred on June 6 to 7, 1995 (USDC 1995). Up to 305 mm of wet snow fell at Coram causing considerable damage to smaller diameter, 43 y-old western larch. Many of these trees were broken or uprooted. Others were so severely bent they will never recover.

Temperature

Mean annual temperatures on the experimental forest range from 2 °C to 7 °C. Summer temperatures average between 13 °C to 17 °C (Hungerford and Schlieter 1984). Maximum temperatures seldom exceed 38 °C. Winter temperatures typically fall below –18 °C, but rarely lower than –29 °C.

In early 1989, following an unusually mild winter, an arctic air mass with high wind and frigid temperatures caused considerable damage to conifers on the Coram Experimental Forest. Stations at Hungry Horse Dam and West Glacier, both near Coram, had temperatures plummet from 11 °C on 31 January (USDC 1989a) to –14 °C at midnight to –29 °C on 1 February (USDC 1989b). Most vegetative, seed cone, and pollen cone buds of conifers in the inland northwest, including the Coram Experimental Forest, were frozen and did not open that spring. Many *Pinus monticola* (western white pine seedlings), that were not covered by snow, and some saplings also froze and died. Some foliage on the conifer species showed damage and mortality. Also, most *Prunus* (cherry) trees in the Flathead Valley were killed.

Length of the growing season, estimated by the number of frost-free days, range from 81-days, near Abbot Creek, to about 160-days, on a nearby east-facing slope. These compare to an average of 98 days at nearby West Glacier (Finklin 1986).

Vegetation

Suitable growing conditions on the Coram Experimental Forest have resulted in a diverse mix of vegetation. Appendix A lists species identified at Coram that have specimens filed in the herbarium at the Forestry Sciences Laboratory in Missoula, Montana.

Western larch grows almost everywhere at Coram in association with *Pseudotsuga menziesii* (Douglas-fir), *Abies lasiocarpa* (subalpine fir), and *Picea* (spruce) (*P. engelmannii* [Engelmann] at higher elevations,

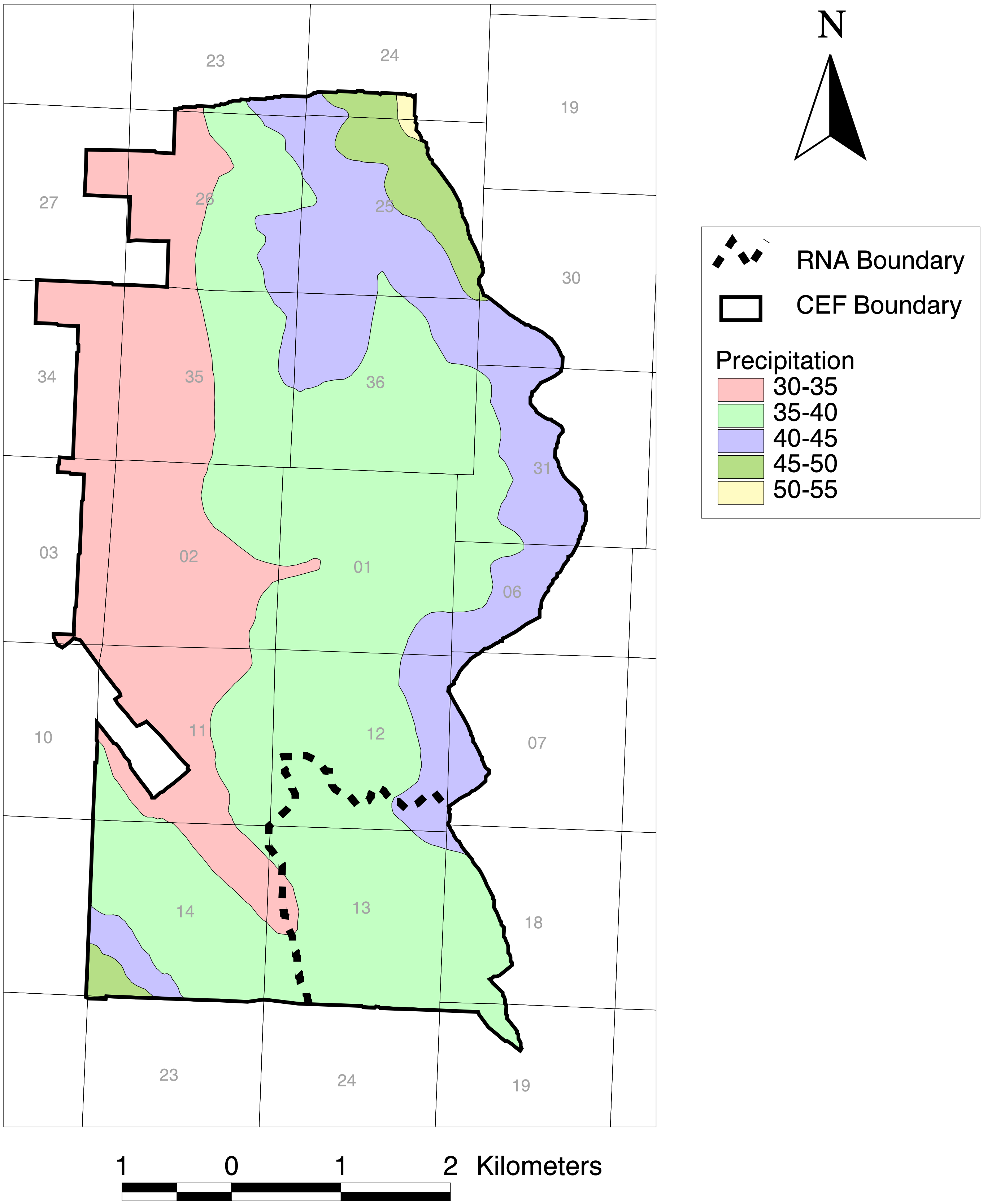

Figure 6. Using records from several long-term and temporary recording stations, a Geographic Information System mean precipitation map was generated for the Coram Experimental Forest.

and hybrids of Engelmann and *P. glauca* [white spruce] at lower elevations). Less common associates are *Pinus contorta* (lodgepole pine), western white pine, *Tsuga heterophylla* (western hemlock), and western redcedar. Larch and *P. ponderosa* (ponderosa pine) grow together on dry, lower-elevation ridges with shallow soil, the only sites where ponderosa pine is found. At high elevations, larch formerly grew with whitebark pine, a species that has been mostly eliminated from this site by the introduced pathogen, white pine blister rust. Occasional individual *A. grandis* (grand fir) trees are found on warm, moist sites. *Taxus brevifolia* (Pacific yew) and *Juniperus communis* (common juniper) grow in shrub form. The only conifers that grow within the range of western larch not represented on the Experimental Forest are *Larix lyallii* (alpine larch) and *Tsuga mertensiana* (mountain hemlock). Predominant hardwood trees are *Betula papyrifera* (paper birch), *Populus trichocarpa* (black cottonwood), and *P. tremuloides* (quaking aspen).

Coram has a diverse mix of shrubs including: *Linnaea borealis* (twinflower), *Physocarpus malvaceus* (ninebark), *Spiraea betulifolia* (shiny-leaf spiraea), *Arctostaphylos uva-ursi* (kinnikinnick), *Alnus sinuata* (Sitka alder), *Salix scouleriana* (Scouler's willow), and *Vaccinium globulare* (globe huckleberry). Common forbs are: *Arnica latifolia* (mountain arnica), *Clintonia uniflora* (queencup), *Epilobium angustifolium* (fireweed), *Trillium ovatum* (trillium), *Fragaria vesca* (strawberry), *Cornus canadensis* (bunchberry dogwood), *Disporum hookeri* (Hooker fairy-bell), and *Xerophyllum tenax* (beargrass).

These productive forests provide habitat and sanctuary for many species of birds and mammals such as *Haliaetus eucocephalus* (bald eagle), *Dryocopus pileatus* (pileated woodpecker), and *Dendragapus obscura* (blue grouse); and mammals including *Ursus americanus cinnamomum* (black bear), *Ursus arctos horribilus* (grizzly bear), *Canis latrans* (coyote), *Canus lupus* (gray wolf), *Alces americanus* (moose), *Cervus canadensis* (elk), *Odocoileus virginianus* (white-tail deer) and *Odocoileus hemionus* (mule deer). Birds and small mammals identified on the Coram Experimental Forest are listed in Appendix B and Appendix C. Introduced *Salvelinus fontinalis* (eastern brook trout) populate Abbot Creek.

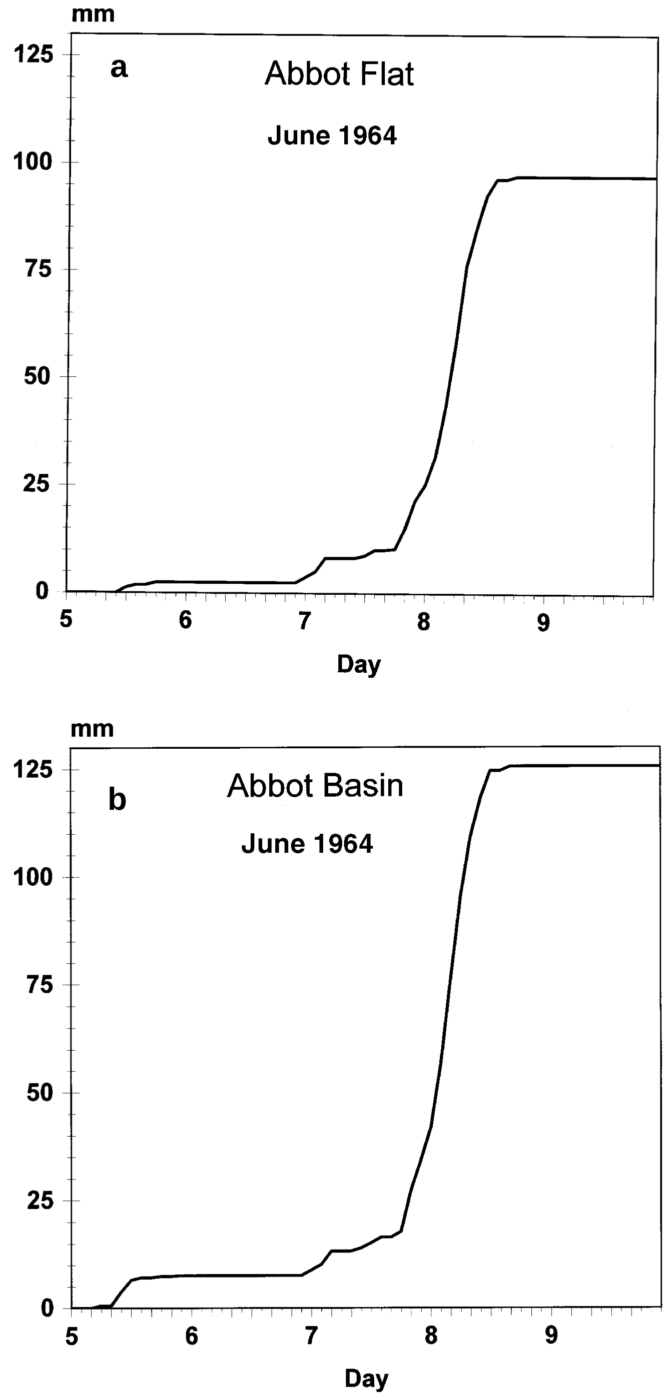

Figure 7. Precipitation at 2 locations on Coram Experimental Forest, June 5 to 9, 1964; (a) Abbot Flat, 1,067 m. (b) Abbot Basin within group seed-tree cutting, 1,295 m.

Habitat Types

Field work in the 1960s included a vegetation habitat type map of the Coram Experimental Forest made by Robert D. Pfister in 1970 (figure 8). Pfister and others (1977) identified 3 forest series: subalpine fir/clintonia (ABLA/CLUN); Douglas-fir/ninebark (PSME/PHMA); western hemlock/clintonia (TSHE/CLUN). In 1974, Bernard L. Kovalchik[1] classified by habitat type most east-facing slopes in Abbot Basin, including the Forest Residues Utilization R&D Program study area (table 1).

[1]Results are presented in an unpublished report on file at the Forestry Sciences Laboratory, Missoula, MT 59807.

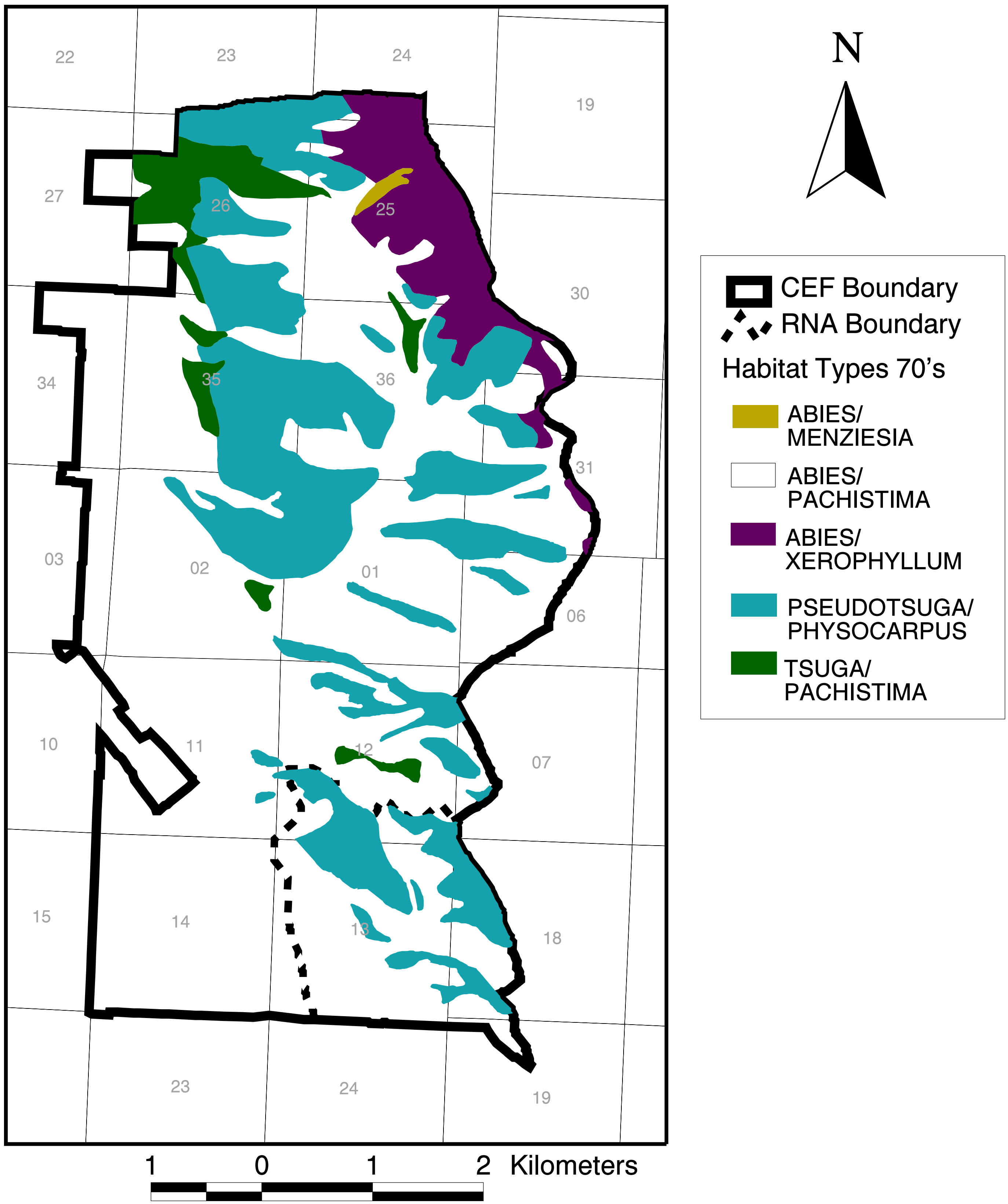

Figure 8. Geographic Information Systems generated vegetation habitat type map of the Coram Experimental Forest by Robert D. Pfister in 1970.

Table 1. Habitat types and phases in percent of area on the residues study by elevation and harvest method[a] on the Coram Experimental Forest 1974.

Habitat type, phase[b]	1,195 m - 1,390 m SW	1,195 m - 1,390 m GS	1,195 m - 1,390 m CC	1,341 m - 1,615 m SW	1,341 m - 1,615 m GS	1,341 m - 1,615 m CC
ABLA/CLUN, ARNU	25	15	40	1	0	0
ABLA/CLUN, CLUN	43	8	0	2	0	0
ABLA/CLUN, MEFE	0	0	0	1	30	10
ABLA/CLUN, PHMA	0	55	10	0	0	0
ABLA/CLUN, XETE	30	10	20	93	70	85
ABLA/CLUN, XETE, PHMA	0	0	0	3	0	0
ABLA/OPHO	0	0	0	0	0	5
PSME/PHMA	0	2	0	0	0	0
TSHE/CLUN, ARNU	2	10	30	0	0	0
Total	100	100	100	100	100	100

[a] SW=shelterwood, GS=group selection, CC=clearcut
[b] ABLA=*Abies lasiocarpa*, PSME=*Pseudotsuga menziesii*, TSHE=*Tsuga heterophylla*, ARNU=*Aralia nudicaulis*, CLUN=*Clintonia uniflora*, MEFE=*Menziesia ferruginea*, OPHO=*Oplopanax horriudm*, PHMA-*Physocarpus malvaceus*, XETE=*Xerophyllum tenax*

Fire

Lightning-caused fires have always played a major role in maintaining the health and diversity of northwest Montana forest ecosystems. The frequency of these fires was determined by factors such as climate, weather, terrain conditions, available fuels, and conditions such as dry grasses, downed trees, and thick layers of needles on the ground.

On August 21, 1929, in the northeast corner of the Coram Experimental Forest, Desert Mountain lookout, Mr. Tunnell watched in horror as the human-caused Half Moon conflagration topped Teakettle Mountain 10 km to the west and moved toward his mountain (figure 9a & 9b). Wind from the canyon of the South Fork of Flathead River turned the fire north where it raced into Glacier National Park and leveled the towns of Coram and Belton (West Glacier). Two days later, Mr. Tunnell returned to Desert Mountain with researcher Harry T. Gisborne to observe the fire and make weather measurements. That afternoon they witnessed 2 forest fire explosions, one to the north (figure 9c & 9d) and the other to the northeast of the lookout station. Gisborne (1929) published these observations in what was probably the first written scientific description of forest fire explosions. Periodically, this type of landscape-changing event has renewed most forests of the northern Rocky Mountains.

In an August 2, 1930, letter to The Forester, Washington, DC, Evan W. Kelley, Regional Forester of the Northern District reported the Half Moon fire burned an estimated 43,800 ha (16,800 ha in Glacier National Park, 7,300 ha in the Flathead National Forest, 100 ha in the Blackfeet National Forest, and 19,600 ha in private ownership). However, less than 2 ha were burned on the Coram Experimental Forest. The fire was not brought under control until rain and snow began in early September. This devastating wildfire affected every community in the area.

Fire episodes have been recorded in northwest Montana as early as 1540 (Barrett and others 1997). A fire chronology dating from 1602 to 1976 was identified from fire scars and stand age-classes within the Coram Experimental Forest (Sneck 1977). Data from Coram is indicative of the broad forest zone of the subalpine fir series from middle elevations to alpine timberline (Arno 1980). Later regeneration research at the Coram Experimental Forest showed the benefit of using fire to perpetuate western larch and other conifers.

A Trail of Desolation

"When Montana's largest man-caused fire, the Half Moon conflagration [figure 9a] ran this summer from Teakettle Mountain to Belton and Glacier Park headquarters in one afternoon, it left a trail of desolation [figure 9b] which will ruin that twelve-mile auto drive for thousands of tourists for many, many years….

"Homesteads, ranches, and small sawmills were reduced, not to heaps of ashes, but to mere traces of light and dark ashes, small patches of fused china and glassware, twisted metal bedsteads, bent drive shafts, and cracked engines and saws. Several families lost all that they had struggled throughout life to acquire….

"At the Desert Mountain forest-fire lookout station, four-miles south of Belton (West Glacier), and 3,000-feet above it, the man on duty (Mr. Tunnell) made fast time down the nine-mile trail to Coram Ranger Station when the head of this fire came roaring toward his mountain…." —H.T. Gisborne (1929)

Figure 9. The 40,500 ha human-caused Half Moon fire in August, 1929 burned small areas of the northwest and northeast corners of the Coram Experimental Forest. (a) On August 19 the fire swept over Teakettle Mountain (photograph by R.E. Marble from the Horn Ranch in Flathead Valley; Badrock Canyon is to the right of the smoke [Glacier National Park photo]). (b) By August 20 the fire raced north into Glacier National Park (photograph by K.D. Swan showing Teakettle Mountain [Glacier National Park photo]). (c) A hurried photograph taken by H.T. Gisborne of the fire explosion in the valley and slopes north of Belton Point, afternoon of August 21 as he and Mr. Tunnell retreat to the Desert Mountain Lookout station (photo no. 81-786, K. Ross Toole Archives, The University of Montana—Missoula). (d) Smoke following a forest fire explosion obscures the upper end of Emery Basin, north of Desert Mountain Lookout station (H.T. Gisborne photograph, no. 81-787, K. Ross Toole Archives, The University of Montana— Missoula).

Fire has created diverse forest vegetation on similar sites and maintained heterogeneous tree age-classes and canopy structure over the landscape (Arno and Sneck 1977). Fire frequencies were about 120 y for valleys and montane slopes, and 150 y for subalpine slopes from 1735 to 1976 (Davis 1980). Fires were small and moderately intense with occasional high intensity runs. Single burns thinned the overstory favoring mixed conifer regeneration. Multiple burns created homogeneous stands or shrubfields.

Human Settlement

Northwest Montana is the ancestral home of the Flathead, Salish-Kootenai, Kalispell, Pend d'Orille, and Blackfeet tribes who traveled the area in pursuit of food. Their migration patterns were determined by their search for buffalo, deer, elk, and salmon, as well as harvesting the cambium (inner bark) from ponderosa pine trees, and roots from the bitterroot plants.

To the tribes living in the Flathead Valley, the Bad Rock Canyon area, 6.4 km west of Coram, was a significant travel route over the mountains to the plains where an abundance of buffalo grazed. This area was also the home of the Blackfeet tribe who followed the same route to the west to fish the mountain streams.

American Indian people used fire as a tool to manage their environment. Grasslands and forests were burned to improve wildlife habitat and clear the land for campsites, travel corridors, and agricultural activities.

The first settlers of European descent were enticed into the area by an abundance of fur bearing animals with high quality pelts. *Martes americana* (marten) and *Castor canadensis* (beaver) were the prime target of the early trappers. *Lutra* sp. (otter), *Martes pennanti* (fisher) and bear skins were also in demand. There were no bag limits, game laws, or area restrictions to hinder these hardy people in their pursuit of pelts. Trappers worked alone or in pairs, built primitive shelters, and lived off the land. The mountain ranges surrounding northwest Montana offered little level ground for development. The difficult terrain, lack of diverse opportunities to make a living, and extreme winter weather conditions discouraged early mass development.

With the completion of a railroad line in 1891 over Marias Pass, through Bad Rock Canyon and into Kalispell, small temporary communities began to develop. An early homestead, filed by Mickey Wagoner, was the farthest homestead up the South Fork of the Flathead and was within the boundaries of the current Coram Experimental Forest. Most homesteaders tried to make a living from timber harvest, agriculture, or mining. Timber was the most abundant natural resource in the area. At first, trees were cut for the railroad or for the government after the Flathead Forest Reserve was set aside by President Cleveland in 1897. There were few minerals found in this area, which discouraged anyone except the most ardent prospectors.

The turn-of-the-century brought a burst of growth and settlement in northwest Montana. The first ranger stations were built at Coram and Spotted Bear shortly before establishment of the Forest Service in 1907. In 1910, President Taft signed legislation creating Glacier National Park. After settlement, fire affected the health and diversity of ecosystems and the lives and property of the settlers. Catastrophic fires, similar to the 1929 Half Moon fire, swept through the northwest after the turn-of-the-century greatly influencing the settlement pattern in the area (Gisborne 1929).

Human Impact

Northern Rocky Mountain ecosystems, similar to those surrounding the Coram Experimental Forest, have historically fulfilled human social and economic needs.

Hungry Horse Dam and Reservoir

The proximity of the Hungry Horse Dam and Reservoir have affected the microclimate, especially on the nearby low-lying areas of the experimental forest. The Bureau of Reclamation began construction of the dam in 1948 on the South Fork of the Flathead River, 13 km above its confluence with the main Flathead River. The dam is less than 1.6 km from the southwest corner of the Coram Experimental Forest and has a drainage basin of over 404,686 ha. The 55 km long reservoir (State Engineer's Office 1965) covers 9,105 ha, and impounds approximately 4.5 billion m^3 of water.

After the Hungry Horse Dam was finished in 1953, the Flathead National Forest assumed the Bureau of Reclamation administrative site at Hungry Horse. The administration building became headquarters for the Coram Ranger District which is now the Hungry Horse Ranger District. The Rocky Mountain Research Station still uses 2 houses at this site for personnel working on the Coram Experimental Forest.

Air Pollution

In 1955, the Anaconda Company began operating an aluminum reduction plant in Columbia Falls, Montana, 13 km west of the Coram Experimental Forest. In 1957, fluoride damage to trees and other vegetation was reported (Carlson and Dewey 1971). The aluminum plant increased in size twice during the 1960s, and the area of fluoride damage expanded. Emissions from the plant were often visible over the Experimental Forest.

The Forest Service studied damage to vegetation and insects in 1969 and 1970. Average fluoride accumulations in western larch and western white pine ranged from 10 to 25 parts ppm at Coram; there was little foliar injury identified. Emission control equipment was installed at the plant and fluoride accumulation in vegetation decreased.

Introduced Plants

Several introduced plants are found on the Coram Experimental Forest. The most common, and of greatest concern, is *Centaurea maculosa* (spotted knapweed). This noxious weed is found on disturbed areas, particularly along roads throughout the forest. Other weeds of concern are *Cirsium arvense* (Canada thistle), *Hypericum perforatum* (goat weed or St. John's-wort), *Potentilla recta* (sulfur cinquefoil), and *Hieracium* sp. (hawkweed). In an attempt to control noxious weeds that were rapidly increasing on road rights-of-way within Flathead County, the Weed Control Department sprayed an herbicide twice in the mid-to-late 1960s. The low level of spraying within the experimental forest and surrounding forest ecosystem caused little, if any change in plant communities.

Gathering and Hunting

Huckleberry products have become a substantial local industry. Bushes grow in many areas of the Coram Experimental Forest. The berries are picked during late July and August for personal use and to sell. *Rubus idaeus* (red raspberry), *Amelanchier alnifolia* (serviceberry), *Rubus parviflorus* (thimbleberry), and mushrooms are picked in lesser quantities. Deer, elk, black bear, moose, and grouse are hunted at Coram and supplement the dietary needs of many local families. Fur bearers are still occasionally trapped for their pelts.

Recreation

Visitors to Coram enjoy dispersed recreation opportunities during all seasons; however to protect study plots and reduce excessive impacts on the area, camping is not allowed and there are no rest room facilities. Roads and trails are open for hiking, horseback riding, mountain biking, and cross country skiing. Because of potential adverse impact on study areas, all terrain vehicles are restricted to ungated roads on the experimental forest. Desert Mountain and Belton Point, former fire observation locations, are accessible by car in the summer and by snowmobile on the groomed Desert Mountain trail in the winter. These sites offer spectacular views into Glacier National Park, the Flathead valley, Swan Mountain range, and Great Bear Wilderness.

Electronic Site

In 1978, an underground electric cable was buried along the Desert Mountain Road 497 through the Coram Experimental Forest to electronic sites near Desert Mountain. Government and private microwave relay and television equipment is located on the high ridge between Desert Mountain and Belton Point. Buildings and equipment were built on sites previously occupied by white bark pine and subalpine fir. Expansion of these facilities on the experimental forest is discouraged because of the adverse impact to this sensitive site and the decreased visual quality of the area as viewed from the valley.

Establishment of Coram Experimental Forest

In 1932, the "Recommendations and Forester's Order for Establishing the Coram Experimental Forest" was signed by acting Regional Forester M. H. Wolff. According to this report, the Coram area contained approximately 2,966 ha located within Townships 30 and 31 North, and Ranges 18 and 19 West, Montana Principal Meridian, on the Coram Ranger District, Flathead National Forest. Foresters who reviewed the plans in 1932 felt Coram was adapted to management and protection as an experimental forest. Named for early-day Kalispell timberman William Coram, the town of Coram was the nearest settlement to the proposed experimental forest. So the Coram Experimental Forest received this name for easy identification.

The Coram Ranger Station was the district ranger headquarters with a mess hall and sleeping facilities, which were used by researchers who worked on the nearby experimental forest. Early officials wanted to minimize travel difficulty to and from field facilities, so they were usually located near railroads. The west boundary of the proposed experimental forest was only 0.8 km from the Ranger Station and 3.2 km from the Great Northern Railway and the nearest highway (U.S. 2). A wood road, passable by car, entered the northwest part of the site for a short distance. There was a network of 7 or 8 trails, about 48 km in combined length, which made the area accessible by foot travel (figure 10).

Site evaluation suggested that small amounts of timber could be sold almost anytime to portable mill operators. Larger amounts were available to other markets by using the railroad. Because most of the merchantable timber was western larch and Douglas-fir, foresters felt they could be harvested and sold for railroad ties. Foresters concluded that Coram was an area that would not interfere with logging opportunities in adjacent areas. Other valuable resources at Coram were grazing, minerals, water storage, and hunting.

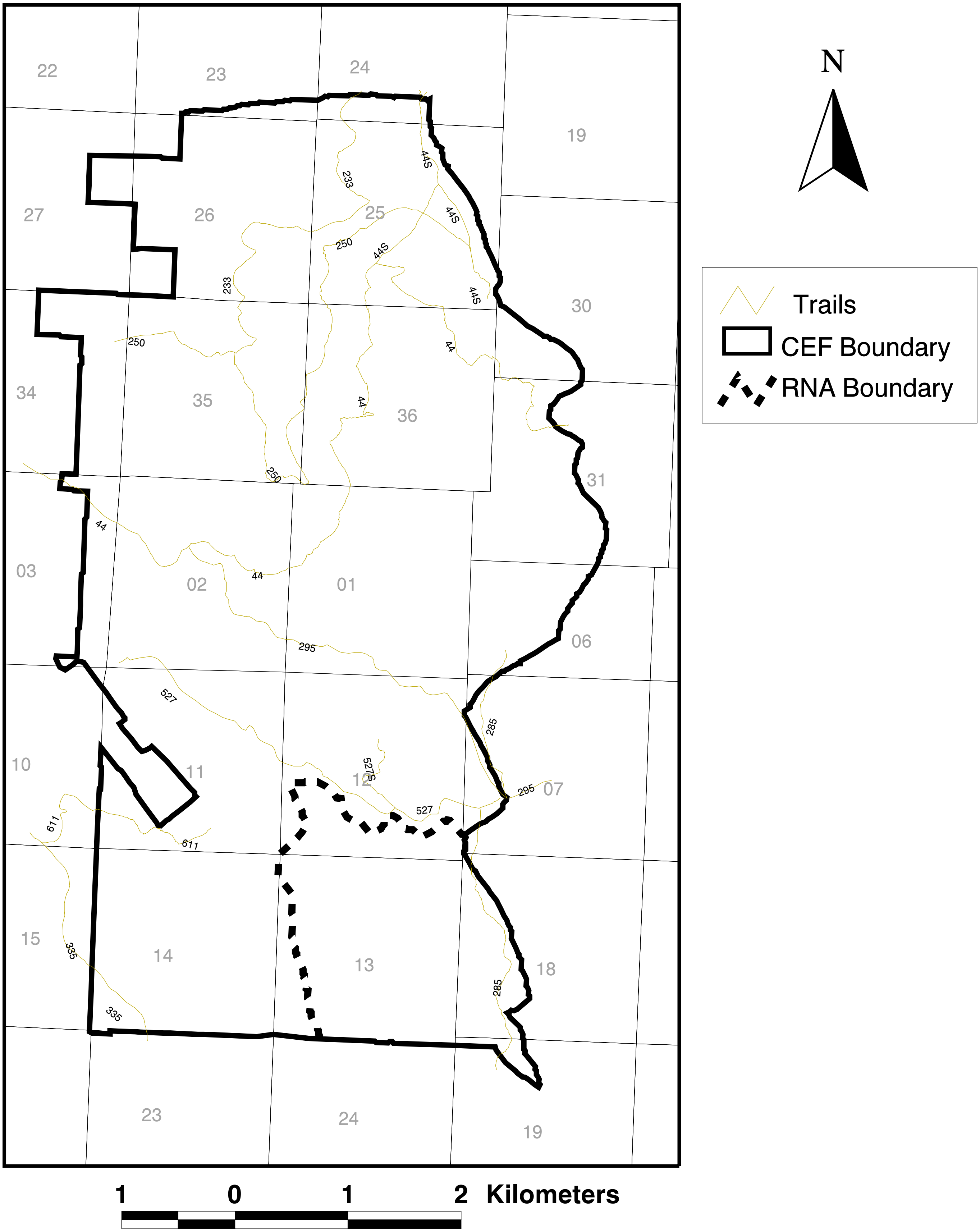

Figure 10. Geographic Information System map showing approximate location of trails on the Coram Experimental Forest in 1934.

The experimental forest boundary follows divides on the east and north sides, and legal subdivision lines on the west and south. The eastern ridgeline, which ranges in elevation from 1,942 m at Desert Mountain near the northeast corner to 1,372 m on the southeast corner, forms the entire east boundary. From Desert Mountain, the highest and most prominent feature of Coram's landscape, a high spur extends to the southwest, then to the south for 2.5 miles (4 km). Abbot Basin, which is the site of considerable research, lies between these 2 ridgelines. The lowest elevation within the landscape is 1,036 m. All land inside the boundary is public except for 23 ha of homestead in the west half of Section 11, T30N, R19W.

The experimental forest is representative of the larch/Douglas-fir forest cover type (Society of American Foresters 1954), renamed the western larch forest cover type (Shearer 1980b), and it has a reasonable diversity of sites, aspects, age classes, and composition. There are old growth larch stands of 300 y-old trees; with a few that exceed 500 y in age that are survivors of a major fire that occurred about the time Columbus discovered America.

The 1932 Timber Report noted that "the old larch of this locality is said to be quite shaky and to have caused considerable cull deduction in former timber sales on the tract." In addition, "although the area contains ample acreage in merchantable timber, there is an absence of young stands between 40 and 160 years. This means a lack of the age class which in the future will represent rotation age."

Absence of significant wildfire from 1770 to 1890 precluded establishment of young stands. An 1890 wildfire and a partial harvest cutting in the early 1900s along the northwestern edge of the Coram area created some young age classes. The cutting contained 414 ha. At the time, it was felt that these timber sale areas furnished excellent conditions to study regeneration within reserved stands. Older cuttings on adjacent private land were also available for research.

Conditions

Forest cover types (species named, predominate in the stands) by area at Coram included:

western larch/Douglas-fir	2,080 ha
Douglas-fir	715 ha
Engelmann spruce	101 ha
lodgepole pine	62 ha
western white pine	8 ha

The major type ranged from almost pure larch to mixtures containing western larch, Douglas-fir, and other species.

Age classes included:

41 to 60 y	158 ha
121 to 140 y	13 ha
161 to 200 y	1,684 ha
200+ y	1,111 ha

The 414 ha area of residual stands left after selective harvest in 1916 was included in the older age class. In 1932, there was an estimated total of 406,173 m^3 of merchantable timber on the site.

Coram Research Natural Area

Charles A. Wellner included most of the southeast quarter of the Coram Experimental Forest as the Coram Natural Area in his 1937 Establishment Report. There, virgin conditions would be maintained to provide baseline information and monitor long-term changes within this old growth forest (figure 11). Later, the area was designated as the Coram Research Natural Area.

In the Establishment Report, Wellner listed 3 points justifying creation of the Coram Natural Area that remain valid today:

1. To provide an area of undisturbed old growth forest for comparison with manipulated tracts on the experimental forest.
2. To maintain undisturbed old growth forests of western larch and Douglas-fir for continued study of ecological processes.
3. To preserve a sample of virgin forests of western larch and Douglas-fir types for educational purposes.

Regional Forester Evan Kelley felt the designation should be handled within the Region. Although the designation request was not sent to Washington, DC. for review and approval by the Chief, the Coram Research Natural Area was included in the Directory of Research Natural Areas established on federal lands (Federal Committee on Natural Areas 1968) and was protected, managed, and regarded as an approved research natural area to be used by scientists for research and for educational purposes. Fifty years later, Charles A. Wellner, as a volunteer after retirement, updated the report and submitted it for approval. The Designation Order was signed June 9, 1988, by Acting Forest Service Chief George M. Leonard.

Figure 11. Micrometeorological station located on Emery Ridge, the east boundary of Coram Research Natural Area, 1994. (Photo by Ray Shearer)

The Coram Research Natural Area is located at the lower elevations of mountainous country where the slopes are gentle to moderately steep. This area is drained by generally west flowing, intermittent streams; most are in shallow drainages that flow into the South Fork of Abbot Creek (State Engineer's Office 1965).

Principal features of the Coram Research Natural Area are representative stands of old growth western larch (figure 12) and Douglas-fir, which are valuable forest types in the inland northwest. Although the 340 ha natural area is commercial forest land, it is excluded from cutting of any kind. In addition, prescribed burning is not used to enhance ecological processes in the Coram Research Natural Area. Disturbance by cutting or burning, needed to maintain seral species in the area, is practiced on the rest of the experimental forest. The research natural area remains an undisturbed old growth forest where succession is developing toward climax species (Habeck 1988).

Wildfire that originates in, or threatens the Coram Research Natural Area is suppressed as soon as practical by methods that will cause the least disturbance within the area. No control of insects or diseases is undertaken unless nearby forests are endangered.

Recreation use is minimal except for occasional hunting activity. Although no threatened or endangered plant species are known to occur in the Coram Research Natural Area, the area is within gray wolf and grizzly bear range.

Figure 12. The Coram Research Natural Area is a good place to study processes in an old growth forest of western larch. (Photo by Steve Wirt)

The Coram Research Natural Area is preserved as a passport in time where scientists can learn in the same environment as the early pioneers of wildland research.

Coram Biosphere Reserve

In 1976, the Coram Experimental Forest (figure 13) and Glacier National Park were designated biosphere reserves by the United Nations Educational, Scientific, and Cultural Organization. Waterton Lakes National Park followed with designation in 1979. This trio forms the Crown of the Continent Biosphere Reserves.

These biosphere reserves protect and conserve examples of the world's subalpine and alpine ecosystems, provide for scientific research and education, and monitor for sustainable development. This network of protected samples of the world's major ecosystem types is devoted to the conservation of nature and enhancement of scientific research for the benefit of all people (U.S. Man and the Biosphere 1990). They provide a standard against which human impact on his environment can be measured.

The United States Man and the Biosphere Program (Condo 1995) promote ecosystem-based management principles on Biosphere Reserves designated in this country. The program incorporates ecosystem protection with sustainable human use and development, documents global change and biological diversity, and participates in regional cooperation for resolving complex issues.

Figure 13. Dedication of Coram Experimental Forest as a biosphere reserve, August 8, 1980. John Emerson, Supervisor, Flathead National Forest; Roger Bay, Director, Intermountain Forest and Range Experiment Station; Jim Corson, representative of United States Man and the Biosphere Program; and Jim Thompson, Deputy Regional Director, National Park Service. (Photo by Ray Shearer)

The ideal biosphere reserve includes areas locally managed for economic development with respect to conservation of the protected areas (U.S. Man and the Biosphere 1990). These managed areas can be used for education, research, forestry, agriculture, and recreation. Cooperation between the biosphere reserves enhances the use of research results on the ecology and management of western larch forests at Coram which are shared world-wide, especially with biosphere reserves containing other larch species.

Glacier and Waterton are undisturbed biosphere reserves which are large protected natural areas used for ecosystem conservation, public education, and baseline monitoring. Coram, a manipulated biosphere reserve, is a field research site managed to understand the effects of alternative forest management practices, especially within western larch forests (Lusk and others 1995). Personnel at Coram, Glacier, and Waterton work cooperatively to fulfill areas of mutual interest meeting important and compatible needs (Shearer 1989; Lusk and others 1995). Collaboration will continue to strengthen bonds between the Forest Service and National Park Service and to promote ecosystem management with sustainable development on a larger scale. The Man and Biosphere Program encouraged and publicized a science conference and community activity that highlighted 50 y of research on the Coram Experimental Forest (Anonymous 1996).

Administrative Actions

Timber Surveys

Two projects at Coram provided basic information about the land and its tree overstory. From the combined data, the experimental forest was divided into 4 compartments and 13 subcompartments for management purposes (figure 14).

The first general timber reconnaissance was completed in 1916 of the area within the South Fork of the Flathead River drainage including the south two-thirds of what is now the Coram Experimental Forest (Roe 1952a). Volume estimates and a cover map showed forest types, area, and limits of merchantable timber information used for establishment of the experimental forest, and as background for early studies.

In 1934, the northern one-third of the experimental forest, not included in the 1916 survey, were cruised to determine timber type, volume, and age class. An experienced crew of 6 men accomplished the field work from August 27 through November 2, 1934. The written report was signed April 15, 1935, by George M. Fisher (Chief of Party) and Hans C. Roffler (Assistant to Technician). This report is a narrative of observations made by the foresters about the existing timber types (figure 15) and the condition of the timber and

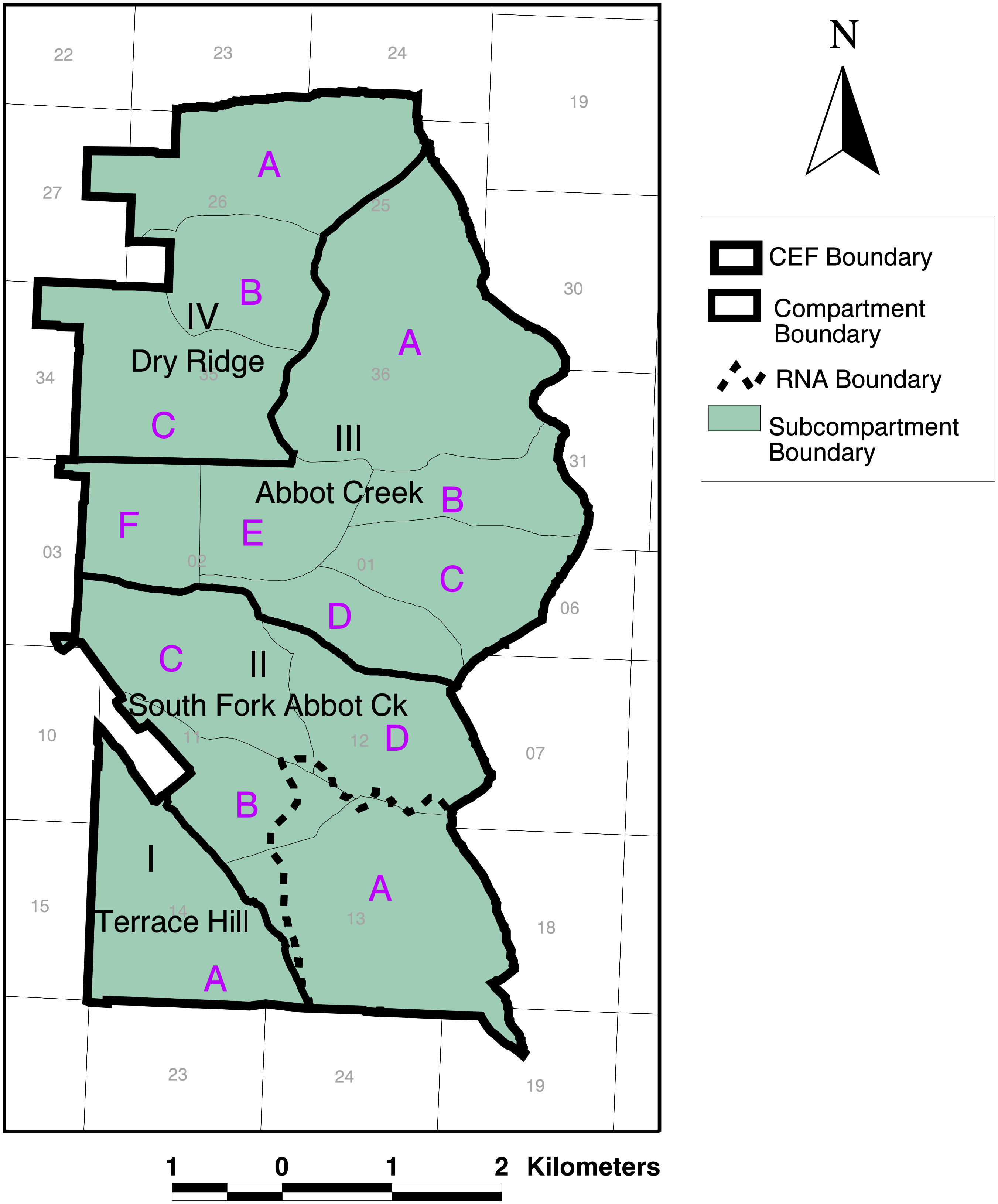

Figure 14. Geographic Information System generated map made in 1998 of compartments and subcompartments identified during the 1934 survey of the Coram Experimental Forest.

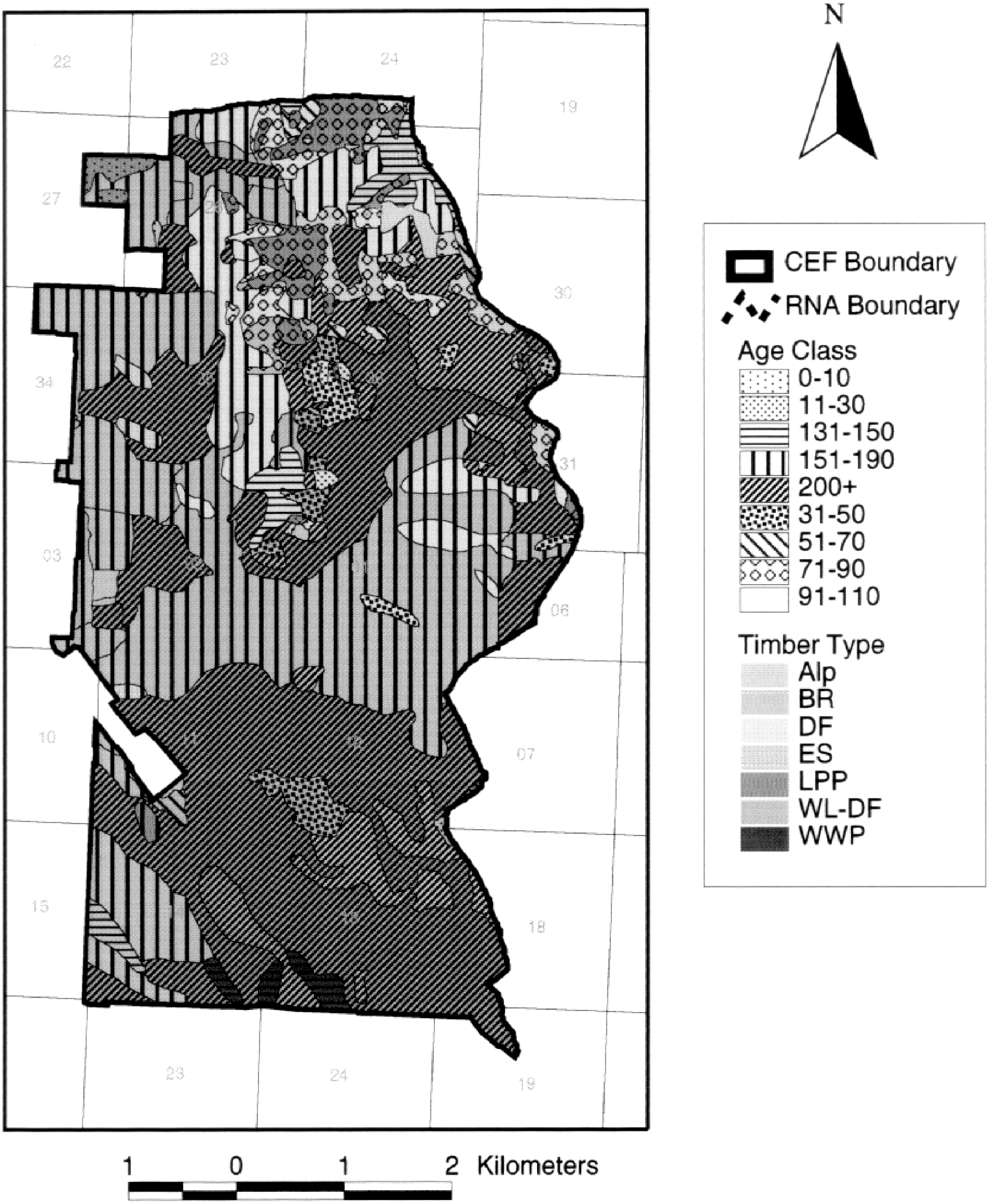

Figure 15. Geographic Information System generated map made in 1998 of age classes and timber types identified on the Coram Experimental Forest from data collected in 1934.

other resources at Coram. Their observations are a "snapshot in time" of existing conditions on the newly created Coram Experimental Forest (Appendix D).

Civilian Conservation Corps

The first Civilian Conservation Corps camp on the Flathead National Forest was established in 1933 near the present main entrance to the Coram Experimental Forest (figure 16) off the South Fork Road (Forest Road 38). Coram District Ranger Tom Wildes was the first camp superintendent. This camp, like all others in the Flathead, had a consignment of 200 men in addition to the administrative force.

Crews were often sent to spike camps where they constructed buildings, water systems, fences, telephone lines, and performed trail maintenance. After receiving training, these crews were also dependable and efficient at fighting forest fires. One of their first summer accomplishments was to locate and build a 19 km road to Desert Mountain Lookout (Forest Road 497). In 1935, the Coram Civilian Conservation Corps camp was moved to Elk Park where crew members built the first road on the west side of the South Fork of the Flathead River, the Spotted Bear landing field, and many other projects.

Timber for the War Effort (1942 to 1946)

World War II brought an increased need for wood products, coupled with a severe manpower shortage. After consultation between personnel at the Northern Rocky Mountain Forest and Range Experiment Station, Region-1, and the Flathead National Forest, a timber sale on the South Fork of Abbot Creek on the Coram Experimental Forest was approved. The purpose of this sale was to help sustain year-long logging operations and maintain a supply of wood products from the Flathead National Forest that was needed during the war.

About 560 ha were cutover from 1942 to 1946, leaving about 12 seed trees per ha composed mostly of 51 to 61 cm western larch, or 36 to 46 cm windfirm spruce. Douglas-fir were left to obtain uniform distribution of seed trees. In 1951, the volume of residual trees 30 cm and larger was 59 m^3 per ha (Roe 1952b).

Transportation System

Before establishment of the experimental forest, the South Fork Road (Road 38) that diagonally crosses its southwest quarter was constructed (figure 17). When research began at Coram, the experimental forest had a "relatively poor road system" which had "grown haphazardly by stages" (Roe 1952a). A few temporary roads permitted removal of logs in 1916

Figure 16. From 1933 to 1935, the Coram Civilian Conservation Corps was located on the western edge of the Coram Experimental Forest: (a) entrance (b) housing. (Photographer unknown)

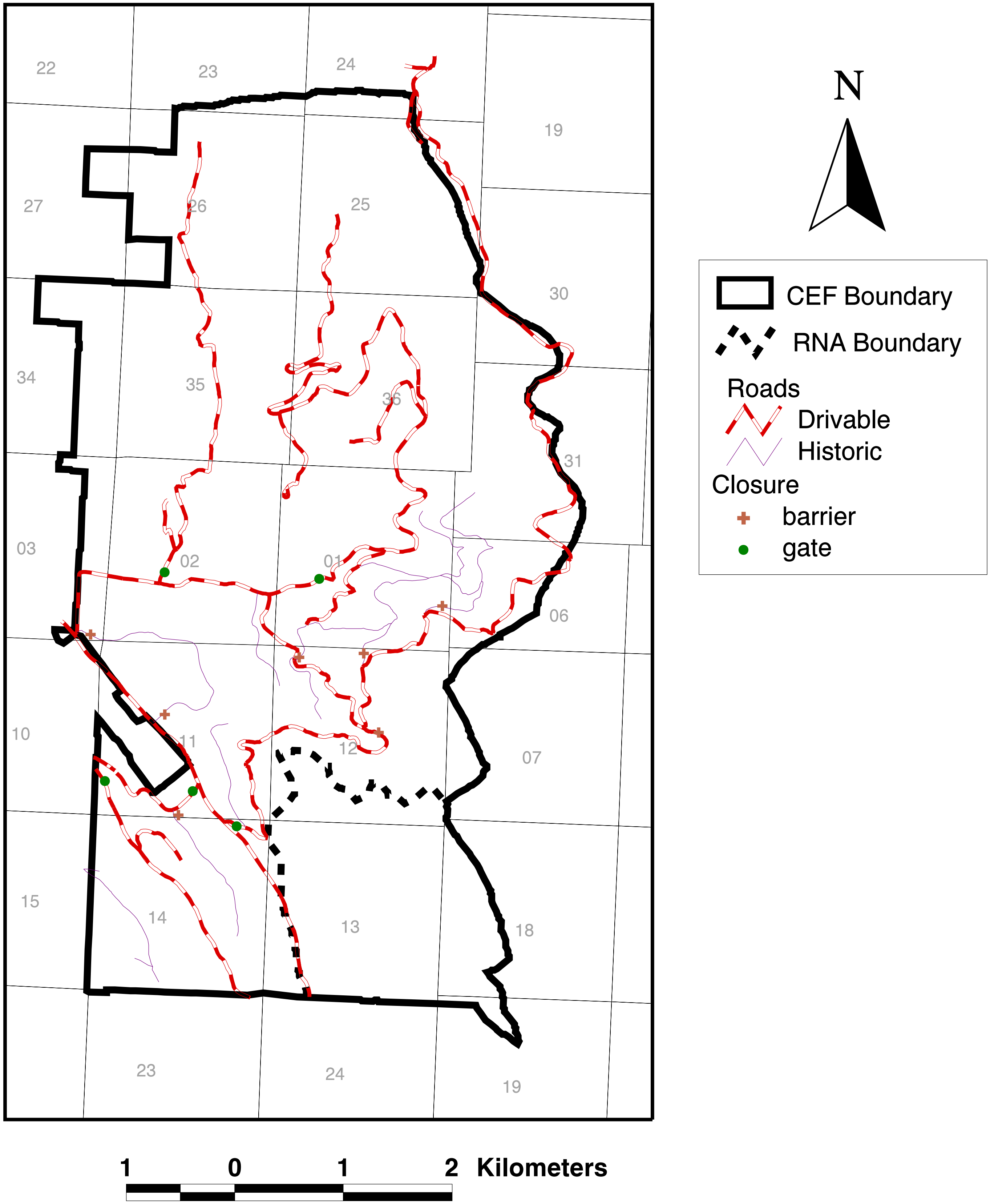

Figure 17. Geographic Information System generated map of roads on the Coram Experimental Forest.

and 1928. After extensive field work in 1935, a preliminary system road-plan was proposed. Between 1934 and 1938, the Desert Mountain Road (Road 497) was built using Civilian Conservation Corps labor.

Later, sections of Roads 38 and 497 were relocated for better alignment and to permit passage of loaded logging trucks. Temporary roads used to remove logs and rough-sawn lumber from 1942 through 1946 were built by timber purchasers. Portions of these roads were later reconstructed and incorporated into the road system. Beginning in 1950, system roads were built by timber purchasers for harvest cutting studies. A summary of these roads by year of construction, length, funding source, and location is shown in table 2.

Withdrawal From Mineral Entry

In 1959, the Coram Experimental Forest was withdrawn from all forms of appropriation under the public land laws, including mineral development. The withdrawal included 3,268 ha on the experimental forest and adjacent national forest land within common land-survey units. The withdrawal specifically prohibited removal of rock or gravel for road construction and surfacing. A request for Coram's continued withdrawal, together with a withdrawal review and mineral report, was submitted to the Bureau of Land Management in 1991 through the Northern Region.

Coram was not excluded from the mineral leasing laws or the act of July 31, 1947 (61 STAT. 681; 30 U.S.C. 601-604), as amended. Although the experimental forest is available for leasing under the mineral leasing act, strict stipulations apply to ensure the protection of research activities.

Partnerships

The Rocky Mountain Research Station is responsible for research and administration of the Coram Experimental Forest. The Flathead National Forest provides close support for studies and monitoring by contributing timber sale administration, road maintenance, law enforcement, fire protection, and other services that promote research. Outstanding cooperation from personnel on the Hungry Horse (formerly Coram) Ranger District enabled accomplishment of research objectives for over 50 years.

A Memorandum of Understanding, detailing responsibilities for administering Coram, was initiated in 1962 and signed by Project Leader Arthur L. Roe for the Intermountain Forest and Range Experiment Station and by Forest Supervisor Fred J. Neitzling for the Flathead National Forest. This Memorandum of Understanding is reviewed at annual planning meetings and revised as needed.

Partnerships with other agencies, educational institutions, local communities, and volunteers enhanced the success of research at Coram. Agreements with these groups expands the scope of research possible and broadens educational opportunities. For example, Glacier National Park uses Coram for manipulative

Table 2. Roads constructed on the Coram Experimental Forest from 1950 to 1999 as designated by the Flathead National Forest.

Road	Year	Length, km	Funding source	Description—beginning and ending points
590A	1962	4.83	Acc. Publ. Works	Road 497, Sec. 2 through 35 to 26
590B	1950	1.61	Timber purchaser	Road 497, Sec. 2 to Sec. 1
590B	1952	0.80	Timber purchaser	NE+ sec. 1
590B	1954	3.38	Timber purchaser	NE+ Sec. 1 to SW+ Sec. 36
590B	1962	0.80	Appropriation	SW + Sec. 36 to SE+ Sec. 35
590B	1973	3.22	Research	Sec. 35 through Sec. 36 to SE+ Sec. 25
590C	1952	2.74	Timber purchaser	Between 590B and 497, Sec. 1 and Sec. 6
590C3	1952	0.97	Timber purchaser	Road 497, Sec. 6 through Sec. 31
590D	1960	2.09	Timber purchaser	Road 497, Sec. 3 to Road 38 in Sec. 11
590E	1960	3.38	Timber purchaser	Road 38, Sec. 14, 11, to Road 497, Sec. 12
590F	1951	1.93	Timber purchaser	Road 497, Sec. 1 to Road 497, Sec. 12
590G	1963	4.83	Acc. Publ. Works	Road 38, Sec. 11 thru Sec. 14 to Road 5301
590J	1960	0.97	Timber purchaser	Road 497, SE+ Sec. 2, to Sec. 11, 12
590K	1960	0.80	Timber purchaser	Road 497, within NW+ Sec. 12
11073	1973	1.29	Timber purchaser	Road 590B within S+ Sec. 36
11074	1965	0.97	Timber purchaser	Road 590B within Sec. 35, 36, 1 (Vista)
11075	1952	1.13	Timber purchaser	Road 590C, Sec. 1 through Sec. 6, 1, 31
11076	1952	1.45	Timber purchaser	Road 590C, Sec. 6 through Sec. 31, 1, 31
11077	1963	0.80	Acc. Publ. Works	Road 590C, Sec. 1 to Road 590F, Sec. 1
11078	1963	0.97	Acc. Publ. Works	Road 590C, Sec. 1 to Road 590F, Sec. 1

research that cannot be conducted inside park boundaries because of different administrative guidelines.

Partners involved in research at Coram include:

- British Columbia Ministry of Forests, Research Branch, Victoria
- Clemson, University, Clemson, South Carolina
- Glacier National Park, Montana
- Michigan Technical University, Houghton
- Montana State University, Bozeman
- The University of Montana, Missoula
- Universitat Münster, Germany
- University of Minnesota, Minneapolis
- University of Wisconsin, Madison
- Washington State University, Pullman
- FORINTEK, Vancouver, British Columbia

Partnerships incorporate data from Coram into ecosystem-based management of national forests, other forest lands, nearby national parks, and science curricula for schools. Inclusion in the Man and the Biosphere Program encourages national and international cooperation that has become an integral part of Coram's partnerships.

Chronology Of Research

Although the Coram Experimental Forest was established in 1933, lack of personnel and facilities precluded initiation of research through 1945. With the end of World War II, research money and personnel became available. By 1947, Arthur L. Roe and Kenneth N. Boe were assigned to conduct research in the western larch/Douglas-fir forests; Anthony E. Squillace joined the project in 1948. Boe was assigned responsibility for administration of the Experimental Forest from 1954 to 1956. Raymond C. Shearer replaced Boe in 1957 and was manager of Coram from 1957 to 1968 and 1975 to 1996. Wyman C. Schmidt was manager from 1968 to 1975. Jack A. Schmidt became manager in 1996 (figure 18). From 1954 to 1997 the experimental forest was included in 2 station mergers and is now within the Rocky Mountain Research Station.

The Coram Experimental Forest's wide range of ecological sites and forest stand conditions has served as the focus for western larch research for 50 y. Continued research will build on a history rich in discovery.

The 1940s: Beginning a Research Program

The late 1940s marked the beginning of research at Coram. Early studies focused on the influence of even-aged harvest methods, a wide range of site preparation treatments, and conifer seed dispersal for

Figure 18. Past managers of the Coram Experimental Forest from left to right: Jack A. Schmidt, Raymond C. Shearer, Wyman C. Schmidt, and Arthur L. Roe, May 1998. (Photo by Steve Wirt)

natural regeneration of conifers, and recovery of other forest vegetation.

In 1947, the Coram Experimental Forest was included as 1 of 21 larch/Douglas-fir stands sampled in western Montana to determine growth response of reserved trees in relation to intensity of cutting. Several 0.08 ha temporary plots were installed within a 414 ha) area in the northwest quarter that had been partially cut in 1916. Growth tables for residual larch and Douglas-fir were published from this data (Roe 1951). Roe recommended that mature and overmature larch/Douglas-fir stands were best managed by even-aged management methods such as shelterwood, seed tree cutting, or clearcutting. Data from this study provided information to publish a classification of tree vigor for western larch and Douglas-fir necessary for accurate tree ranking (Roe 1948a). Trees of highest vigor grew nearly 1.5 times more in volume than those in the moderate vigor group. Poor vigor trees grew about 0.5 times less in volume than those in the moderate vigor group.

Slow growth of mature larch trees results from old age and from competition for light and soil water reserves and understory vegetation competing for soil and water (Roe 1956). Roe (1950) determined that the maximum growth of reserved trees occurred in open stands with the least amount of competition. Results from this study indicated that advance regeneration should be eliminated and open conditions were needed to establish and enhance early growth of western larch (Roe 1948b). At Coram, bare mineral soil was superior for larch regeneration than the natural forest floor (Polk and Boe 1951). However, site preparation during the normal logging operation was insufficient for adequate larch regeneration (Polk 1949). Data from Coram helped Roe and Benson (1966) develop a procedure for evaluating the diameter growth of young stands in relation to potential growth. Applications included determining relative growth performance of trees and stands, confirming the need for thinning and priority setting among stands, and determining the growth impact of disease and other growth depressing agents.

The objective of the first research studies at Coram was to determine the influence of site preparation on natural regeneration of western larch and associated conifer species within areas harvested during World War II. Three studies began in 1949 on sites harvested during World War II.

1949 to 1955: Natural Regeneration Study

Limited natural regeneration occurred following a 560 ha harvest cutting made during World War II. Within these stands, 12 dominant seed trees per ha were retained (Fredeking 1953). Most conifer regeneration established where the ground surface was disturbed by logging activity on skid trails and landings, not in the large areas between them. It was apparent that some form of seedbed preparation was needed, particularly for the shade-intolerant western larch.

In 1949, a twice replicated experiment was installed on north-facing and south-facing slopes on sites harvested in 1943. The experiment compared natural regeneration on seedbeds prepared by prescribed burning, bulldozer scarification, slashing small trees and tall shrubs, hand piling and burning slash, and a control (Roe 1952a). Results showed mineral soil exposed by fire or scarification favored establishment of larch and other more shade tolerant conifers (Roe 1955a; Schmidt and others 1976) (figure 19).

Figure 19. Scarification by bulldozer in 1949 was a site preparation method tested to enhance germination and establishment of conifers on the Coram Experimental Forest. (Photo by Art Roe)

1949 to 1955: Seed Dispersal Study

Concurrent with the natural regeneration study, dispersal of conifer seeds from seed trees onto the plots was documented starting in 1949. Seedfall was estimated from contents of 1.8 m^2 seed traps. Seed dispersal for larch was ranked as good in 1952 and 1954, fair in 1949, and poor in 1950, 1951, 1953, and 1955 (Roe 1955b). The good seed crop of 1952 dispersed nearly 985,000 per ha, an average of about 22,000 seeds per tree.

1949 to 1969: Terrace Hill Natural Regeneration Study

A portion of Terrace Hill, located in the southwest corner of the Coram Experimental Forest, was harvested in 1943. Approximately 12 larch seed trees were left per ha. Mineral soil was exposed by harvest activities and by burning piled slash in 1944. In 1945, 6 ha of this area were designated for study, 3 ha of understory trees and shrubs were slashed and the other 3 ha were untreated. Natural regeneration increased dramatically when vegetation was removed, demonstrating that seedbed, light, and competition are important factors in conifer seedling establishment (Roe 1952a; Schmidt 1969; Cole and Schmidt 1986). Regeneration of all conifer species benefited from the exposure of mineral soil, but larch more than other species. Larch stocking correlated positively with the amount of sunlight that reached the ground (figure 20).

The 1950s: Building Blocks for the Future

During the 1950s conditions that would be used in future research were established. Throughout this decade, researchers demonstrated even-aged management practices identified in the 1947 cutover-area study (Roe 1951). The advantages and limitations of even-aged harvest cutting methods were identified. The interaction of site preparation, cone production, and seed dispersal were evaluated in subsequent natural regeneration of western larch and associated species. These cutover areas, and their varied site conditions, provided opportunities for a wide range of future research.

Natural Regeneration Cuttings

Six even-aged harvest cutting methods were established in the Abbot Creek drainage (figure 21). Several site preparation methods were imposed after harvest, either singly or in combination.

Shelterwood, Vigor Shelterwood. A 23 ha unit was placed on a 27% northwest-facing slope (figure 22). About 55% of the stand volume, composed of the most vigorous and dwarf mistletoe-free trees, was retained

Figure 20. In 1945, understory trees were slashed (left half of picture) on Terrace Hill, Coram Experimental Forest, permitting light to reach the ground and increasing survival of western larch natural regeneration. The remainder of the area was untreated and far fewer larch were established. (Photo by Wyman Schmidt)

Figure 21. Regeneration cuttings in Abbot Basin, Coram Experimental Forest; 1951 photograph from Desert Mountain. (Photo by Art Roe)

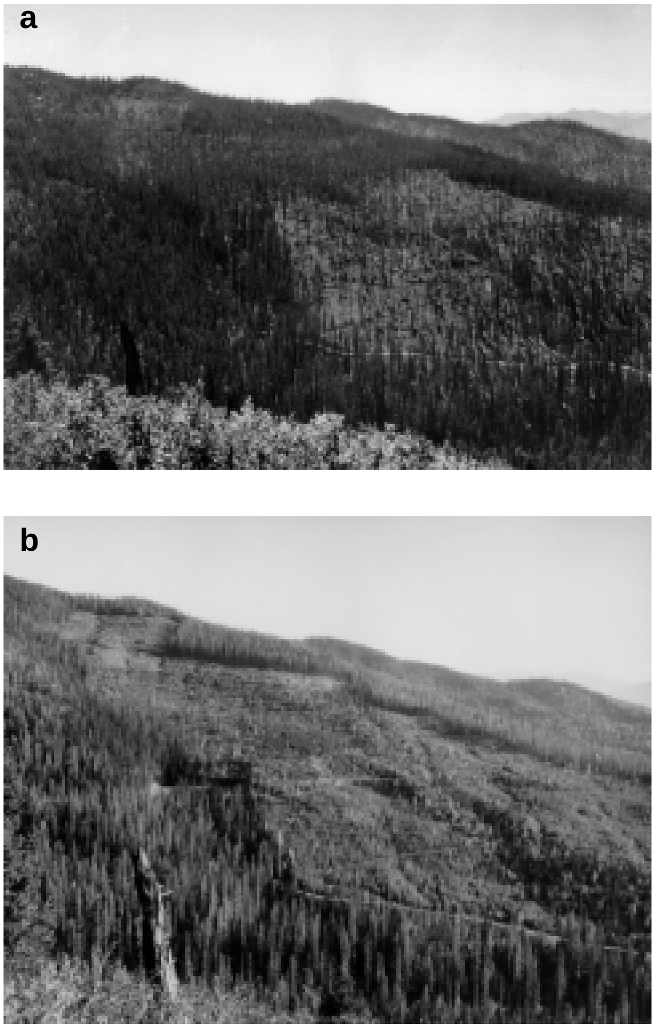

Figure 22. Shelterwood, vigor selection (denser tree cover below upper road); scattered seed tree (open tree cover, center and to the right); and shelterwood, economic selection (above and below lower road) harvested in 1951 on the Coram Experimental Forest; photographed (a) 1954 by Tony Squillace and (b) 1965 by Ray Shearer.

for shelter and seed production (Roe 1955a). Treatments were: harvest (December 1950 to August 1951), bulldozer slash piling and scarification (August 1951), slash piles burned (September 1951), prescribed burning (September 1952). Differences in logging costs between this method and the shelterwood, economic selection and scattered seed trees, were published (Roe and Squillace 1953).

Shelterwood, Economic Selection. A 16 ha unit was placed on a northwest-facing slope that averaged 18% slope (figure 22). About 40% of the stand volume, composed of numerous small and a few large reserve trees, was retained for shelter and as a seed source for natural regeneration (Roe 1955a). Treatments: cut (December 1950 to August 1951), bulldozer slash piling and scarification (August 1951), slash piles burned (September 1951), prescribed burning (September 1952).

Scattered Seed-tree. A 17 ha unit was established on a northwest-facing slope averaging a 25% slope (figure 22). About 11% of the commercial volume was reserved for seed (mostly larch) 10 to 12 dominant, vigorous, well-distributed trees per ha (Roe 1955a). Treatments were: cut (December 1950 to Aug 1951), bulldozer slash piling and scarification (August 1951), slash piles burned (September 1951), prescribed burning (September 1952).

Block Clearcuts. There were three units (6, 12, 24 ha) located on north-facing slopes ranging from 15 to 65% in steepness (figure 23). Merchantable trees that were 25 cm diameter breast height (d.b.h.) and larger, with one 5 m log, were cut from October 1951 to August 1952. In August 1952, all remaining trees were felled or pushed over by bulldozer to eliminate any confounding effect these trees could have on estimating seed dispersal from the uncut timber into the openings. Piles of slash and unmerchantable trees were burned the first 2 weeks of September 1952. However, slash on steep, north-facing slopes on the 12 and 24 ha clearcuts failed to burn because of moist fuels and frost that persisted until afternoon.

Strip Clearcuts. There were 8 alternate 61 and 101 m wide clearcut strips separated by alternate uncut strips of the same width that were oriented at right angles to the contours on northwest facing slopes (figure 24). This orientation reduced the prevailing wind that caused windthrow and minimized the

Figure 23. Square clearcuts of 6, 12, and 24 ha were made in 1952 on the Coram Experimental Forest to measure the timing, amount, and dispersal distances of conifer seed within the openings. This picture of the 24 ha clearcut was taken in the summer of 1952. Unmerchantable trees were also cut and the site prepared. (Photo by Art Roe)

Figure 24. Seven strip clearcuts 60 and 101 m wide were installed in 1953 to compare with block clearcuts for regeneration efficiency and damage to bordering trees on the Coram Experimental Forest. (Photo by Ray Shearer)

length of contour access roads that crossed the narrow width of these cuttings. The strips varied in length from 194 to 814 m (table 3) depending on topography. Three cut strips were in 1 sub-drainage and 5 in another.

From December 1952 through April 1953, trees that were 20 cm d.b.h. and larger with one 5 m log, were cut. Logs were yarded (moved from the stump to a landing) by bulldozer. On slopes up to 40%, logging slash and defective trees were piled in the center of the strips by bulldozer equipped with a brush blade. Where possible, slash was piled near the top and bottom of steeper pitches. Areas with light scattered slash or vigorous young trees were not treated. Younger understory trees, mostly Douglas-fir, spruce, and subalpine fir, were retained to study their subsequent growth. Slash was burned in early November 1953.

Group Seed-tree. The method of retaining seed trees in groups, rather than scattering them within a 51 ha harvest area, was tested to determine if windthrow and wind breakage was reduced and if removal of seed trees was simplified. This was the last of the initial 6 even-aged harvest cutting methods tested in the Abbot Creek drainage.

Table 3. Strip clearcuts harvested in 1953 on the Coram Experimental Forest.

Strip	Area	Width	Length	Elevation	Slope
	ha	- - - - - - - - - - -	*m* - - - - - - - - - - - -		*%*
1	4.8	61	792	1265-1494	15-45
2	6.3	101	623	1311-1478	15-40
3	1.5	61	245	1442-1469	05-15
4	1.4	61	226	1173-1210	20-25
5	4.4	101	434	1183-1326	25-75
6	3.8	61	631	1265-1390	25-90
7	8.2	101	814	1268-1463	35-45
8	1.2	61	194	1436-1521	45-60
Total	31.6				

All trees were harvested from December 1955 through June 1956, except for those reserved in 7 uncut circular groups evenly spaced throughout the area (figure 25). In the area, 3 groups were 0.2 ha and 4 groups were 0.1 ha. Slopes faced 180° to 360° and ranged in steepness from 5 to 70%. Most logs were yarded by jammer (winch with a wooden spar mounted on a vehicle) to the landing, the remainder by bulldozer. On slopes under 40%, bulldozers exposed some mineral soil by scarification while piling slash during August and September 1956.

Slash piles were burned in early October, 1956. Slopes over 40% were prescribed burned from May 5, to 9, 1958; these were the first spring burns on the Coram Experimental Forest. The fire burned through the 0.1 ha group killing all trees except the larch.

Wind Damage

Soon after each harvest cutting, wind uprooted or broke residual old growth trees left next to the openings or as scattered or groups of seed trees. Unusually severe winds on December 17, and 22, 1955, caused a heavy tree loss, especially on upper slopes within the shelterwood and scattered seed-tree cuttings and within uncut timber surrounding block and strip clearcuts. Three years after harvest, nearly a third of the volume within the seed-tree groups was affected by wind, this increased to 40% after 7 years. Most trees within the seed-tree groups that were located on slopes were blown over or broken by wind.

Seed Production and Dispersal

Western larch seed production (figure 26) from 1952 to 1962 at Coram was rated good in 1952 (Boe 1953) and 1954, fair in 1958 and 1962, and poor or failure in the other 7 years. Other conifers also produced good crops in 1952 and 1954, but often varied in relative amounts from western larch in other years. Dispersal of viable conifer seeds occurred mostly in September and October on thermal slope winds with upslope motion (Shearer 1959a,b; McCaughey and others 1986). Because managers need information about potential western larch cone crops, Roe (1966) developed a procedure to forecast crop size several months before cones mature.

Natural Regeneration

Conifers regenerated quickly due to combining of mineral soil exposed by fire or scarification with plenty of seed under favorable conditions for seed germination and seedling establishment (Schmidt and

Figure 25. Circular groups of seed trees of 0.2 and 0.1 ha were left to provide seed within this 51 ha opening after harvest in 1956 on the Coram Experimental Forest. In June 1958, the second year after scarification, *Arnica cordifolia* (heartleaf arnica) flowered profusely. The microclimatic station was equipped with rain gage, hygrothermograph, and maximum and minimum thermometer. (Photo by Ray Shearer)

Figure 26. The effectiveness of seed traps, 0.093 m^2 and 1.022 m^2 were compared to estimate seed dispersal away from groups of seed trees on the Coram Experimental Forest. (Photo by Ray Shearer)

others 1976). Of the 6 harvest cuttings in Abbot Basin, the first 5 received seed from the excellent 1952 and 1954 cone crops or from only the 1954 cone crop. Plenty of seed was carried into the center of openings as large as 24 ha in years of abundant cone production, to regenerate conifers on exposed soil (figure 27).

Only the group seed-tree cutting failed to regenerate successfully after site preparation because too few seeds were dispersed from the reserved seed-tree groups or from the adjacent uncut forest. By 1962, it was evident that the seedbed for regenerating larch was lost. This demonstrated the need to coordinate expected seed crop with site preparation.

Water Infiltration

In 1952, soon after treatments within the shelterwood (economic selection), the rate of water infiltrating

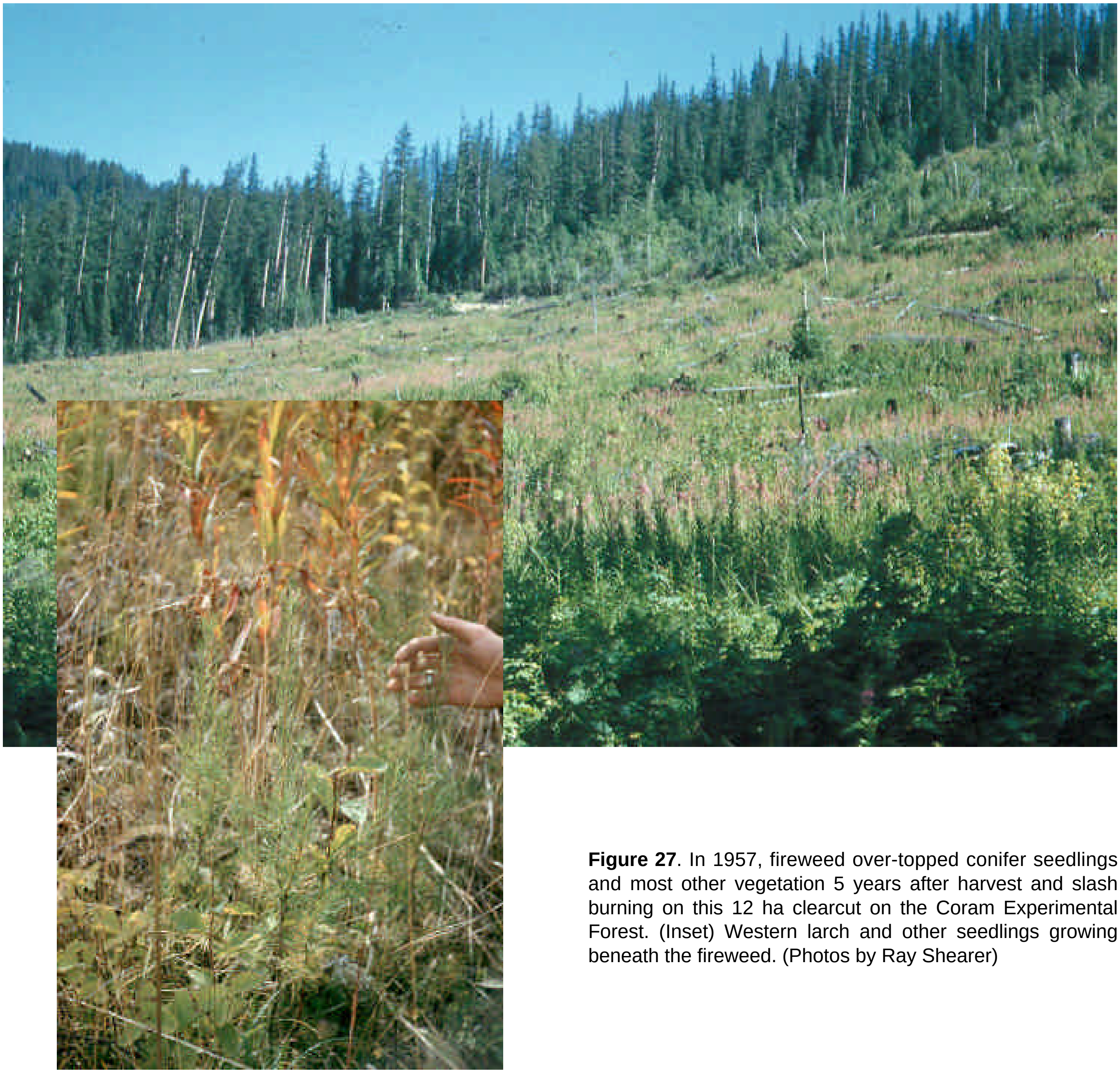

Figure 27. In 1957, fireweed over-topped conifer seedlings and most other vegetation 5 years after harvest and slash burning on this 12 ha clearcut on the Coram Experimental Forest. (Inset) Western larch and other seedlings growing beneath the fireweed. (Photos by Ray Shearer)

into the soil was measured on an undisturbed control, tractor skid roads, bulldozer scarified soil, and on broadcast burned seedbeds. Penetration of water into the soil was 50% slower on mechanically disturbed, and 90% slower on tractor skid road scarified soil than on undisturbed forest floor or broadcast-burned seedbeds (Tackle 1962). Although infiltration improved, some of the differences lasted at least 20 y (Schmidt and others 1976).

In 1953, Coram was included in a nation-wide test of Krilium (a soil conditioner) on skid roads in the shelterwood (economic selection). The conditioner was applied to skid roads that were covered by slash, and to some left uncovered (control), to determine if the chemical reduced sheet erosion caused by rain or snowmelt. After 2 y, Krilium had not caused any profile changes on the skid road plots, and it was judged ineffective in reducing surface runoff on skid roads covered or not covered by slash (Boe 1955).

The 1960s: Young Stand Management and Artificial Regeneration

Using areas treated in the 1950s, research in the 1960s focused on: the influence of spacing young western larch on growth and the interaction with water use, vegetation development, snow damage, insects, and animals; how to artificially regenerate western larch and associated conifers through planting nursery-grown bare root seedlings or by direct seeding.

Thinning Naturally Regenerated Western Larch

Conifers, especially western larch, regenerated profusely on harvest-cutting areas at Coram in the 1950s where mineral soil was exposed by fire or scarification and plenty of seed was dispersed to the site. Thinning was essential to promote tree growth for useful forest products and other forest values on most of the heavily regenerated sites. This typified many harvested stands within the natural range of larch. In 1961, a thinning study of young western larch began in the 9 y-old stands of trees on portions of the 30 12 ha clearcut, seed tree, and economic selection harvest cutting areas.

Objectives of this 40 y study are to identify the effects of thinning on growth, form, and crown characteristics by number of trees per ha (1,680, 890, 494), by number of years (10, 20, or 40) between thinnings, and by shrub competition and developing spacing guides for use in managing young western larch. A total of 28 plots have been established to meet the objectives of this study (figure 28).

Diameter and height growth responded to stand density. The greatest individual tree growth occurred in the least dense stands, but total stand volume was greater on heavily stocked stands (Schmidt 1996, 1978; Schmidt and Seidel 1988) (figure 29).

In 1965, herbicides 2,4-D amine; 2,4,5-T ester; 2,4,5,-T amine; tordon 101; and cacodylic acid were used to determine their effectiveness in thinning western larch and other conifers within the area harvested reserving a vigor shelterwood for seed and shade. Protective oil cloth hoods effectively shielded the leave trees from these chemicals. All chemicals tested effectively killed selected larch seedlings and saplings (figure 30).

Figure 28. In 1961, excess conifer regeneration was thinned to an average spacing of 6.1 m on this plot within the 12 ha clearcut on the Coram Experimental Forest. (Photograph taken in 1970 by Ray Shearer)

Figure 29. After 32 y, larch spaced an average of 6.1 m apart on the 12 ha clearcut had exceptional growth. (Photograph taken in 1993 by Ray Shearer)

Additional research has been undertaken on the larch spacing plots to take advantage of conditions promoted by the design of the study.

Water use. Beginning in 1968, water use within the thinned plots was studied to determine the influence of spacing on amount, rate, and season of water use and recharge of soil profile (figure 31). The site receives about 800 mm of precipitation annually, and soil profiles are usually fully saturated at the beginning of each growing season (Schmidt 1998). Water is often a limiting factor later in the summer. Schmidt (1998) determined that at age 19, 10 y after thinning, plots with 2,200 trees per ha used 92% and 500 trees per ha used 82% of the available water as compared to unthinned stands with 91,000 trees per ha. After 20 y, the differences diminished between the densities as the trees fully occupied the sites (Schmidt 1978).

Phenological observations. Needle and flower buds open from mid to late April depending on average daily temperature; bud opening is delayed by increasing elevation. Seed cone elongation is 90% complete by the end of May (Shearer and Carlson 1993). Larch effectively distributes needle, diameter, and height growth (figure 32) during the growing season (Schmidt 1998). When needle growth starts to decline in mid May, diameter growth begins. Average daily diameter growth peaks in mid to late June, when needle growth ceases and height growth begins. Height growth peaks about mid July and is complete by mid August.

Figure 31. Jack A. Schmidt, forester, Intermountain Forest and Range Experiment Station, records information from neutron meter to determine soil water use within the western larch spacing study on the Coram Experimental Forest. (Photo by Ray Shearer)

Figure 30. Thinning excess western larch with herbicides on Coram Experimental Forest, 1965. (a) On June 30, Wyman Schmidt, research scientist, Intermountain Forest and Range Experiment Station, fits a protective cloth hood over naturally regenerated western larch crop trees. (b) On July 1, the study area ready for herbicide spraying. (c) Joseph Pechanec, Director, Intermountain Forest and Range Experiment Station, views results on August 25. (Photos by Art Roe)

Leaf area. At age 30, total leaf area was reduced by nearly 33% in thinned stands compared to the unthinned controls (Bidlake and Black 1989). The vertical distribution of leaf-area index in an unthinned stand resembled a normal distribution, as did the thinned stand for a truncated distribution of leaf-area index at the canopy base.

Shrub removal. In 1961, bases of cut shrubs associated with thinning of western larch on 6 plots were sprayed with a 3% solution of 2,4,5-T and fuel oil. These plots were compared with plots that were only thinned to evaluate competition of major shrub species on the growth of the remaining larch. There was

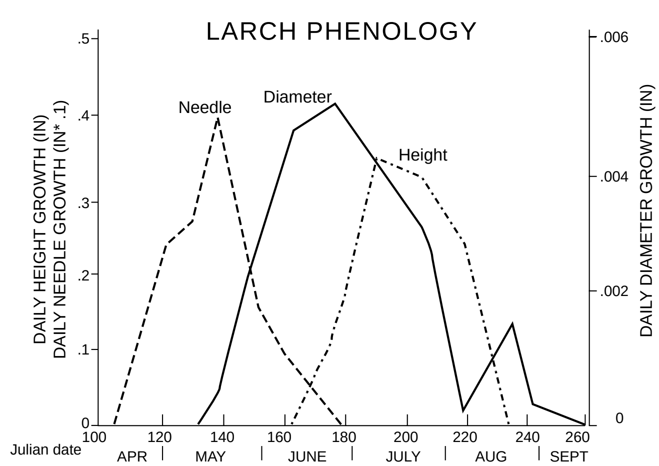

Figure 32. Relative seasonal growth of needle, diameter, and height of young western larch, western Montana (from Schmidt 1998).

little difference in either diameter or height growth with or without the shrubs, probably because lesser vegetation soon occupied the sites where the major shrubs had been removed (Schmidt 1998).

Snow bend. In June 1966, heavy wet snow (USDC 1966) settled on these young trees bending many nearly to the ground (figure 33). The young forest had practically no mortality and most recovered remarkably well (Schmidt and Schmidt 1979). However, 30 y later a similar late-spring snow caused considerable breakage and bending of small-diameter larch on plots with high stand densities. Little snow damage occurred to larger diameter trees growing in less dense plots.

Western spruce budworm. Rather than consuming foliage as it does on other conifer species, budworm larvae feed primarily in July on elongating terminal and upper shoots of western larch (Schmidt 1998) causing reduced height growth and deformed tops of many crop trees. An outbreak of this insect occurred at Coram during the late 1960s to mid 1970s (Shearer and Schmidt 1999). When budworm populations collapse, as it did at Coram in 1975, the trees soon recover; the most rapid recovery occurs on trees in the least dense stands (Fellin and Schmidt 1973). Budworm larvae also feed on developing seed and pollen cones from the time their buds open in April through May (Shearer and Carlson 1993).

Figure 33. Heavy, wet snow falling on western larch with foliage can cause considerable damage. (a) on June 4, 1966, many 14 y-old larch at Coram were bent over; most recovered with little permanent damage (photo by Wyman Schmidt). (b) On June 6 and 7, 1995, in the same area, many smaller diameter 42 y-old larch were uprooted, broken, or permanently bent over. (Photo by Ray Shearer)

Larch casebearer. This introduced defoliating insect arrived at Coram about 1970. A study was installed that year on the 24 ha clearcut at Coram, which paralleled the spacing study established in 1961 (Schmidt 1998) and was designed to show the influence of spacing on development of the insect. This adjunct study showed that casebearer populations per tree increased quickly on plots with the fewest trees, probably because of fewer targets for evenly dispersed insects. The population was in 20% of the needle clusters by year 5 in plots with 494 trees per ha. The next year, the population began to collapse and has never rebuilt. As a result, interactions of casebearer feeding and stand density could not be evaluated.

Needle diseases. Shoot blight, needle blight, and needlecast have been identified on trees in the spacing study, but none have yet caused significant damage as related to stand density (Schmidt 1998).

Bear. Black bears frequently feed on the inner bark of larch in late spring; often killing trees by completely girdling them (figure 34). Usually the largest and most vigorous trees in stands with the fewest trees are targets (Schmidt and Gourley 1992). Some years up to about 5% of pole-size larch at Coram have been damaged or killed.

Vegetation development. To complement growth and phenological data of western larch, and differences in soil-water use, a 1970 study was initiated to determine the composition and development of understory vegetation (figure 35). Usually, understory vegetation responded positively to increased light and water availability in the stands with few trees. However, little difference in growth of western larch was measured between plots with and without shrubs removed (Schmidt 1998).

Arceuthobium laricis. Larch dwarf mistletoe was found on occasional old growth larch on the Coram Experimental Forest in 1968. On the 6 ha clearcut, 15 y-old naturally regenerated larch were artificially inoculated with 30 to 50 larch mistletoe seeds on branches at heights of 0.6 to 1.8 m (Wicker and Wells 1983). Trees were thinned to 2.4, 4.3, or 6.1 m average spacing.

Height growth of the young larch from 1978 to 1988 was over 4 times the rate of the advance of the dwarf mistletoe up the trees (Wicker and Hawksworth 1991). The level of dwarf mistletoe was not expected to reduce tree height or diameter growth although spread from inoculated trees to previously uninfected ones has occurred at each spacing level. Spacing up to an average of 6.1 m does not prevent tree-to-tree spread.

Cone production. From 1985 to 1996 the frequency and amount of seed (figure 36) and pollen cone production was estimated on trees within the following average spacings: unthinned (<0.6), 2.0, 2.4, 3.4, 4.6, 6.1 m. The best 10 trees on each plot were measured. The number of seed and pollen cones usually increased as average spacing increased (Shearer and Schmidt 1987, 1988). Unthinned trees had neither new seed, new pollen, nor old seed cones. Some trees in the 3.4 m and wider spacings were damaged by black bears partially stripping bark at the base of the trees. All bear-damaged trees, but not all undamaged trees, produced seed cones.

Figure 35. Vegetation development in 1964 near the center of the 24 ha clearcut that was harvested and burned in 1952, Coram Experimental Forest. (Photo by Ray Shearer)

Figure 34. Carl Sobczak examines this black bear girdled 45 y-old western larch that was regenerated from seed dispersed in 1952, Coram Experimental Forest. (Photo by Ray Shearer)

Cone production with $GA_{4/7}$. Western larch trees regenerated in 1952 and thinned in 1961 to an average spacing of 4.6 m and 6.1 m were selected for study. Sixty trees in each spacing were randomly chosen. In 1991, half of the trees in each spacing were injected (figure 37) with a solution of $GA_{4/7}$ dissolved in alcohol; the other half were controls. In 1994, half of the trees treated in 1991 and half of the controls were injected with $GA_{4/7}$. The remaining trees were not treated. The

Figure 36. Cones of western larch are red or green (pictured) and average between 25 and 32 mm long and average over 100 seeds per cone. (Photo by Ray Shearer)

Figure 37. Jack A. Schmidt in June 1991 injects a 38 y-old western larch tree on the Coram Experimental Forest with a growth regulator mixture of gibberellin $A^{4/7}$ to promote flowering. (Photo by Jennifer Falacy)

GA treatments increased the number of trees bearing mature cones and the number of cones produced per tree (Shearer and others, in press). Seed quality and other cone characteristics were unaffected by the treatment. No carry-over effects from previous treatments was evident. Foliar damage due to the treatment was short-lived. Pollen cone production was unaffected by GA treatment.

Fertilizing young larch. In 1966, 13 research areas were established in western Montana to study the influence of fertilization with N (nitrogen), P (phosphorus), and K (potassium) on young western larch. One site was located in a 13 y-old stand of western larch natural regeneration thinned to an average spacing of about 2 m x 2 m within the 24 ha clearcut on the Coram Experimental Forest (Behan 1968). Six combinations of N, P, and K were applied (NPK, NP, NK, PK, N, and none) and replicated 3 times. Results were not published.

Soil/site relations. Coram was included in a soil-site study of western larch in western Montana. Results showed height growth varied inversely with stand density and with elevation and varied directly with effective soil depth (Embry 1960). He concluded these studies are more accurate when soils and physiographical characteristics of the site are related to tree growth.

Artificial Regeneration

Abundant natural regeneration of western larch, Douglas-fir, Engelmann spruce, subalpine fir and other conifers occurred following all cutting methods tested when site preparation exposed mineral soil and seeds were available (Schmidt and others 1976). Some areas at Coram did not adequately regenerate because of inadequate site preparation or too little seed. On these areas, supplementary site preparation was required followed by either planting or seeding.

Test planting. A few western larch seeds were collected in 1952 from trees felled on the Coram Experimental Forest. They were grown at the Forest Service Savenac Nursery at Haugen, Montana, then planted at Coram near the center of a 24 ha clearcut. A third were planted May 12, 1954, as 1-0 (1 y grown in the nursery bed - 0 y in transplant bed) seedlings; a third on May 26, 1955, as 1-1 (1 y grown in the nursery bed - 1 y in transplant bed) seedlings; and the remainder on May 27, 1955, as 2-0 (2 y grown in the nursery bed - 0 y in transplant bed) seedlings. Survival in 1960 was 73% for the 1-0 stock, but only 16% for the 1-1 and 2-0 stock. The surviving seedlings were small and mostly of poor vigor. Because of the short growing season at the Savenac Nursery, the 1-0 seedlings were too small for outplanting, while the 2-0 seedlings were too large, and, although the 1-1 seedlings were about the right size, they were costly to produce. No other planting was done on the experimental forest until 1964.

Operational planting. When larger 1-0 larch bare root stock was produced during longer growing seasons at the newly constructed Forest Service nursery at Coeur d'Alene, Idaho, 2 understocked areas were planted at Coram. Several thousand of these bare root seedlings (figure 38) were planted by machine or mattock within the area harvested during World War II and within the group seed-tree area harvested in 1956. Five-year survival was above 90% for machine planting and about 75% for mattock planting. Continued survival and growth information was not followed.

Methods of planting. In autumn 1963, the poorly regenerated and less steep slopes of the area cut during World War II and the group seed-tree cutting area were scarified using a disk pulled by a small crawler tractor. Bare root western larch 1-0 seedlings were machine planted in May 1964. Three methods of planting western larch seedlings were tested in the disked furrows: 15 cm diameter, 20 cm deep holes were dug with a planting shovel (similar to holes dug by auger), 20 cm deep slits opened using the short-handled mattock (most used tool for planting in Region 1 at that time) and approximately 20 cm-deep slit opened by a planting machine.

The 5 y height growth was significantly greater among machine-planted and shovel-planted seedlings than among mattock-planted seedlings (Schmidt and others 1976), and it continued through 1990. Diameter growth through 1990 was significantly greater for machine and shovel planted larch trees than for those planted by the short-handled mattock.

Douglas-fir and Engelmann spruce are major components of forests at Coram. A multidisciplinary study, begun in 1974, included planting these species in 4 consecutive years (1976-1979) following harvest cutting and site preparation to compare their survival and growth as influenced by treatment differences. Douglas-fir survival in 1987 was higher on burned than unburned sites (Shearer and Schmidt 1991). Douglas-fir, regardless of year planted, were significantly taller than the tallest Douglas-fir natural regeneration.

Direct seeding. When artificial regeneration is required to establish conifers, direct seeding may offer a less costly alternative to planting. However, broadcast and spot seeding are uncertain. Both methods were tested in the 1960s with wide ranging results.

Figure 39. Research of spot seeding western larch began in 1960 on the group seed-tree harvest cutting area of the Coram Experimental Forest. Some spots were open to all birds and mammals, some were covered by large mesh screens (self-photo by Ray Shearer) that excluded all birds and ground squirrels, and others were covered by small mesh screens that excluded animals except shrews and invertebrates.

Figure 38. Dwight Dauber, Hungry Horse Ranger District, Flathead National Forest (retired) planting 1-0 western larch seedlings on the poorly regenerated group seed-tree area harvested in 1956, Coram Experimental Forest, May 1964. (Photo by Ray Shearer)

In May 1958, untreated seeds of western larch, Douglas-fir, Engelmann spruce, and subalpine fir were sown on bare soil within the group seed-tree area, cut in 1956. Three weeks later, a high-intensity rain washed out or buried much of the seed (Shearer 1959c). This study, repeated in spring 1959, resulted in 2% of each species germinating because they did not receive pretreatment (Shearer 1961). Results showed the need to cold stratify (store seeds near freezing in moist medium for about a month) or pretreat spring-sown of these species to overcome dormancy and enhance rapid and complete germination.

The effects of aspect, date of seeding, and presowing treatments of western larch seeds were studied on seed spots protected from small mammals and birds by three degrees of screening (figure 39). Seeds, collected in 1958 at Coram near the study area, were spot seeded in mid April and in early May 1960. Germination and survival of spot sown seed were best when seeds were stratified 30 days at 2 °C then sown on north-facing slopes just after snowmelt. Decreased germination and survival resulted from sowing on west and south-facing slopes (Shearer and Halvorson 1967). Drought, insolation, frost heaving, and fungi caused most seedling mortaility. Seedling loss to animals was slight.

Two additional studies at Coram in 1962 showed twice as much germination from spot seeding as from broadcast seeding (Schmidt and others 1976). Spot seeding is more reliable than broadcast seeding because seeds are on favorable microsites and covered with soil which maintains high moisture around the seeds and close contact between seed and soil. In these studies, seed spots were selected to avoid competing vegetation, whereas broadcast seeds were distributed randomly.

These studies also showed the advantage of coating seeds with a material that inhibits fungi, insects, and rodents. They demonstrated that larch seeds usually germinate well if sown in the fall or stratified and sown in the spring soon after snowmelt. Survival of Douglas-fir and Engelmann spruce seedlings was greater from spring-sown than fall-sown seeds. However, fall sowing was preferable for maximum establishment of western larch seeds. Overwintering seed loses were high for Douglas-fir because of rodent feeding, and for Engelmann spruce because of fungi. When larch, Douglas-fir, and spruce seeds are sown together, spring seeding is preferable to reduce overall seed losses.

Reforesting a shrubfield. A 14 y-old shrubfield and an adjacent uphill, new 14 ha clearcut on a steep north-facing slope were successfully prescribed burned (figure 40) on August 23, 1966 (Shearer and Schmidt 1982). The shrubfield originated after a September 1952 prescribed fire on wet fuels failed to expose mineral soil on about a third of the 24 ha clearcut. Natural regeneration was poor except on skid roads. Regeneration began in 1967 after a combination of natural seed dispersal, aerial seeding of larch, Douglas-fir and spruce, and planting of 1-0 bare root larch. By 1981, the old shrubfield and the 1966 clearcut were well stocked by conifers.

The 1970s: Forest Residues Utilization Research and Development Program

The first comprehensive research and development program in the Northern Rocky Mountains evaluating multiple factors associated with intensive forest management was centered on the Coram Experimental Forest. In 1974, a multidisciplinary research and development program used the experimental forest to investigate alternative tree harvesting practices that promote intensive, environmentally compatible, tree utilization (Barger 1975, 1980, 1981). Participants had skills in engineering, wood technology, economics, meteorology, microbiology, mycology, pathology, entomology, silviculture, fire management, hydrology, and wildlife habitat. Although research was site-specific, results from Coram and other study sites in the Rocky Mountains have management implications for coniferous forests in general.

A major component of the program was to evaluate the biological and resource management consequences of alternative harvesting practices and site treatment in a mostly Douglas-fir and western larch forest. Results of these studies enhanced the application of ecosystem-based management principles. Investigations included harvesting systems, silvicultural prescriptions, and utilization standards. Study emphasis was on determining the biological consequences of successively intensive utilization levels and alternative post-harvesting residue treatments.

The study site at Coram was in Abbot Basin on a steep, east-facing slope in old growth forest composed mostly of Douglas-fir and some western larch, Engelmann spruce, and subalpine fir (Barger 1975, 1980, 1981). Management objectives for the site included: protecting esthetic values, timely regeneration and subsequent stand development, maintaining species diversity—especially in retaining western larch in the stand; avoiding high road density and adverse

Figure 40. An August 23, 1966, prescribed fire on a steep north-facing slope within the Coram Experimental Forest exposed mineral soil for natural regeneration. This fire burned slash on a clearcut harvested in May 1966, and dead shrubs on a bordering downhill clearcut harvested in 1952 that failed to regenerate. Shrubs were killed by an herbicide applied in June 1966. (Photo by Ray Shearer)

Figure 41. Decreasing the clearing width of forest roads (upper two switchbacks in upper left of picture) diminishes their visibility on the landscape, Coram Experimental Forest. (Photo by Ray Shearer)

biological impacts on the forest ecosystem. To access the upper study area, an experimental logging road (upper segment of Road 590B [Table 2]) designed to minimize environmental and esthetic impact (Garner 1978) was constructed in 1973. This road was a single-lane (4.3 m finished surface, 1 m ditch), constructed along the contour. Esthetically, this road was judged far superior to existing roads (figure 41).

Three harvest cutting methods included:

- clearcutting—harvest all merchantable trees included under specified utilization standards
- shelterwood cutting—harvesting approximately 50% of the merchantable volume, leaving an overstory composed of the best mature Douglas-fir, most of the old growth larch, and other species to help establish a new multi-species stand
- group selection cutting (figure 42)—removing all trees specified as merchantable under the utilization standard from irregular, randomly spaced 0.4 to 0.8 ha subunits.

Four utilization treatments, representing successively intensive practices, were imposed within each of the 3 harvest cutting prescriptions (table 4). The treatments ranged from sawlog utilization standards that were in common use to near complete utilization of all trees. Cutting units were established to take advantage of roads and included up and down hill yarding (Gardner 1980). A running skyline system (figure 43) allowed laying out the large units up to 610 m in slope length (Barger and Benson 1981). Damage to residual trees left within and surrounding the blocks was assessed by Benson and Gonsior (1981). Prescribed broadcast burning was accomplished in September 1975 (Artley and others 1978). In addition, relationships for predicting duff reduction, mineral soil exposure, and consumption of downed woody fuel

Figure 42. Four levels of log utilization and residue treatments were used on these eight group selection cuttings, Coram Experimental Forest, 1974. (Photo by Ray Shearer)

Table 4. Forest Residues Utilization Program pre- and post-harvest treatments on 2 clearcuts, on 2 shelterwoods, and 2 sets of 8 group selection units cut and slashed in 1974 on the Coram Experimental Forest.

Utilization standard	Post-harvest woody material removed	Treatment
Conventional sawlog: trees down to 178 mm d.b.h. cut, except designated shelterwood trees	Live and recently dead logs 140 mm top; 1/3 or more sound	Remaining understory slashed; broadcast burned September 1975
Close *log* utilization, trees down to 178 mm d.b.h. cut, except designated shelterwood trees	Live and dead standing or down logs to 76 mm top and 2.4 m long, if sound enough to yard	Remaining understory not slashed; unburned
Close *tree* utilization, trees down to 127 mm d.b.h. cut, except designated shelterwood trees	Live and dead standing or down logs to 76 mm top and 2.4 m long, if sound enough to yard	Remaining understory slashed; broadcast burned September 1975
Close *fiber* utilization, cut all trees except designated shelterwood trees	Live 25 mm -50 mm d.b.h. material bundled tree length; live logs to 76 mm top and 2.4 m long, if sound enough to yard	Remaining understory slashed; unburned

Figure 43. In 1974, logs were carried from where they were cut to the road by cable, causing minimal site disturbance on the Coram Experimental Forest. (Photo by Herm Whitman)

that were determined at Coram contributed to the development of a fire-danger rating on mesic forest cover types in the northern Rocky Mountains (Brown and others 1985).

A wide range of biological disciplines cooperated to evaluate the early post harvest biological and management consequences of the 4 treatments (Barger 1980, 1981). Research included: biomass, meteorology, nutrient status, hydrology, and microbiology responses to treatment; consequences relating to insect activity, site productivity, stand regeneration and development, understory vegetation, esthetics, wildlife habitat, and fuels management; and implications for resource protection and management on the site. To coordinate research activity, a grid of 10 permanent sampling points was established in each subtreatment unit. Scientists were assigned specific locations around each point for their sampling needs (figure 44).

In 1979, researchers reported final, or interim results, of their Coram studies at the symposium “Environmental Consequences of Timber Harvesting in Rocky Mountain Conifer Forests” (USDA Forest Service 1980). The following synopsis gives major findings divided into environmental responses, biological implications, and resource management options to harvest cuttings at Coram.

Environmental Responses

Woody material. In the western larch forest type at Coram, total volume of wood 8 mm in diameter and larger, including live, standing dead, and down trees

Figure 44. Raymond C. Shearer explaining plot layout on the forest residues utilization study on the Coram Experimental Forest, September 1995. (Photo by Dave Tippets)

averaged 477 m^3 per ha (Benson and Schlieter 1980c). Typically, about half of this volume is removed in logging (figure 41), while the remaining residues include up to 50% or more sound wood, plus material in various stages of decay (Benson and Johnston 1976; Benson and Schlieter 1980a, 1980b, 1980d). Close utilization at the time of sawlog removal recovered more of the material than if a second entry was made to remove small logs left after the initial harvest (Benson and Schlieter 1981).

Microenvironment. Mean daily net radiation was similar for the clearcuts and group selections but only 70% as much for the controls and 46% as much in the shelterwood cuttings (Hungerford 1980). Differences in monthly mean daily net radiation were similar from May through September but were not as great during the winter. Midsummer maximum surface temperatures were 25 °C higher on unshaded surfaces in clearcuts and 10 °C to 15 °C higher in partial cut stands than in uncut stands.

These potentially lethal ground surface temperatures occurred mostly in the clearcuts and group selection units and were directly related to the thermal properties of the surface materials (Hungerford and Babbitt 1987). Daily air temperature, shortwave radiation, relative humidity, and precipitation data from these units were combined from many other areas to develop a model (MTCLIM) for calculating daily microclimate conditions in mountainous terrain (Hungerford and others 1989).

Steep harvested slopes had a longer frost-free period than the creek bottom, but freezing temperatures occurred 10 days sooner in the clearcuts than within the uncut timber. Compared to the clearcuts, shelterwood cuts and uncut stands received 15% and 25% less precipitation because of interception (figure 45).

Figure 45. Measurement of stream flow near the source of Abbot Creek on the Coram Experimental Forest (a) began in 1974 with the establishment of an H-flume (photo in 1977 by Jack Schmidt). (b) In 1994, the H-flume was replaced by a Parshall flume. Dave Ondov, Hungry Horse Ranger District, Flathead National Forest examines the new flume in 1997. (photo by Ray Shearer)

Water use. Compared to the uncut forest floor, snow accumulation increased 80% in clearcuts, 50% in group selections, and 40% in shelterwoods (Newman and Schmidt 1980). The first 4 y after treatment, the uncut forest used about 75%, the shelterwoods only 4%, group selections 10%, and clearcuts 11% of the total annual precipitation. Initially, the light-burn treatments significantly affected vegetation resulting in decreased water use. However, the effects of all residues-management treatments were of short duration. Streamflow has been monitored since 1974 near the source of Abbot Creek, first by an H-flume (figure 45a) and then by a replacement Parshall flume (figure 45b) installed in 1994.

Nutrient cycling. Prescribed fires with surface soil temperatures less than 316 °C can be used indefinitely on a 50 y rotation without loss of long-term productivity on these soils (Stark 1980). Harvest of wood and bark in clearcuts did not remove more nutrients than will be returned through precipitation in 70 to 100 y. Intensive harvests (wood, bark, and branches) should not remove more nutrients in fiber than can be returned from precipitation, soil solution available nutrients, pollen, and normal decay in 70 y time.

Residue decay. Brown-cubical decayed wood in soil is functionally unique (Larsen, Harvey, and Jurgensen 1980). Wood in soil functions similarly to other soil components but may more efficiently store nutrients and water. Tree roots and certain fungi that together form mycorrhizae, which promote tree establishment, survival, and growth, develop in decaying wood. Decayed wood is an important site for fixation of nitrogen gas from the atmosphere. Long-term site deterioration is avoidable by assessing the impact of increasing levels of utilization before forest harvest.

Nitrogen cycling. Nitrogen fixation by soil bacteria is reduced, particularly in the surface organic horizons, following tree harvest and this is related to low moisture levels on the surface of cleared sites (Jurgensen, Larsen, and Harvey 1980). Decaying wood in the soil is a major site of nitrogen fixation. Establishment of nitrogen-fixing plants on logged areas can compensate for low nitrogen fixation rates by soil bacteria. Most sites had an insufficient numbers of these plants. Increases in ammonium and nitrate concentrations in the soil after treatment is beneficial to tree regeneration and growth.

Ectomycorrhizae. The activity of ectomycorrhizal symbionts depends on host trees, while stand manipulation provides control of their function (Harvey, Larsen, and Jurgensen 1980). Organic materials, such as litter, humus, decayed wood, or charcoal, which are in the mineral soil, govern ectomycorrhizal activity in forest soil. Organic materials are most important in soils on the harsh sites because they buffer wide variations of pH, moisture, and temperature.

Biological Implications

Forest soils. The relative quality and productivity of the soils at Coram are related to microbiological populations (Harvey, Jurgensen, and Larson 1980). There is an interdependence between above-ground (organic matter input) and below-ground (nutrient and moisture availability) processes to influence site productivity.

Both total and available nitrogen were lost from the burned forest floor at Coram, but these increased in underlying unburned layers (Mroz and others 1980). Increased nitrogen in the lower layers was caused by the downward movement of nitrogen compounds during the burn.

Wood is a critical soil organic component; its importance varying by site (Harvey, Jurgensen, and Larson 1980). Intensive fiber utilization had the greatest potential negative impact on the Douglas-fir/ninebark habitat type at Coram as shown by ectomycorrhizal activities supported by soil wood. There was less potential negative impact on the subalpine fir/clintonia habitat type, and least on the western hemlock/clintonia habitat type.

Residues management enhances sites with limited organic matter production. Based on normal utilization practices common in the mid 1970s, there should not be a shortage of organic residues on productive sites at Coram. However, substantial increases in utilization intensity, hot wildfire, or excessive site preparation could reduce stand productivity, especially on harsh, cold, or dry sites (Harvey and others 1981b).

Understory vegetation. Volume, cover, and biomass of shrubs and herbs were measured before harvest, and 2 and 4 y after harvest. All harvest cutting and residue management treatments substantially reduced the volume and biomass of live shrubs to as little as 3% of the preharvest volume on burned treatments (Schmidt 1980).

All vegetation responded rapidly after treatments at Coram; in some cases vegetation approached preharvest levels in 4 y. Herbs responded earlier to treatments than the shrubs. Total biomass of live understory vegetation, excluding trees, averaged over 5,044 kg per ha in the mature forest. Vegetation responses are rapid the first 2 to 4 y, then slowly approach levels found in mature forests (Schmidt and others 1995).

Twelve years after harvest, height and diameter growth of understory Douglas-fir, Engelmann spruce, and subalpine fir accelerated (Carlson and Schmidt 1989) Trees growing well before harvest grew well after harvest. Post harvest mortality of understory trees was greatest when half of the overstory was retained. Defoliation by western spruce budworm reduced post harvest growth of Douglas-fir, but it did not affect Engelmann spruce or subalpine fir.

Natural regeneration. Natural regeneration began slowly at Coram because of inadequate site preparation and low seed dispersal. Western spruce budworm larvae killed most seed cones on trees other than western larch (Shearer 1980a), limiting cone production on Douglas-fir, subalpine fir, and spruce. Thermal slope winds dispersed most seeds uphill in September. Upslope winds diminished in October and the sun angle decreased, resulting in less warming of the forest floor. Germination and growth of conifer seedlings was enhanced on burned sites.

Regeneration of western larch began in 1975, mostly where soil was exposed during logging or prescribed fire (Shearer and Schmidt 1999). Quick recovery of competing vegetation curtailed establishment of larch past 1979. Douglas-fir regenerated prolifically between 1979 and 1992, after the budworm outbreak subsided. Other conifer species regenerated slowly. In 1992, an average of nearly 11,400 established seedlings per ha grew on the units, 90% were Douglas-fir. Eighty percent of the plots were stocked with at least one established conifer (figure 46).

Forest floor arthropods. Arthropods, most abundant and most negatively affected by harvest and utilization practices, are spiders (*Arachnida:Araneida*), ants (*Hymenoptera:Formicidae*), and beetles (*Coleoptera*), especially the families *Carabidae* and *Staphylinidae*

Figure 46. Western larch (left back) and Douglas-fir (center and right front) natural regeneration in 1992 are competing with well-developed herbaceous vegetation on the "Forest Residues Utilization R&D Program" study area on the Coram Experimental Forest. This western larch will probably die because of shade and competition, but the shade-tolerant Douglas-fir will survive. (Photo by Ray Shearer)

(Fellin 1980a, Fellin 1980c). Most treatments adversely affected macrofauna in 1977 (which was 3 y after harvest and 2 y after burning) at Coram. The light prescribed fires stimulated a resurgence of some groups. Treatments, by decreasing impact on forest floor fauna, were: shelterwood-leave residue, shelterwood-burn residue, shelterwood-mechanically remove residues (intense fiber utilization), clearcut-burn residue, clearcut-mechanically remove residue.

Forest litter, humus, and soil arthropods. Mites (*Arachnida, Acarina*) and springtails (*Insecta, Collembola*) were most affected by harvest cutting and utilization treatments at Coram (Fellin 1980b). Based on data taken in 1976, 2 y after harvest and 1 y after burning, mesofaunal reduction, in decreasing order of treatment, were: clearcut-residue burned, clearcut-residue mechanically removed, shelterwood-residue burned, and shelterwood-residue mechanically removed. Management practices involving harvest, residues, and fire all influence forest succession (Fellin 1980c).

Resource Management Implications

Fuels and fire. Fuels and fire behavior potentials were unaffected by cutting method but varied by utilization standards (Brown 1980). Predicted rates of spread on units logged with usual utilization standards were 3 to 4 times greater than on units with near-complete utilization. Conventional utilization left fireline intensities exceeding capabilities for direct fire control for 3 to 20 y or more. Fuel less than 76 mm in diameter was reduced to 0.7 of that created by cutting. Whole tree skidding coupled with slashing left unacceptable hazards for 3 to 5 y. Near-complete utilization left acceptable levels of hazard but also left insufficient fuel for prescribed burning (figure 47).

Esthetic quality. The visual appearance of an area after tree harvest is a measure of public feeling (Benson 1980). The esthetic impact of different harvest and utilization alternatives used at Coram were evaluated by the scenic beauty estimation method using color slides rated by panels of viewers to provide a quantitative measure of public feeling. In general, the less an area shows logging debris and signs of soil disturbance, the better the area is rated. Esthetic quality improves as trees and other vegetation regenerate following treatment. These evaluations provide guides for harvesting, especially in visually sensitive areas, and a means for evaluating the effectiveness of alternative harvesting methods in meeting visual objectives (figure 48).

Cavity-nesting birds. Impacts of harvesting and residues management treatments on nesting and feeding of cavity nesters, especially woodpeckers, was studied from 1974 to 1979 (McClelland 1979; McClelland and

Figure 47. Prescribed fires in September 1975 did not reach prescription because of wet fuels and frequent rain on the "Forest Residues Utilization R&D Program study area (upper shelterwood shown). Above average precipitation prevented needed drying of slash and litter on the Coram Experimental Forest. (Photo by Herm Whitman)

Frissel 1975). These birds prefer western larch, black cottonwood, paper birch, or aspen nest trees with heartwood decay (McClelland and others 1979).

Forests with old growth larch supported the greatest density and diversity of cavity nesters (McClelland 1980). Uncut controls received the highest percentage of feeding use. Clearcuts received little use, regardless of the intensity of residue utilization.

Of trees that were greater than 23 cm d.b.h., Douglas-fir was about 5 times more abundant than western larch, but larch outnumbered Douglas-fir as nest trees for the pileated woodpeckers about 17 to 1. Larch retains a protective layer of relatively firm sapwood surrounding the decaying interior and Douglas-fir does not (figure 49), which creates nesting, roosting, and feeding opportunities for many birds and small mammals incapable of excavating the dense wood of western larch (McLelland 1995). In addition, many

Figure 48. This shelterwood is composed of many mature trees, provides seed for regeneration, protection for new trees, and esthetically pleasing on the Coram Experimental Forest. (Photo by Ray Shearer)

birds and small mammals prefer larger diameter (>80 cm) trees, especially snags.

The 1980s: Understanding Forest Processes

As research shifted from Coram to other areas, long-term studies were remeasured on schedule. New studies focused on dynamics of old growth in the Coram Research Natural Area, of cone production in young larch by spacing, of habitat needs of bird populations, and of revegetating road cuts in cooperation with Glacier National Park.

Old Growth Dynamics

In 1985, the U.S. Man and the Biosphere Program funded establishment of 4 permanent baseline monitoring plots in representative forest ecosystems in the Coram Research Natural Area (Habeck 1985; Habeck 1990). This area serves as a control to similar areas where manipulative research is conducted elsewhere on the experimental forest. This was the first formal effort to study the succession dynamics of the research natural area. These plots were established at low elevations near the western edge of the research natural area; 3 in 200+ y-old stands, and 1 in a 100+ y-old stand all within the western larch forest cover type.

The Forest Service Natural Areas Program funded establishment of 4 additional plots in 1993 to include forest cover types and elevations not originally represented (Elzinga 1994). They are established at low elevations in Engelmann spruce/subalpine fir and interior Douglas-fir forest cover types and at higher elevations in the western larch and interior Douglas-fir forest cover types. Stand structure, understory

Figure 49. Pileated woodpecker feeding young in a cavity of western larch on the Coram Experimental Forest. (Photo by Steve Wirt)

composition, and tree seedling composition are described for each plot (Elzinga and Shearer 1997). The 8 plots clearly showed a successional trend toward shade-tolerant conifers, placing old growth stands at risk of loss from succession or catastrophic fire.

Cone Production in Young Larch

Research began in 1985 to study the influence of stand density on the frequency and amount of seed cone production on two 32 y-old stands at Coram (Shearer 1986). The average number of cones per tree increased as average spacing increased. Unthinned (control) trees almost never produced cones, while trees with an average spacing of 3.4, 4.6, and 6.1 m produced an increasing number of cones as distance between trees increased (Shearer and Schmidt 1987; Shearer and Schmidt 1988).

Bird Populations in Logged and Unlogged Forest

Differences in avian assemblage after logging and site-preparation on the Coram Experimental Forest, and within the nearby uncut Coram Research Natural Area, were studied from 1989 to 1991. Plots in treated areas were established near temporary plots used in a preharvest survey of birds in 1984. Of 32 species of abundant breeding birds, populations of 10 species differed significantly between small cutting units and adjacent uncut research natural area (Tobalske and others 1991). Foliage foragers and tree gleaners were less abundant in cutting units than flycatching species and ground foragers. Conifer tree nesters were least abundant in cutting units than ground nesters. Snags and broadleaf trees of all species should be retained to help maintain tree dependent bird species.

Other research at Coram and elsewhere (Tobalske and others 1990) showed that there was no significant difference in the relative abundance of Red-naped sapsuckers among clearcut, partial-cut, fragmented, and contiguous forest (Tobalske 1992). Retaining snags and living trees mitigated the effects of timber harvest for the sapsuckers in spite of the drastic alteration of forest composition and structure associated with logging (Tobalske 1991; Intermountain Research Station 1992).

Cooperative Research with Glacier National Park

Reconstruction of the Lake McDonald section of the Going-to-the-Sun Road in Glacier National Park began in 1991. Results from the revegetation of cuts and fills by native shrubs and forbs on a road at Coram (Hungerford 1984) helped park planners. However, information was lacking for regenerating several other species. Cooperation between these 2 governmental organizations was enhanced because both Glacier National Park and the Coram Experimental Forest are biosphere reserves, units of the international United Nations Man and the Biosphere Program.

In 1987, a study was installed on a similar site at Coram to learn how to revegetate several native herbaceous species on cut slopes and ditches (Shearer and others 1996). Results from these studies (Lange and Lapp 1999) helped planners implement successful strategies to quickly restore native vegetation on cuts, fills, and ditches after road reconstruction (figure 50).

The 1990s: Research, Conservation, and Education

Application of Coram research results to ecosystem management enhanced the value of the area for educational purposes. Research at Coram was featured at the international symposium “Ecology and Management of *Larix* Forests: A Look Ahead” held in 1992. The International *Larix* Arboretum, associated with the Coram Experimental Forest and located nearby in Hungry Horse, was dedicated during the symposium. New research included: installing 4 additional old

Figure 50. In June 1991 Dave Lange (upper left), Glacier National Park, explains cooperative research on the Coram Experimental Forest to scientists, managers, and other employees of Glacier National Park and how results will help to successfully revegetate road cuts with native plants after reconstruction of the Going-to-the-Sun Highway. (Photo by Ray Shearer)

growth vegetation structure plots within the Coram Research Natural Area; evaluating small mammal habitat needs; evaluating stand density effects on wood quality; and increasing monitoring of climate and stream flow.

Research Encourages Biological Diversity

Research at Coram includes regeneration of forest trees after harvest cutting and site treatment, culture and growth of young forests, and interaction of flora, fauna, and water after a wide range of forest treatments.

Ongoing studies in the 1990s include:

- cone production
- conifer seed dispersal
- establishment of regeneration after harvest cuttings
- effect of stand culture treatment on forest development
- insects, diseases, birds, and animals
- effect of wood utilization on site productivity
- influence of silvicultural practices on watershed, esthetics, and wildlife values

This research provides valuable data on vegetation succession, soils, birds, mammals, insects, disease, climate, and hydrology. Resource managers use these results to make environmentally sound decisions. Research at Coram will continue to assist the development of ecosystem-based management strategy and encourage biological diversity through long-term studies on new and old growth forests.

New studies by cooperators include:

- needlefall accumulation and decomposition rates in old growth larch forests
- avian productivity and survivorship
- height/diameter ratio and tree stability relationships for pole-size western larch
- wood quality as related to stand density and site

Down wood and needlefall. Coram was used from 1994 to 1998 as one of 2 sites in western Montana to quantify downed woody material, conifer needlefall accumulation, and decomposition rates, and then compare the results with forest productivity (Keene 1997a). While smaller twigs are deposited proportionately to litter, larger twigs and branches seem to be deposited stochastically across the surface (Keene 1997b). Larger woody fuel accumulation is difficult to relate to litterfall. Nearly the same litterfall rate occurs on similar sites, but not for similar stands on different sites.

Monitoring Avian Productivity and Survivorship Program (*MAPS*). In 1992, the Coram Experimental Forest (1 of 4 sites on the Flathead National Forest) was selected to provide annual regional indices and estimates of adult population size, post-fledging productivity, adult survivorship, and recruitment into the adult population for various landbird species. This information is used to provide crucial information upon which to initiate research and management actions to reverse declines of North American landbirds (DeSante and Walker 1994).

Data collected in 1993 and 1994 at Coram is listed in a national database and reviewed in the MAPS Program (DeSante and others 1996). The fifth consecutive year of mist-netting and banding was completed in 1997.

Tree stability. Larch within the buffer zone surrounding the spacing study were sampled and included with larch from other sites in western Montana to determine the influence of height to diameter ratio as an indicator of susceptibility to snow bend or breakage. When the ratio exceeds 80:1, likelihood of damage is high (Wonn 1998). Live crown ratio, however, is not a good predictor for damage.

International Symposium: Ecology and Management of Larix Forests

Research within the Coram Experimental Forest was a major part of the impetus for presentations and field trips during the international 1992 *Larix* Symposium in Whitefish, Montana (Tippets 1996). Although the research and management of western larch was emphasized during the symposium, information from participants expanded the knowledge of all larch species. The program was designed for natural resource managers, research scientists, educators, and specialists. A proceedings was issued that included all papers presented at the symposium (Schmidt and McDonald 1995).

International Larix Arboretum

Since research began at Coram, the establishment of an arboretum to feature the world's 10 species of *Larix* has been envisioned. In 1991, the seeds of nine species and several hybrids and varieties were acquired and grown as container stock. Seed for the tenth species was obtained in 1997 and sown in containers in 1998. Seedlings were outplanted in the fall of 1999.

Western larch, alpine larch, and their reciprocal hybrids were produced in the Forestry Sciences Laboratory greenhouse. All others species, hybrids, and varieties were grown in the Forest Service Coeur d'Alene Nursery. Instead of being planted on the Coram Experimental Forest, all but 1 species were outplanted in 1992 in the Hungry Horse Ranger Station compound, which is across the street from the Coram Experimental Forest field headquarters (Tippets 1996).

This 0.5 ha site (figure 51) has many advantages over a site on the experimental forest:

- a water supply to help establish and maintain the trees
- lower risk of contaminating nearby larch with foreign pollen
- easy public access
- reduced incidents of vandalism

The arboretum was dedicated October 7, 1992 after field tours associated with the *Larix* Symposium (Shearer and others 1995). It is a symbol of global cooperation and increases public awareness of the world wide distribution, importance, and differences within the genus *Larix* and provides an opportunity to compare species, varieties, and hybrids. A newspaper article called this arboretum "one of the region's best kept secrets" (Jokerst 1996).

Conservation Education in an Outdoor Classroom

The Coram Experimental Forest is a quality field site; a living learning center for educational programs about the environment. Fifty years of research provides a base of information on the beginning, development, and function of these forest ecosystems (Kiehn 1995/1996). Research at Coram also shows how these forests respond to harvest and site preparation, manipulation of conifer tree regeneration, and to other treatments. Interpretation of research projects at Coram provides an opportunity to explore the value of this experimental forest as a laboratory for social, cultural, and natural resource studies.

Coram provides interpretive and educational opportunities to people who visit the site each year.

Figure 51. International Larix Arboretum, Hungry Horse, Montana, was dedicated on October 7, 1992. (Photo by Steve Wirt)

People visit Coram for information about conservation and the sustainable use of forests. Scientists, resource professionals, students, and individuals can see the effects of many treatments on forest land and can gain an understanding and appreciation of natural resources. For example, long-term climatic and hydrologic stations at several locations on the experimental forest monitor temperature, radiation, wind, precipitation, and stream flow to help interpret study data. In addition, there are educational trails with ecological learning stations and areas suitable for student research.

Students take to the field. The University of Montana forestry students visit Coram annually to complement classroom studies and see ecology research and management in action. The Glacier Institute teaches the basics of forest ecology and sampling methods to high school students each summer. Teacher training workshops (figure 52) help teachers to bring conservation education curriculum into the classroom. Instructional field packets also provide students with hands-on learning opportunities. In 1995, an environmental education curriculum was developed for teachers. Brochures are also available that explain the purpose and function of Coram.

A three-way partnership, between Columbia Falls School District Six, the Rocky Mountain Research Station, and the Flathead National Forest provides a positive outdoor learning experience for students. This partnership offers students an opportunity to practice science in a meaningful manner and promotes the importance of natural resource stewardship. School District Six, centered in Columbia Falls, adopted Coram as a field-study site for a middle school science curriculum (figure 53) and the Eagle School in Coram conducts a comprehensive stream monitoring project that includes permanent plots at 3 locations on Abbot

Figure 52. Lynne Dixon (Forest Service volunteer), Silja Meier (Clemson University intern), and Don Kiehn (Forest Service volunteer) conducted workshops in October 1995 to help teachers learn how to use the Coram Experimental Forest for field and stream ecology curricula. (Photo by Ray Shearer)

Creek. Teachers and students are developing aquatic teaching tools to explore stream integrity and are also developing a Coram Experimental Forest home page.

Volunteers assist with field education. Dedicated volunteers have helped raise the awareness of Coram as an outdoor classroom through development of the Coram Experimental Forest conservation education program. With continued assistance from natural resource and conservation education program funding, the following educational tools have been developed for the Coram Experimental Forest:

- a comprehensive teacher's manual and curriculum, and an environmental education trunk containing environmental education resources, such as aerial photos, hands-on equipment
- four rough trails with site-specific learning and interpretive activities
- a Flathead Valley school watershed monitoring project (Project Free Flow) on Abbot Creek (several sites in the watershed were located and equipment was purchased for use by students and teachers)
- informal field trips for all local teachers to Coram wetland sites, and formal teacher workshops to integrate use of Coram into existing school curricula
- a formal partnership between the USDA Forest Service and the Columbia Falls School District to support a district science teacher to serve as a Coram education coordinator.

Figure 53. Students from Columbia Falls (Montana) High School study vegetation and macro invertebrates of Abbot Creek, Coram Experimental Forest for hands-on environmental learning experiences. (Photo by Don Kiehn)

Other educational opportunities. The Coram Experimental Forest also meets educational needs in the following ways:

- In response to requests for information from educators, researchers, and natural resource managers, the Northern Alliance, leaders of universities and the Forest Service within Idaho, Montana, and Utah, identified 14 outdoor laboratories in these states that provide basic information about ecosystem function (Schmidt and Friede 1996). An overview of the Coram Experimental Forest is included in this publication (Shearer 1996).
- In 1994, the Western Montana Ecosystem Management Learning Center Program was organized at the University of Montana and includes the Coram Experimental Forest as a key learning center.
- Coram is part of the Crown of the Continent Ecosystem Education Consortium. This group provides a bio-regional focus on education in the area surrounding the Continental Divide north of Missoula, Montana, into southwest Alberta, Canada, and southeast British Columbia, Canada.
- The Montana Natural History Center, Missoula, Montana, is assembling a Network for Ecological and Conservation Education in the Crown of the Continent Region with Coram as a participant.
- Continuing participation in the Northwest Montana Environmental Education Core Group.

Commemorating 50 y of research. Beginning in 1998, special events were developed to Commemorate the 50 y of continuous research on the Coram Experimental Forest including:

- Walk With Larch (Shearer and Kiehn 1999), a self-guided trail, which is part of the Coram Experimental Forest conservation education program. The trail provides further opportunities for students and forest visitors to explore this unique area.
- Living in the Landscape, a Flathead community celebration which celebrated 50 y of research at Coram (Shearer 1998). This event encouraged science students to complete a 1 or 2 y mentored research project. The student's work added to the knowledge of the area and was featured in public presentations and field tours in 1998.
- A local community celebration was held to mark Coram's 50th anniversary and to explore people's connection to the landscape. A community quilt, science symposium (Living in the Landscape 1998a), concert, student research projects, art exhibits (Living in the Landscape 1998b), community anthology and field trips were featured.

Summary

For 50 y, the Coram Experimental Forest has been a focal point for western larch research surpassing all other areas with the number and diversity of western larch research. Results during the first 40 y of research were shown to a wide range of visitors including American and foreign researchers, college students, and land managers.

From 1948 to 1960, a wide range of practical studies at Coram and elsewhere helped land managers effectively plan harvest cutting and site preparation treatments to regenerate forest land with western larch and associated conifers. In 1961, a 40 y thinning study began within recently regenerated young stands at Coram and 2 other locations in western Montana to learn the effects of different spacings on the growth characteristics of western larch. Later, other studies within these plots showed how differing spacings influenced soil water use, cone production, damage to young trees, and development of shrubs and forbs on the plots. Advantages and disadvantages of planting and seeding were also identified in the 1960s. A multidisciplinary research effort in the 1970s provided managers with greater understanding how ecosystems respond to removal of differing amounts of woody residues. Research in the 1980s looked at changes occurring in old growth forests and on the influence of treatments associated with tree harvest on habitat for resident and migratory birds.

In addition to continued research at Coram during the 1990s, research findings in the last 10 y were shared with science teachers in nearby schools for use in classrooms. Teachers were encouraged to use the experimental forest as an outdoor classroom. The Walk With Larch trail (Shearer and Kiehn 1999) was opened to celebrate 50 y of research by showing visitors examples of natural processes that followed several treatments starting in 1951 and demonstrating their influence on management options in western larch dominated forests.

Future research and management on the Coram Experimental Forest will build on a history rich in discovery and add to our expanding environmental knowledge. In addition to old growth forests at Coram, a broad range of younger age classes are now available because harvest cutting from 1916 to 1974 provided opportunities for a wide range of new studies (figure 54). Research at Coram will continue to provide data for developing ecosystem management strategies and enhance understanding of biological diversity through long-term studies. Ecosystem-based management focuses on the entire landscape, so it is necessary to blend the social and economic needs of people with the ability of the natural system to sustain itself. Research and land management information from studies at Coram helps to complete the ecosystem puzzle in northwest Montana and contributes useful data throughout the natural range of western larch.

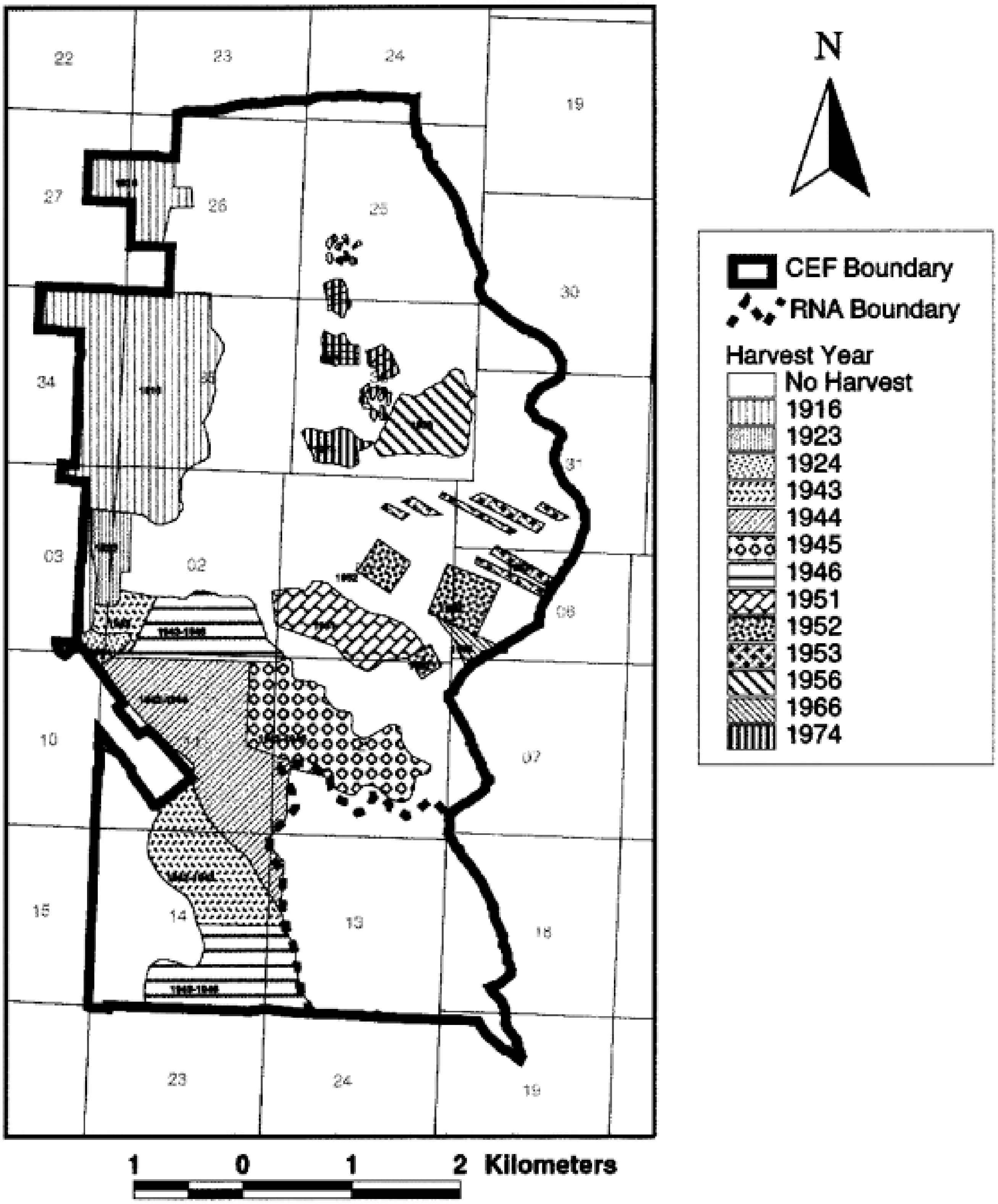

Figure 54. Geographic Information System generated map of harvest cuttings from 1916 to 1974 on the Coram Experimental Forest.

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Keywords: western larch, Douglas-fir, Engelmann spruce, subalpine fir, seed, germination

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Keywords: spacing,

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Keywords: forest residues, wood utilization, timber harvesting, forest practices

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Keywords: western larch, susceptibility, snow bend, snow breakage, live crown ratio

Appendix A: Coram Experimental Forest Flora Checklist (1998)

This checklist was compiled by Peter F. Stickney, plant ecologist, retired from USDA Forest Service, Intermountain Research Station. The species listing is through Sept. 21, 1998.

Botanical name[a]	Status[b]	Common name[c]
Trees		
Abies grandis	N	grand fir
Abies lasiocarpa	N	subalpine fir
Betula papyrifera	N	paper birch
Larix occidentalis	N	western larch
Picea engelmannii	N	Engelmann spruce
Pinus albicaulis	N	whitebark pine
Pinus contorta	N	lodgepole pine
Pinus monticola	N	western white pine
Pinus ponderosa	N	ponderosa pine
Populus tremuloides	N	quaking aspen
Populus trichocarpa	N	black cottonwood
Pseudotsuga menziesii	N	Douglas-fir
Pyrus malus	X	apple
Thuja plicata	N	western redcedar
Tsuga heterophylla	N	western hemlock
Shrubs		
Acer glabrum	N	Rocky Mountain maple
Alnus incana	N	thin-leaved alder
Alnus sinuata	N	Sitka alder
Amelanchier alnifolia	N,P	serviceberry
Ceanothus sanguineus	N,P	redstem ceanothus
Ceanothus velutinus	N,P	snowbrush or shinyleaf ceanothus
Cercocarpus ledifolius	P	curlleaf mountain-mahogany
Cornus stolonifera	N,P	red-osier dogwood
Crataegus douglasii	N	hawthorn
Holodiscus discolor	N,P	ocean spray
Juniperus communis	N	common juniper
Lonicera involucrata	N	black twin-berry
Lonicera utahensis	N	Utah honeysuckle
Menziesia ferruginea	N	fools huckleberry
Oplopanax horridum	N	devilsclub
Pachistima myrsinites	N	mountain-lover
Penstemon fruticosus	X,P	bush penstemon
Physocarpus malvaceus	N,P	ninebark
Prunus emarginata	N	bittercherry
Prunus pumila	P,?	sandcherry or dwarfcherry
Prunus virginiana	N,P	chokecherry
Rhamnus alnifolia	N	alder buckthorn
Rhus glabra	X,P	smooth sumac
Ribes lacustre	N	swamp black gooseberry
Ribes viscosissimum	N	sticky current
Rosa acicularis	N	prickly rose
Rosa gymnocarpa	N	baldhip rose
Rosa woodsii	N,P	Woods rose
Rubus idaeus	N	red raspberry
Rubus leucodermis	P	black raspberry or blackcap
Rubus parviflorus	N,P	thimbleberry

Botanical name[a]	Status[b]	Common name[c]
Shrubs		
Salix drummondiana	N	Drummond willow
Salix exigua	N	sandbar willow
Salix scouleriana	N	Scouler willow
Sambucus cerulea	P	blue elderberry
Sambucus racemosa	N,P	black elderberry
Shepherdia canadensis	N	buffalo-berry
Sorbus scopulina	N	mountain ash
Spiraea betulifolia	N,P	shiny-leaf spiraea
Symphoricarpos albus	N	snowberry
Taxus brevifolia	N	Pacific yew
Vaccinium caespitosum	N	dwarf huckleberry
Vaccinium globulare	N	globe huckleberry
Vaccinium myrtillus	N	low bilberry
Vaccinium scoparium	N	grouse whortleberry
Subshrubs or Low-woody Plants, including woody matformers and vines (V)		
Antennaria microphylla	N,P	rosy pussytoes
Antennaria neglecta	N,P	field pussytoes
Antennaria racemosa	N	raceme pussytoes
Arctostaphylos uva-ursi	N	kinnikinnick
Berberis repens	N	Oregongrape
Chimaphila umbellata	N	princes-pine or pipsissewa
Clematis columbiana	N (V)	clematis or virgins-bower
Cornus canadensis	N	bunchberry dogwood
Linnaea borealis	N	twinflower
Lonicera ciliosa	N (V)	orange honeysuckle
Lycopodium annotinum	N	clubmoss
Lycopodium complanatum	N	ground cedar
Pyrola secunda	N	one-sided wintergreen or sidebells pyrola
Rubus pubescens	N	dwarf red black raspberry
Selaginella densa	N	compact lesser-clubmoss
Veronica serpyllifolia	N	thyme leaved speedwell
Xerophyllum tenax	N,P	beargrass
Perennial Herbaceous Plants		
Achillea millefolium	N	yarrow
Achillea nobilis	X	yarrow
Actea rubra	N	baneberry
Adenocaulon bicolor	N	pathfinder or trail-plant
Agropyron intermedium	X	intermediate wheatgrass
Agropyron repens	X	quack grass
Agropyron spicatum	N,P	bluebunch wheatgrass
Agrostis alba	X	redtop
Agrostis exarata	N	bentgrass
Agrostis scabra	N	tickle-grass
Alisma plantago-aquatica	N	American waterplantain
Allium cernuum	N	nodding onion

Botanical name[a]	Status[b]	Common name[c]
Perennial Herbaceous Plants		
Alopecurus pratensis	X	meadow foxtail
Anaphalis margaritacea	N,P	common pearly-everlasting
Angelica arguta	N	angelica
Apocynum androsaemifolium	N	dogbane
Arabis hoeboellii	N	Holboell rockcress
Arceuthobium laricis	N,P	larch dwarfmistletoe
Aralia nudicaulis	N	wild sasparilla
Arenaria capillaris	N	sandwort
Arnica cordifolia	N	heart leaf arnica
Arnica latifolia	N,P	mountain arnica
Arnica rydbergii	N	Rydberg arnica
Artemisia absinthium	X	absinthium
Aster conspicuus	N	showy aster
Aster engelmannii	N	Engelmanns aster
Aster laevis	N,P	smooth aster
Aster modestus	N	great northern aster
Astragalus canadensis	N	Canada milkvetch
Athyrium filix-femina	N	lady fern
Botrychium virginianum	N	Virginia grapefern
Bromus carinatus	N,P	California brome
Bromus inermis	X,P	smooth brome
Bromus vulgaris	N	brome
Calamagrostis canadensis	N	bluejoint reedgrass
Calamagrostis rubescens	N	pinegrass
Callitriche verna	N	water starwort
Calochortus apiculatus	N	sego lily
Calypso bulbosa	N	fairy-slipper
Campanula rotundifolia	N	bellflower
Cardamine pensylvanica	N	bittercress
Carex concinnoides	N	northwest sedge
Carex cusickii	N	Cusick sedge
Carex deweyana	N	Dewey sedge
Carex geyeri	N	elk sedge
Carex lasiocarpa	N	slender sedge
Carex limnophila	N	pond sedge
Carex microptera	N	small winged sedge
Carex rossii	N	Ross sedge
Carex vesicaria	N	inflated sedge
Castilleja hispida	N	harsh paintbrush
Castilleja miniata	N	common paintbrush
Castilleja sulphurea	N	sulfur paintbrush
Centaurea maculosa	X	spotted knapweed
Chrysanthemum leucanthemum	X	oxeye-daisy
Cinna latifolia	N	woodreed
Circaea alpina	N	enchanters nightshade
Cirsium arvense	X	Canada thistle
Claytonia lanceolata	N	springbeauty
Clintonia uniflora	N	queenscup
Corallorhiza maculata	N	spotterd coralroot
Corallorhiza mertensiana	N	Mertens coralroot
Corallorhiza striata	N	striped coralroot
Corallorhiza trifida	N	yellow coralroot
Coronilla varia	X	crown vetch
Crepis acuminata	N	hawksbeard
Cypripedium montanum	N	mountain ladyslipper

Botanical name[a]	Status[b]	Common name[c]
Perennial Herbaceous Plants		
Dactylis glomerata	N,P	orchardgrass
Danthonia intermedia	N,P	timber oatgrass
Deschampsia cespitosa	P	tufted hairgrass
Deschampsia elongata	N	slender hairgrass
Disporum hookeri	N	Hooker fairybell
Disporum trachycarpum	N	wartberry fairybell
Dryopteris austriaca	N	woodfern
Dryopteris filix-mas	N	male fern
Elymus glaucus	N,P	blue wildrye
Epilobium angustifolium	N	fireweed
Epilobium glandulosum	N	willowherb
Epilobium watsonii	N	Watson willowherb
Equisetum arvense	N	common horsetail
Equisetum fluviatile	N	water horsetail
Equisetum hyemale	N	scouringrush
Equisetum sylvaticum	N	wood horsetail
Equisetum variegatum	N	variegated scouringrush
Erigeron peregrinus	N	subalpine daisy
Eriogonum flavum	N	yellow buckwheat
Erythronium grandiflorum	N	glacier lily
Festuca arundinaceae	X,P	tall fescue
Festuca occidentalis	N	western fescue
Festuca rubra	P	red fescue
Fragaria vesca	N	wild strawberry
Fragaria virginiana	N	wild strawberry
Galium boreale	N	northern bedstraw
Galium trifidum	N	small bedstraw
Galium triflorum	N	sweetscented bedstraw
Geum macrophyllum	N	geum
Glyceria elata	N	tall mannagrass
Glyceria grandis	N	American mannagrass
Goodyera oblongifolia	N	rattlesnake-plantain
Gymnocarpium dryopteris	N	oak fern
Habenaria dilatata	N	white bogorchid
Habenaria orbiculata	N	round leaf orchid
Habenaria saccata	N	slender bog orchid
Habenaria unalascensis	N	rein-orchid
Heracleum lanatum	N	cow-parsnip
Heuchera cylindrica	N	alumroot
Hieracium albertinum	N	hawkweed
Hieracium albiflorum	N	white hawkweed
Hieracium aurantaicum	X	king devil
Hieracium cynoglossoides	N	hawkweed
Hieracium floribundum	X	hawkweed
Hieracium gracile	N	subalpine hawkweed
Hypericum perforatum	X	goatweed or St. John's-wort
Iliamna rivularis	N	wild hollyhock
Juncus parryi	N	Parry rush
Juncus tenuis	N	slender rush
Lathyrus ochroleucus	N	peavine
Lemna minor	N	duckweed
Limosella aquatica	N	mudwort
Linaria vulgaris	X	butter and eggs
Listera caurina	N	twayblade
Listera cordata	N	heartleaf twayblade
Lomatium dissectum	N	fernleaf biscuitroot

Botanical name[a]	Status[b]	Common name[c]
Perennial Herbaceous Plants		
Lomatium sandbergii	N	Sandberg biscuitroot
Lotus corniculatus	X,P	birdsfoot trefoil
Lupinus argenteus	P	silvery lupine
Lupinus caudatus	N	tailcup lupine
Lupinus laxiflorus	N	spurred lupine
Luzula campestris	N	field woodrush
Luzula parviflora	N	smallflower woodrush
Lycopus uniflorus	N	bugleweed
Melica subulata	N	oniongrass
Mentha arvensis	N	field mint
Mitella nuda	N	mitrewort
Monotropa uniflora	N	Indian-pipe
Nuphar polysepalum	N	spatter-dock
Oryzopsis asperifolia	N	roughleaf ricegrass
Oryzopsis exigua	N	little ricegrass
Osmorhiza chilensis	N	sweetroot
Pedicularis bracteosa	N	lousewort
Pedicularis contorta	N	lousewort
Pedicularis racemosa	N	lousewort
Penstemon albertinus	N	Albert penstemon
Penstemon confertus	N	yellow penstemon
Penstemon fruticosus	X,P	shrubby penstemon
Penstemon venustus	X,P	Blue Mountain penstemon
Petasites sagittatus	N	arrowleaf coltsfoot
Phleum pratense	X	timothy
Plantago major	X	plantain
Poa compressa	X,P	Canada bluegrass
Poa pratensis	X,P	Kentucky bluegrass
Potentilla argentea	X	silvery cinquefoil
Potentilla glandulosa	N	sticky cinquefoil
Potentilla gracilis	N	cinquefoil
Potentilla palustris	N	marsh cinquefoil
Potentilla recta	X	sulpher cinquefoil
Prenanthes sagittata	N	prenanthes
Prunella vulgaris	X	selfheal or healall
Pteridium aquilinum	N	bracken fern
Pterospora andromedea	N	pinedrops
Pyrola asarifolia	N	pink pyrola
Pyrola chlorantha	N	greenish pyrola
Ranunculus acris	X	meadow buttercup
Rumex acetosella	X	sheep sorrel
Rumex crispus	X	curly dock
Rumex salicifolius	N	willow dock
Sagina saginoides	N	irish moss
Sanicula marilandica	N	snake-root
Scirpus microcarpus	N	small-fruited bulrush
Sedum lanceolatum	N	lanceleaf stonecrop
Sedum stenopetalum	N	common stonecrop
Senecio hydrophilus	N	alkali marsh butterweed
Senecio integerrimus	N	western groundsel
Senecio pseudaureus	N	streambank butterweed
Senecio serra	N	butterweed groundsel
Senecio triangularis	N	arrowleaf groundsel
Silene parryi	N	Parry silene
Sium suave	N	waterparsnip
Smilacina racemosa	N	false Solomon's seal

Botanical name[a]	Status[b]	Common name[c]
Perennial Herbaceous Plants		
Smilacina stellata	N	starry false Solomon's seal
Solidago canadensis	P	Canada goldenrod
Sparganium minimum	N	burreed
Spiranthes romanzoffiana	N	hooded ladiestresses
Stellaria calycantha	N	northern starwort
Stellaria crispa	N	crisped starwort
Stenanthium occidentale	N	stenanthium
Stipa occidentalis	N	needlegrass
Streptopus amplexifolius	N	twisted stalk
Tanacetum vulgare	X	tansey
Taraxacum laevigatum	X	redseed dandelion
Taraxacum officinale	X	common dandelion
Thalictrum occidentale	N	meadowrue
Tiarella trifoliata	N	false miterwort
Trifolium hybridum	X	alsike clover
Trifolium pratense	X	red clover
Trifolium repens	X,P	Dutch white clover
Trillium ovatum	N	trillium or wake-robin
Trisetum canescens	N	trisetum
Trisetum spicatum	N	spike trisetum
Veratrum viride	N	false hellebore
Veronica americana	N	veronica or speedwell
Vicia americana	N	vetch
Viola adunca	N	early blue violet
Viola canadensis	N	Canada violet
Viola glabella	N	stream violet
Viola macloskeyi	N	white violet
Viola orbiculata	N	roundleaf violet
Annual, biennial or short lived perennial Herbaceous Plants		
Arabidopsis thaliana	X	mouseear cress
Arabis glabra	X	towermustard
Arenaria serpyllifolia	X	thymeleaf sandwort
Cardamine pensylvanica	N	bittercress
Cirsium vulgare	X	bull thistle
Collinsia parviflora	N	blue-eyed Mary
Conyza canadensis	N	horseweed
Dianthus armeria	X	Deptford pink
Dracocephalum parviflorum	N	dragonhead
Epilobium paniculatum	N	annual willowherb
Erigeron acris	N	bitter fleabane
Erigeron philadelphicus	N	Philadelphia fleabane
Erigeron strigosus	N	daisy fleabane
Filago arvensis	X	filago
Gentiana amarella	N	annual gentian
Geranium bicknellii	N	Bicknell geranium
Gratiola neglecta	N	American hedge-hyssop
Lactuca biennis	N	tall blue lettuce
Lactuca serriola	X	prickly lettuce
Lolium multiflorum	P	Italian ryegrass
Lychnis alba	X	white campion
Madia glomerata	N	cluster tarweed
Matricaria matricarioides	N	pinapple weed
Medicago lupulina	X	black medic
Melampyrum lineare	N	cow-wheat

Botanical name[a]	Status[b]	Common name[c]
Annual, biennial or short lived perennial Herbaceous Plants		
Melilotus alba	X	white sweetclover
Melilotus officinalis	X	yellow sweetclover
Microsteris gracilis	N	microsteris
Myosotis micrantha	X	annual for-get-me-not
Poa annua	X	annual bluegrass
Polygonum douglasii	N	Douglas knotweed
Ranunculus uncinatus	N	little buttercup
Sanguisorba occidentalis	N	annual burnet
Senecio vulgaris	X	groundsel
Spergularia rubra	X	sandspurry
Tragopogon dubius	X	salsify or oyster plant
Trifolium agrarium	X	hop clover
Verbascum thapsus	X	mullein

[a]Botanical nomenclature: Hitchcock and Cronquist (1973)
[b]Indiginous status in Coram Experimental Forest
N Native plant species
X Exotic plant species (unintentional introduction)
P Species planted or seeded for experimental purposes (intentional introduction)
? Exotic introduction status uncertain
[c]Local usage given preference

Appendix B: Coram Experimental Forest Avian Checklist

These birds were identified on Coram Experimental Forest and were listed in Hasbrouck (1984), McClelland (1980, 1995), McClelland and others (1979), and Tobalske and others (1991).

Scientific name	Common name
Accipiter cooperii	Cooper's hawk
Aegolius acadicus	Saw-whet owl
Bombycilla cedrorum	Cedar waxwing
Bonasa umbellus	Ruffed grouse
Bucephala sp.	Goldeneye sp.
Buteo jamaicensis	Red-tailed hawk
Canachites canadensis	Spruce grouse
Carduelis pinus	Pine siskin
Carpodacus casinii	Cassin's finch
Catharus ustulatus	Swainson's thrush
Certhia americana	Brown creeper
Chaetura vauxi	Vaux's swift
Charadrius vociferus	Killdeer
Coccothraustes vespertinus	Evening grosbeak
Colaptes auratus	Northern flicker
Contopus borealis	Olive-sided flycatcher
Contopus sordidulus	Western wood-pewee
Corvus corax	Common raven
Cyanocitta stelleri	Steller's jay
Dendragapus obscurus	Blue grouse
Dendroica coronata	Yellow-rumped warbler
Dendroica petechia	Yellow warbler
Dendroica townsendi	Townsend's warbler
Dryocopus pileatus	Pileated woodpecker
Empidonax hammondii	Hammond's flycatcher
Empidonax oberholseri	Dusky flycatcher
Falco sparverius	American kestrel
Glaucidium gnoma	Pygmy owl
Hylocichla ustulata	Swainson's thrush
Icterus galbula	Northern oriole
Iridoprocne bicolor	Tree swallow
Ixoreus naevius	Varied thrush
Junco hyemalis	Dark-eyed junco
Loxia curvirostra	Red crossbill
Melanerpes lewis	Lewis's woodpecker
Molothrus ater	Brown-headed cowbird
Myadestes townsendi	Townsend's solitaire
Nucifraga columbiana	Clark's nutcracker
Nuttallornis borealis	Olive-sided flycatcher
Oporornis tolmiei	MacGillivray's warbler
Parus atricapillus	Black-capped chickadee
Parus gambeli	Mountain chickadee
Parus rufescens	Chestnut-backed chickadee
Passerella iliaca	Fox sparrow
Perisoreus canadensis	Gray jay
Pheucticus melanocephalus	Black-headed grosbeak
Picoides arcticus	Black-backed three-toed woodpecker
Picoides pubescens	Downy woodpecker
Picoides tridactylus	Three-toed woodpecker
Picoides villosus	Hairy woodpecker
Pinicola enucleator	Pine grosbeak
Piranga ludoviciana	Western tanager
Regulus calendula	Ruby-crowned kinglet
Regulus satrapa	Golden-crowned kinglet
Seirus noveboracensis	Northern waterthrush
Selasphorus rufus	Rufous hummingbird
Setophaga ruticilla	American redstart
Sialia currucoides	Mountain bluebird
Sitta canadensis	Red-breasted nuthatch
Sphyrapicus nuchalis	Red-naped sapsucker
Sphyrapicus thyroideus	Williamson's sapsucker
Sphyrapicus varius	Yellow-bellied sapsucker
Spinus pinus	Pine siskin
Spizella passerina	Chipping sparrow
Strix varia	Barred owl
Tachycineta bicolor	Tree swallow
Troglodytes aedon	House wren
Troglodytes troglodytes	Winter wren
Turdus migratorius	American robin
Vermivora celata	Orange-crowned warbler
Vireo gilvus	Warbling vireo
Vireo olivaceus	Red-eyed vireo
Vireo solitarius	Solitary vireo
Wilsonia pusilla	Wilson's warbler

Appendix C: Coram Experimental Forest Small Mammal Checklist (1998)

These small mammals were identified on Coram Experimental Forest and were listed in Gruemme (1994) and Shearer and Halvorson (1967).

Scientific name	Common name
Clethrionomys gapperi	Red-backed vole
Eutamias ruficaudus	Red-tailed chipmunk
Microtus pennsylvanicus	Meadow vole
Mustela frenata	Long-tailed weasel
Permyscus maniculatus	Deer mouse
Phenacomys intermedius	Montane spruce vole
Sorex cinereus	Masked shrew
Sorex monticolus	Dusky shrew
Sorex vagrans	Vagrant shrew
Tamiasciurus hudsonicus	Red squirrel
Zapus princeps	Western jumping mouse

Appendix D: Excerpts from the 1934 Coram Experimental Forest Timber Survey Report

Introduction

"The area includes approximately 2,207.3 acres (893 ha) of the Coram Experimental Forest, comprising a total of 7,244.5 acres (2,932 ha). The Forest is situated in the western larch/Douglas-fir type of northwestern Montana ... It lies in the main drainage of the Flathead and South Fork of the Flathead River... The immediate general location is east of the Coram Ranger Station, and west and south of Desert Mountain. All lands within the area are in National Forest ownership.

"In general, the topography of the area is very steep and frequented by numerous water eroded gullies and small benches. Except for the Abbott Creek and South Fork of Abbott Creek watersheds, which drain the north central and southern portions of the area respectively, the streams are all intermittent…."

Previous Land Surveys

"At present, practically all of the Experimental Forest area is unsurveyed for public land lines except portions of T31N, R19W, which was surveyed by the General Land Office in 1903. Immediately adjacent to the western forest boundary, in Sections 10 and 11, T30N, R19W, is located an H.E.S., No.817, of 135.7 acres (55 ha). The location of this site causes a series of angular jogs in the boundary. This area was surveyed out jointly by the Forest Service and General Land Office in 1918….

"A general timber reconnaissance of the South Fork of the Flathead River was completed in 1916. The purpose of this survey was to prepare general management plans for timber regulation, and for the examination of bodies of timber proposed for sale. A ten percent strip coverage was employed. Topography was mapped on a 50-foot (15 m) contour interval, with an intermediate 25-foot (8 m) interval used on very rough relief, on base maps of a scale of 4-inches (10 cm) to the mile. Volume estimates of each species in mature stands were obtained from the strip cruises and compiled by 40-acre (16 ha) subdivisions, expressed to the nearest M (thousand) board feet. A forest cover map was also compiled on the survey showing forest types, area, and limits of merchantable and accessible timber."

History and Personnel

"A three-man crew was used regularly on all strip and boundary surveys. The crews were characterized by flexibility in handling the work, all members being familiar with each job and able to fill in at any time.

"Due to the rigid time limit set up for finishing the survey and numerous miscellaneous jobs done on this area, it was practically impossible to carry out any regular system of check cruising. As a substitution measure, individual plot checks and considerable instruction were given regularly in the field, and members of the crews exchanged frequently in the estimating job, making checks on each other's work. In addition, check mapping was done on all boundary surveys and section line control…."

Forest Types and Descriptions

"Timber types were mapped in conjunction with age classes (fig. 54). It was the duty of one man on the crew to do all this mapping, together with topography on the area where this was included. With a ten percent strip coverage a standard of mapping areas closing in to 2 1/2 acres was adhered to for individual type and age classes. To maintain this standard considerable investigation, or side scouting, was often necessary on either side of the strip lines.

"Restocking cut-over areas, cut prior to 1929, with a present cover type of ten percent stocking or more, and experimental areas cut selectively at any time, were designated as Restocked Cut-overs (Re-Cu). Designations of this type were accompanied by a combination symbol listing the date of cutting and the timber type and age class of the present cutting type. Restocked cut-overs on the Coram Experimental Forest include subalpine, Engelmann spruce, lodgepole pine, and western larch, Douglas fir cover types now present.

"Only one small area on the forest, near the Desert Mountain Lookout, has been cut over since 1929. This was a selective cutting, removing all large trees for the purpose of increasing the visibility around the lookout. Most of the cuttings on the Coram area were made around the year 1916 and were included in the type maps of the 1916 timber reconnaissance.

"In 1929, the large Half Moon fire burned into the northwest and northeast corners of the forest. The acreage left from this fire constitutes the only relatively recent burned-over found on the forest."

Descriptions of 11 Forest Types Identified in the 1934 Timber Survey

"1. **Western Larch/Douglas-fir (WL-DF)**—75 percent or more of volume of a mixture of these two trees with the proportion of western larch varying from 10 percent to practically pure. Lodgepole pine, alpine fir, Engelmann spruce, and western white pine are often found in this mixture. Western larch is the key tree.

“2. **Douglas-fir (DF)**—60 percent or more of the volume of DF present. The principal associates in mixture are western larch, lodgepole pine, and Engelmann spruce. If there is 10% or more of western larch present, it goes into the western larch—Douglas-fir type.

“3. **Engelmann Spruce (ES)**—50 percent or more of Engelmann spruce by volume. May be found in pure stands, but usually associated with alpine fir, western larch and Douglas-fir, lodgepole pine, and white bark pine.

“4. **Lodgepole Pine (LPP)**—50 percent or more of lodgepole pine by volume. It is usually in pure stands, but sometimes in mixture with alpine fir, white bark pine, Douglas-fir, Engelmann spruce and western larch.

“5. **Western White Pine (WWP)**—15 percent or more of western white pine by volume. Western larch and Douglas-fir are usually the chief associates, with alpine fir, white bark pine, Engelmann spruce, and lodgepole pine also present in considerable amounts.

“6. **Subalpine (Alp)**—defined as containing a varying mixture of subalpine species, none of which are abundant enough to throw the stand into any of the types already described, or rarely in pure stands. Usually unmerchantable, and valuable for protective purposes only. Principal associates of the mixture are alpine fir, white bark pine, Douglas-fir, western larch, Engelmann spruce, lodgepole pine, and western white pine.

“7. **Brush (Br)**—Areas with an existing cover of shrubs or stunted trees usually of deciduous hardwood species.

“8. **Cultivated (Clt)**—an area under cultivation or lying fallow. No cultivated type was present on the Coram Experimental Forest, but a small area just outside the Forest boundary on H.E.S. No. 817 was included on the timber type and age class map.

“9. **Stump Pasture (StP)**—logged-off or burned-off lands as part of a farm unit now devoted to grazing, and upon which all the stumps and snags have not, as yet, been removed. No stump pasture type was present on the Coram Experimental Forest, but a small area just outside the Forest boundary on H.E.S. No. 817 was included on the timber type and age class map.

“10. **Restocked Cut-overs (Re-Cu)**—restocking cut-over areas, cut prior to 1929, with a present cover type of 10 percent stocking or more. On experimental areas this may include stands cut selectively at any time. Designations of this type are usually accompanied by a combination symbol listing the date of cutting with the timber type and age class of the present cover type. Restocked cut-overs on the Coram Experimental Forest include subalpine, Engelmann spruce, and western larch, Douglas-fir cover types now present.

“11. **Restocked Burns (Re-Bu)**—restocking burned-over areas, burned prior to 1929, with a present cover type of 10 percent stocking or more. Designations of this type are usually accompanied by a combination symbol listing the date of burn with the timber type and age class of the present cover type. Restocked burns on the Coram Experimental Forest include subalpine, and lodgepole pine cover types now present.”

RMRS
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