An Annotated Bibliography of Scientific Literature on Research and Management Activities Conducted in Coram Experimental Forest

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Adams, Gerard C.; Kropp, Bradley R. 1996. *Athelia arachnoidea*, the sexual state of *Rhizoctonia carotae*, a pathogen of carrot in cold storage. Mycologia. 88(3): 459-472. **Abstract**: *Athelia arachnoidea* was collected during winter on dead leaves of deciduous trees in Oregon. Minute sclerotia (0.2-1.0 mm) were seen on hymenia, whereas in culture sclerotia were much larger (1.0-5.0 mm). The pathogenicity, morphological characteristics, and temperature growth responses of the anamorphic state, were identical to *Rhizoctonia carotae*. The relationship between the sclerotial anamorph and the teleomorph was confirmed by DNA sequence of the internal transcribed spacers of the nuclear ribosomal repeat unit. The sequences were homologous among the specimens of *A. arachnoidea* and the sclerotial anamorph from Oregon, A. arachnoidea and *R. carotae* isolates from culture collections, and several isolates of *R. carotae* from carrot cold-storage facilities. Like *R. carotae, A. arachnoidea* produced abundant crystals of calcium oxalate on the hyphae, was pathogenic on carrot at 3 C, and caused crater rot symptoms equivalent in severity. Sclerotia of *A. arachnoidea-R. carotae* did not germinate under conditions suitable for eruptive germination in *A. rolfsii*. The DNA sequence of *A. epiphylla* from Europe was identical (within 6 bp) to *A. arachnoidea-R. carotae*, whereas *A. epiphylla* from North America varied by 34-46 independent base pair changes. *Athelia epiphylla* and *A. arachnoidea* formed similar sclerotia. Connecting the *Rhizoctonia* root pathogen to the *Athelia* teleomorph links the disparate literatures on the natural history of this fungus and reveals significant insights into the epidemiology of the disease. *Fibularhizoctonia* gen. nov. is proposed to encompass *Rhizoctonia* species with clamp connections, and the description of *R. carotae* and *R. centrifuga* are emended.

Adams, Mary Beth; Loughry, Linda; Plaugher, Linda, comps. 2004. Coram Experimental Forest (Montana). In: Experimental forests and ranges of the USDA Forest Service. Gen. Tech. Rep. NE-321. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station: 113-115. **Abstract**: The USDA Forest Service has an outstanding scientific resource in the 77 Experimental Forests and Ranges that exist across the United States and its territories. These valuable scientific resources incorporate a broad range of climates, forest types, research emphases, and history. This publication, revised in March 2008, describes each of the research sites within the Experimental Forests and Ranges network, providing information about history, climate, vegetation, soils, long-term data bases, research history and research

products, as well as identifying collaborative opportunities, and providing contact information.

Adams, Mary Beth; Loughry, Linda; Plaugher, Linda, comps. 2008. Coram Experimental Forest (Montana). In: Experimental forests and ranges of the USDA Forest Service. Gen. Tech. Rep. NE-321 (Revised). Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station: 113-115. **Abstract**: The USDA Forest Service has an outstanding scientific resource in the 79 Experimental Forests and Ranges that exist across the United States and its territories. These valuable scientific resources incorporate a broad range of climates, forest types, research emphases, and history. This publication describes each of the research sites within the Experimental Forests and Ranges network, providing information about history, climate, vegetation, soils, long-term data bases, research history and research products, as well as identifying collaborative opportunities, and providing contact information.

Arno, Stephen F. 1980. Forest fire history in the northern Rockies. Journal of Forestry. 78(8): 460-465. **Abstract**: Recent fire-scar studies in the northern Rocky Mountains have documented forest fire history over the past few centuries. They reveal that in some forest types fire maintained many-aged open stands of seral trees. In other types, major fires caused replacement of the stands. Often, however, fires burned at variable intensities, creating a mosaic of stands differing in composition and structure.

Arno, Stephen F.; Sneck, Kathleen M. 1977. A method for determining fire history in coniferous forests of the mountain west. Gen. Tech. Rep. INT-42. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 28 p. **Abstract**: This General Technical Report describes a method for investigating the history and ecological influences of wildfire in the inland coniferous forests of western North America. The method relies on the collection and analysis of cross sections of fire-scarred trees and the identification, from increment cores, of age classes of postfire tree species. In logged areas, fire-scar and age-class data can be gathered from stumps. The report covers selection and layout of study areas, and the collection and analysis of samples. The authors tell how to interpret fire frequency, intensity, and size, the influence of fire on stand composition and structure, and the effects of modern fire suppression.

Artley, Donald K.; Shearer, Raymond C.; Steele, Robert W. 1978. Effects of burning moist fuels on seedbed preparation in cutover western larch forests. Res. Pap. INT-211. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 14 p. **Abstract**: In early September 1975, two clearcuts, and one shelterwood cutting were broadcast burned principally for seedbed preparation and fuel reduction on the Coram Experimental Forest. The objective was to develop a model for predicting duff reduction and mineral soil exposure resulting from the fires, using only preburn measurements for inputs. In addition, the influence of the fires on soil heating, soil water content, and nonconiferous root mortality was quantified.
Because of the relatively low maximum air temperatures and high precipitation on the

study area during August, the fuels were relatively moist at the time of ignition. As a result, the fires generally spread poorly, especially in the shelterwood, except where the fuels were concentrated. The prescribed fires reduced the duff an average of 27 percent in the clearcuts and 11 percent in the shelterwood. Mineral soil exposure averaged 19 percent in the clearcuts and 10 percent in the shelterwood. The amount of water within the upper 4 inches of soil was not changed greatly, there was no significant heating of the surface soil above 113°F (45° C), and root mortality was low.
Multivariate regression analysis was used to derive prediction equations for duff reduction and mineral soil exposure. However, because of extremely poor correlation between the dependent variables, duff reduction and mineral soil exposure, and all combinations of the independent variables, no statistically valid equations resulted. The expected correlation between duff consumption and lower duff water content was not evidenced. This was attributed to the high water content of the duff itself, which averaged nearly 150 percent in the three blocks studied. These results substantiate Shearer's (1975) conclusions. Broadcast burning for seedbed preparation should not be attempted in this forest type when lower duff water contents exceed about 100 percent.

Aune, Philip S. 1991. Seed-tree method. In: Genetics/Silviculture Workshop proceedings; 1990 August 27-31; Wenatchee, WA. [Washington, DC]: U.S. Department of Agriculture, Forest Service: 224-234. **Abstract**: The seed-tree method has been used to successfully regenerate even-age stands for many years. This brief review of selected literature has described some of the key features for a successful seedtree system, including careful selection of the seed trees, adequate site preparation for natural regeneration, and control of competing vegetation. It is not clear if the seed-tree method will meet the larger postulation described in proposals for "new forestry" and "new perspectives." That applicability will depend on the development of clear stand-management objectives considering features such as composition, structure, and function of the resultant stand over time.

Barger, R. L. 1975. Toward more complete utilization. Western Wildlands. 2(2): 16-20. **Abstract**: This article reviews the research conducted by the Intermountain Forest and Range Experiment Station Forest Residues Utilization Research and Development Program pertaining to timber harvest activities and utilization of the wood resource. Research topics reviewed include utilization and engineering, resource inventory, economic analyses, and biological impacts of intensive utilization.

Barger, Roland L. 1980. The forest residues utilization program in brief. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: symposium proceedings; 1979 September 11-13; Missoula, MT. Gen. Tech. Rep. INT-90. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 7-25. **Abstract**: Since 1974, the Intermountain Experiment Station has directed a coordinated program of research, the Forest Residues Utilization R&D Program, toward investigating alternative timber harvesting practices that may facilitate more intensive, environmentally compatible, timber utilization. The evaluation of biological and resource management consequences of alternative harvesting practices has been a major component of the Program. Most of

the research has been conducted in forest ecosystems common to the lodgepole pine, larch, and Douglas-fir forests of Wyoming and Montana. Investigations of environmental consequences have covered an array of harvesting systems, silvicultural prescriptions, and utilization standards. Emphasis has been directed toward determining the biological consequences of successively more intensive levels of utilization, and alternative post-harvesting residue treatments. Although the research has necessarily been site-specific, the results have management implications for coniferous forests in general.

Barger, Roland L. 1981. The forest residues utilization R&D program. In: Harvesting and utilization opportunities for forest residues in the Northern Rocky Mountains: symposium proceedings; 1979 November 28-30; Missoula, MT. Gen. Tech. Rep. INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 5-16. **Abstract**: Since 1974 the Intermountain Station has directed an integrated program of research toward developing methods to achieve more efficient timber utilization, consistent with responsible management of the forest ecosystem. This research combines the efforts of scientists in utilization, engineering, economics, marketing, and the biological sciences. Research in residue characterization has defined the volume, character, and product potential of residues in various timber types and harvesting situations. Research in products, processes, and markets has included work relating to solid wood and chip and fiber products. Particular emphasis has been given the processing and use of dead timber, by far the largest residue component in the Intermountain West. Other research has explored the feasibility of achieving closer utilization with conventional cable and ground skidding harvesting systems under different silvicultural and management prescriptions. Related research is developing new harvesting system concepts and practices, with emphasis upon systems that can function more efficiently in handling small timber, residue material, and small volumes per acre. More efficient utilization of the wood resource represented by forest residues can substantially extend the resource base.

Barger, Roland L.; Benson, Robert E. 1981. Intensive utilization with conventional harvesting systems. In: Harvesting and utilization opportunities for forest residues in the Northern Rocky Mountains: symposium proceedings; 1979 November 28-30; Missoula, MT. Gen. Tech. Rep. INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 77-95. **Abstract**: Forest residues utilization research has included case studies of the efficiency of existing harvesting systems in achieving close fiber utilization. Field evaluations included the use of in-woods chipping systems in gentle terrain, crawler skidder systems in gentle terrain, and skyline systems in steep terrain. In each situation, utilization standards ranged from conventional saw log utilization to near-total utilization of available fiber. Intensive utilization has been achieved concurrent with saw log harvesting, rather than through postharvest salvage. The total costs of harvesting merchantable material and residue together are partitioned to derive costs of residue recovery. Costs of recovery vary significantly among the case situations studied, and also vary with the method by which costs are allocated. Residue recovery costs commonly run $30-$60 per dry ton ($33-$67 per tonne).

Barrett, Stephen W.; Arno, Stephen F.; Key, Carl H. 1991. Fire regimes of western larch-lodgepole pine forests in Glacier National Park, Montana. Canadian Journal of Forest Research. 21(12): 1711–1720. **Abstract**: We conducted a detailed investigation of fire frequencies, patterns of fire spread, and the effects of fire on tree succession in the western larch - lodgepole pine (*Larix occidentalis - Pinus contorta* var. *latifolia*) forests west of the Continental Divide in Glacier National Park, Montana. Master fire chronologies for 1650 to the present were constructed based on tree fire scars and fire-initiated age-classes. Two kinds of primeval fire regimes were identified: (i) a mixed-severity regime ranging from nonlethal underburns to stand-replacing fires at mean intervals of 25-75 years and (ii) a regime of infrequent stand-replacing fires at mean intervals of 140-340 years. The former regime is characteristic of the North Fork Flathead valley and appears to be linked to a relatively dry climate and gentler topography compared with the McDonald Creek - Apgar Mountains and Middle Fork Flathead areas, where the latter fire regime predominates. Fire frequency in the entire North Fork study area was 20 fire years per century prior to 1935 and 2 per century after 1935. In the other two study areas it was 3-5 per century both before and after 1935. We suggest that fire suppression has altered the primeval fire regime in the North Fork, but not in the central and southern areas.

Beaufait, William R. 1972. Fire and smoke in Montana forests. In: Weddle, Richard L., ed. Forest land use and the environment. Missoula, MT: University of Montana, Montana Forest and Conservation Experiment Station: 1-23. **Abstract**: Fuel accumulation, the natural role of fire, characteristics of smoke, and smoke production in Montana forests are reviewed. Resource management alternatives and factors that affect fire and fuels management decisions are discussed. The necessity to use fire as a tool in forest management is stressed.

Behan, Mark J. 1968. Fertilization in western larch forests. Note 6. Missoula, MT: University of Montana, Montana Forestry and Conservation Experiment Station. 14 p. (+figures and supplement). **Abstract**: This report describes the status of fertilization research in the western larch type in Montana and lists the locations of established experimental forest fertilization plots.

Benson, Robert E. 1980. Esthetic impacts of harvesting and residue management: Public preference ratings. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: symposium proceedings; 1979 September 11-13; Missoula, MT. Gen. Tech. Rep. INT-90. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 433-440. **Abstract**: The public concern about timber harvesting emphasizes its effect on the visual appearance of an area. The esthetic impact of different harvest and utilization alternatives were evaluated by the Scenic Beauty Estimation method that uses color slides rated by panels of viewers to provide a quantitative measure of public likes and dislikes. In general, the less an area shows logging debris and signs of soil disturbance, the better the area is liked. Esthetic quality improves as trees and other vegetation regenerate in the years after logging or road construction. These evaluations can

provide guidelines for harvesting, especially in visually sensitive areas, and a means for evaluating the effectiveness of alternative harvesting methods in meeting visual objectives.

Benson, Robert E.; Gonsior, Michael J. 1981. Tree damage from skyline logging in a western larch/Douglas-fir stand. Res. Pap. INT-268. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 15 p. **Abstract**: Damage to shelterwood leave trees and to understory trees in shelterwood and clearcut logging units logged with skyline yarders was measured, and related to stand conditions, harvesting specifications, and yarding system-terrain interactions. About 23 percent of the marked leave trees in the shelterwood units were killed in logging, and about 10 percent had moderate to serious damage. About 40 percent of the understory trees were killed. Heaviest damage in shelterwood was associated with steeper slopes, more trees per acre, and cross-slope angle to the skyline. Understory damage was greater on larger saplings than on seedlings.

Benson, Robert E.; Johnston, Cameron M. 1976. Logging residues under different stand and harvesting conditions, Rocky Mountains. Res. Pap. INT-181. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 15 p. **Abstract**: Volume and characteristics of logging residues from 34 clearcut and partial cut harvest areas are presented. Residue volumes ranged from almost 3,600 cubic feet per acre down to 550 cubic feet per acre, depending on treatment. More than 60% of the residues were sound.

Benson, Robert E.; Schlieter, Joyce A. 1980. Logging residues in principal forest types of the northern Rocky Mountains. Res. Pap. INT-260. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 14 p. **Abstract**: An estimated 466 million ft^3 of forest residue material (nonmerchantable, 3 inches diameter and larger) is generated annually in the Northern Rocky Mountains (Montana, Idaho, Wyoming). Extensive studies of residues in the major forest types show a considerable portion is suited for various products. The lodgepole pine type has the greatest potential for increased residue utilization. In most other forest types, form and condition of residues limit potential use to fiber or fuel. In all forest types, volume, condition, and product potential vary widely from stand to stand.

Benson, Robert E.; Schlieter, Joyce A. 1980. Appendix supplement to: Volume and weight characteristics of a typical Douglas- fir/western larch stand, Coram Experimental Forest, Montana. GTR-INT-92. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Forestry Sciences Laboratory. 135 p. **Abstract**: In 1973, an intensive study was begun on the Coram Experimental forest in northwestern Montana. One of the study objectives was to compare three silvicultural cutting methods and four levels of utilization before and after harvest. The purpose of this report is to make available detailed preharvest and postharvest information that was obtained for each cutting-utilization treatment combination. This information supplements the data contained in the General Technical Report INT-92, “Volume and weight Characteristics of a Typical Douglas-fir/western

larch Stand" by Benson and Schlieter (1980).

Benson, Robert E.; Schlieter, Joyce A. 1980. Volume and weight characteristics of a typical Douglas-fir/western larch stand, Coram Experimental Forest, Montana. Gen. Tech. Rep. INT-92. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 28 p. **Abstract**: An overmature Douglas-fir/western larch stand on the Coram Experimental Forest in Montana was skyline logged using three different cutting methods and four different levels of utilization. Prior to harvest, the total volume of wood averaged 7,300 ft^3/ acre (511 m^3/ha) and ranged from 4,400 to 15,000 ft^3/acre (308 to 1,042 m^3/ha) on the various cutting units. Fifty-seven percent of this was sound green material; the rest was dead or rotten. In addition, there was about 57 tons/acre (128 t/ha) of fine material including tree crowns, duff, and litter. After harvest, the volume of wood remaining ranged from about 40 percent of the preharvest volume in conventional saw log utilization to under 20 percent where intensive utilization was practiced. Type of material and size of residues also varied by utilization treatment. Fine material increased from 3 to 10 tons/acre (7 to 22 t/ha) depending on utilization level. The amount and condition of woody material and changes with harvesting on this typical site provide a basis for evaluating woody biomass conditions before harvesting is undertaken.

Benson, Robert E.; Schlieter, Joyce A. 1980. Woody material in northern Rocky Mountain forests: volume, characteristics, and changes with harvesting. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: symposium proceedings; 1979 September 11-13; Missoula, MT. Gen. Tech. Rep. INT-90. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 27-36. **Abstract**: In mature coniferous stands in the Northern Rockies, total volume of wood 3 inches in diameter (7.6 cm) and larger, ranges from 3,000 to 8,000 ft^3/a (210 to 560 m^3/ha). Typically about half of this volume is removed in logging, and the remaining residues include up to 50 percent or more sound wood, plus material in various stages of decay. In Wyoming, Montana, and Idaho over 450 million ft^3 (13 million m^3) of residue may be left on site annually, but residue is being utilized to meet demands for wood.

Benson, Robert E.; Schlieter, Joyce A. 1981. Residue characteristics in the Northern Rocky Mountains. In: Harvesting and utilization opportunities for forest residues in the Northern Rocky Mountains: symposium proceedings; 1979 November 28-30; Missoula, MT. Gen. Tech. Rep. INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 33-43. **Abstract**: In the northern Rocky Mountains, 350-450 million cubic feet (9.9 to 12.7 million m^3) of logging residue is generated each year. This residue consists of dead standing and down trees, green unmerchantable trees, broken pieces and the tops and branches of those trees removed in logging. Up to 60 percent of the residue material is technologically suitable for wood products, but condition, size and product potential vary among forest types. Other factors which influence residue utilization are level of harvest, trends in wood processing, industrial uses and economic conditions.

Benson, Robert E.; Ullrich, James R. 1981. Visual impacts of forest management activities: findings on public preferences. Res. Pap. INT-262. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 14 p. **Abstract**: The visual impact of various timber harvest and road construction alternatives was measured using the Scenic Beauty Estimation Method. Panels of viewers rated color slides on a 0 to 9 scale of "dislike" versus "like." Numerous case studies have shown the method gives consistent and reliable measures of viewer preferences. In general, partial harvesting is preferred to clearcutting: the less logging debris, the higher the preference. In addition, less soil disturbance and more revegetation along roads, the higher the preference.

Bidlake, William R.; Black, R. Alan. 1989. Vertical distribution of leaf area in *Larix occidentalis*: a comparison of two estimation methods. Canadian Journal of Forest Research. 19(9): 1131-1136. **Abstract**: Total leaf-area index and the vertical distribution of leaf-area index were described for an unthinned stand (density 11 250 stems/ha) and a thinned stand (density 1660 stems/ha) of 30-year-old *Larix occidentalis* Nutt. Two independent methods were used to estimate leaf-area index in each of the two stands. The first method is based on allometric relationships that are applied to stem measurements, and the second method is based on gap-fraction analysis of fisheye photographs. Leaf-area index estimates obtained by the two methods were not significantly different. The gap-fraction method provides a desirable alternative because much less fieldwork is required, however, use of this method is limited to canopies where the light-blocking elements are randomly displayed. Total leaf-area index values for the unthinned and thinned stands were 5.0 and 3.6, respectively. The vertical distribution of leaf-area index in the unthinned stand resembled a normal distribution. The vertical distribution of leaf-area index in the thinned stand would have resembled a normal distribution, except that thinning operations resulted in a truncated distribution of leaf-area index at the canopy base.

Boe, Kenneth N. 1953. Western larch and Douglas-fir seed dispersal into clearcuttings. Res. Note No. 129. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p. **Abstract**: Western larch and Douglas-fir seed dispersal into clearcut stands was measured in Coram Experimental Forest. Seeds were trapped and counted at regular intervals across cutting units. The quantity of seed that fell to the ground decreased rapidly from the timber edge up to about four chains for Douglas-fir and six chains for larch. Beyond these distances the quantity remained fairly constant at a low level to the farthest sampling point 12 chains (792 feet) from the source.

Boe, Kenneth N. 1958. Silvics of western larch. Misc. Pub. 16. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 17 p. **Abstract**: The silvics of the more important North American tree species are being collected and published by the U. S. Forest Service experiment stations. This report is the second of seven including western white pine, ponderosa pine, lodgepole pine, western larch, western redcedar, grand fir, and black cottonwood being prepared by the Intermountain Forest and Range Experiment Station.

Brown, James K. 1980. Influence of harvesting and residues on fuels and fuel management. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: symposium proceedings; 1979 September 11-13; Missoula, MT. Gen. Tech. Rep. INT-90. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 417-432. **Abstract**: Fuel and fire behavior potential in clearcut lodgepole pine and in Douglas-fir/larch under clearcutting, group selection, and shelterwood silvicultural systems were compared after logging to near-complete and conventional utilization standards. Fuels and fire behavior potentials were unaffected by silvicultural systems but varied substantially by utilization standards and method of skidding. Predicted rates of spread on conventional units were 3-4 times greater than on near complete units. Predicted fireline intensities were 6-10 times greater on the conventional units. Conventional utilization left fireline intensities exceeding capabilities for direct fire control for 3-5 years up to 20 years or more. Whole tree skidding without slashing reduced hazard to acceptable levels by trampling and transporting material from the site. Fuel less than 0.25 inches in diameter was reduced to 0.4 of that created by cutting while all fuel less than 3 inches in diameter was reduced to 0.7 of that created by cutting. Whole tree skidding coupled with slashing left unacceptable hazards for 3-5 years. Near-complete utilization left acceptable levels of hazard but also left insufficient fuel for prescribed burning. Methods with which land managers can appraise fuel and fire behavior potentials on specific cutting units are presented. Deciding "how much fuel is acceptable" is discussed.

Brown, James K.; Marsden, Michael A.; Ryan, Kevin C.; Reinhardt, Elizabeth D. 1985. Predicting duff and woody fuel consumed by prescribed fire in the northern Rocky Mountains. Res. Pap. INT-337. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 23 p. **Abstract**: Relationships for predicting duff reduction, mineral soil exposure, and consumption of downed woody fuel were determined to assist in planning prescribed fires. Independent variables included lower and entire duff moisture contents, loadings of downed woody fuels, duff depth, National Fire-Danger Rating System 1,000-hour moisture content, and Canadian Duff Moisture Codes. Results apply to a number of mesic forest cover types.

Carlson, Clinton E.; Dewey, Jerald E. 1971. Environmental pollution by fluorides in Flathead National Forest and Glacier National Park. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region Headquarters, Division of State and Private Forestry, Insect and Disease Branch. 57 p. **Abstract**: The US Forest Service initiated a study in 1969 to determine the major cause of vegetational injury and damage on forested lands proximal to the Anaconda Aluminum Company, the source of the cause, the area affected, whether insects were accumulating fluorides, and if insect populations were being affected by fluorides in the Flathead National Forest and Glacier National Park. Fluorides emitted from the Anaconda Aluminum Company were determined to be the primary cause of the injury and damage to vegetation in the surrounding area. Data indicated that fluorides were carried by air movement to Glacier National Park. Varying degrees of visible fluoride injury were found on more than 69,120 acres. Elevated fluoride levels were found in vegetation on more than 214,000 acres.

Histological reactions to elevated fluorides occur in conifer needle tissue. Fluorides were found to accumulate in insect tissue. Insect population samples indicated that elevated fluoride levels in pine needles leads to a buildup of the pine needle scale.

Carlson, Clinton E.; Schmidt, Wyman C. 1989. Influence of overstory removal and western spruce budworm defoliation on growth of advance conifer regeneration in Montana. Res. Pap. INT-409. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 14 p. **Abstract**: Twelve-year postharvest diameter growth of advance Douglas-fir, Engelmann spruce, and subalpine fir regeneration and 11-year height growth of Douglas-fir and subalpine fir accelerated in response to decreasing competition. Competition was reflected in degree of overstory removal and change in plot basal area. Notwithstanding the influence of change in competition, the most influential variable affecting postharvest height and diameter growth was 10-year radial growth prior to overstory removal; trees growing well before harvest grew well after harvest. Postharvest mortality was greatest where about 50 percent of the overstory was removed. Defoliation by western spruce budworm reduced growth of Douglas-fir but did not affect subalpine fir or Engelmann spruce.

Celebration Committee. 1996. Flathead community celebration—living in the landscape. U.S. MAB Bulletin. 20(3): 3,7. **Abstract**: Coram Experimental Forest, which has been a biosphere reserve since 1976, will celebrate its 50th year of continuous research in 1998. Miller Creek Demonstration Forest, a nearby study area, marks its 30th year of research in 1997. These sites plus Glacier National Park, a biosphere reserve since 1976, and other long-term study areas have become the object for a celebration of research and other community sponsored activities in the upper Flathead River valley.

Chew, Jimmie D.; Reinhardt, Elizabeth D. 1995. Knowledge-based systems for *Larix* forests. In: Schmidt, Wyman C.; McDonald, Kathy J., Ecology and management of *Larix* forests: a look ahead: proceedings of an international symposium; 1992 October 5-9; Whitefish, MT. Gen. Tech. Rep. INT-319. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 476-477. **Abstract**: This article reviews knowledge-based systems that can be used to manage *Larix* forests. Knowledge-based systems that are currently being developed or employed include: landscape analysis system, stand diagnosis system (expert system), stand culture system (based on silvicultural research), and prescribed fire system (based on prescribed fire research and expertise).

Chew, Jimmie D.; Stalling, Christine; Moeller, Kirk. 2004. Integrating knowledge for simulating vegetation change at landscape scales. Western Journal of Applied Forestry. 19(2): 102-108. Managers of public lands are increasingly faced with making planning decisions for dynamic landscapes with conflicting objectives. A modeling system has been designed to serve as a decision support system to help managers and resource specialists integrate the available knowledge of vegetation change and disturbance processes, and quantify concepts that are often difficult to interpret for specific landscapes. The system is named SIMPPLLE, an acronym taken from “SIMulating vegetation Patterns and Processes at Landscape scaLEs.” SIMPPLLE can be used to

help define and evaluate future conditions at landscape scales, to identify areas that are more prone to disturbances over a given time frame, to identify the options for influencing these disturbance processes, and to help design and evaluate different strategies for achieving desired future conditions. The emphasis in this article is to give an overview of the design of the system, the types of knowledge integrated, and the type of output produced. The initial validation work discussed indicates that the approach used for capturing and integrating process knowledge in SIMPPLLE does predict realistic results at landscape scales. SIMPPLLE provides managers a tool to integrate and interpret concepts of desired future conditions, range of variability, and the interaction between vegetation patterns and disturbance processes. SIMPPLLE provides a way to help evaluate proposed management scenarios within a future that includes stochastic processes.

Cole, Dennis M.; Schmidt, Wyman C. 1986. Site treatments influence development of a young mixed-species western larch stand. Res. Pap. INT-364. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 p. **Abstract**: Four treatments, all combinations of leaving or removing residual trees and shrubs or scarifying or not scarifying seedbeds, were evaluated for species differences in growth, vigor, and expression of dominance. Western larch was the dominant species in regeneration and growth but had begun to lose some of its advantage by age 25, particularly on scarified areas where overstocking commonly occurred. Douglas-fir was less sensitive to the treatments and, although significantly slower in absolute growth than larch, began to accelerate after 15 years of age. This study confirms that early cleaning and thinning will be necessary to achieve composition, density, and performance goals.

Davis, Kathleen M. 1980. Fire history of a western larch/Douglas-fir forest type in northwestern Montana. In: Stokes, Marvin A.; Dieterich, John H., tech. coords. Proceedings of the fire history workshop; 1980 October 20-24; Tucson, AZ. Gen. Tech. Rep. RM-81. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 69-74. **Abstract**: Mean frequencies were about 120 years for valleys and montane slopes and 150 years for subalpine slopes in this western larch/Douglas-fir forest from 1735 to 1976. 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.

DeSante, David F.; Burton, Kenneth M.; O'Grady, Danielle R. 1996. The monitoring avian productivity and survivorship (MAPS) program fourth and fifth annual report (1993 and 1994). Bird Populations. 3: 67-120. **Abstract**: The fourth and fifth annual reports of the Monitoring Avian Productivity and Survivorship (MAPS) Program, covering data collected during 1993 and 1994, are combined here. This report provides a brief review of the background, objectives, and methodology of the MAPS Program, summarizes the results of the fifth and sixth years of the Program (1993 and 1994), and compares these results with those of the immediately preceding years. MAPS continued to grow from 178 stations in 1992 to 236 stations in 1993 (a 33% increase) and to 326 stations in

1994 (a 38% increase). Changes between 1992 and 1993 in adult population size and post-fledging productivity were determined from 144 stations operated in a constant-effort manner in the two years, while changes between 1993 and 1994 were derived from constant-effort data from 213 stations operated comparably in both years. Indices of adult population size generally tended to decrease between 1992 and 1993 all across the continent; the decreases in the Northwest were highly significant and may have been caused by low recruitment of new breeders due to heavy, late-lingering snowpacks in montane areas throughout the Northwest Region. The patterns of decreases across the continent generally mirrored analagous patterns from the North American Breeding Bird Survey (BBS). Productivity (proportion of young in the catch) also decreased significantly in the Northwest, but tended to increase elsewhere, particularly in the Northeast Region. Indices of adult population size tended to remain stable between 1993 and 1994 in the Northwest, tended to decline in the North-central Region, and showed mixed trends over the rest of the continent; most species that declined in 1993 appeared to recover somewhat in 1994. Population changes from MAPS between 1993 and 1994 mirrored analagous changes from the BBS only in western regions. Productivity increased significantly in 1994 in the Northwest and tended to increase slightly in most other regions. Productivity indices were affected significantly by year, nest location, and migration strategy; cavity nesters and permanent resident species showed the highest productivity indices, while tree and (especially) shrub nesters and Neotropical-wintering species showed the lowest. Estimates of adult survival rates were obtained from four years (1991-1994) of data for the Northwest and Northeast regions and for all of eastern North America using the standard Cormack-Jolly-Seber ("non-transient") model and a newly developed "transient" model that provides estimates for the proportion of (summer) resident individuals among newly-captured adults and the survival probability of those resident birds. The transient model was selected as the most appropriate (or a competing) model [by means of the Akaike Information Criterion (AIC)] for about 62% of the species. On average, use of the transient model increased estimates of survival and recapture probabilities by 34% and 41%, respectively; with little or no loss in the precision of the estimates. The increase in precision of estimates of survival rates by including a fourth year of data was comparable to a seven-fold increase in the number of stations contributing data.

DeSante, David F.; Walker, Brett L. 1994. The 1993 annual report of the monitoring avian productivity and survivorship (MAPS) program on the Flathead National Forest. Point Reyes Station, CA: The Institute for Bird Populations. 40 p. **Abstract**: Six Monitoring Avian Productivity and Survivorship (MAPS) stations were established on or adjacent to Flathead National Forest, including one site in Coram Experimental Forest. Bird count and habitat data were collected to estimate adult population size, post-fledging productivity, adult survivorship, and recruitment into the adult population for various landbird species. During the summer of 1993, a total of 697 birds and 49 species were captured with highest capture rates from stations that included substantial meadow or riparian habitat. The capture rate of adult birds and young birds of all species pooled, decreased from 1992 to 1993 (by 23% and 55.9%, respectively). These decreases in estimated population size and productivity were likely due to the heavy

and late-melting snowpack and rainy spring-summer in 1993.

Elzinga, Caryl; Shearer, Raymond C.; Elzinga, Glenn. 2005. Observer variation in tree diameter measurements. Western Journal of Applied Forestry. 20(2): 134-137. **Abstract**: Tree diameter breast height (dbh) was measured on 879 permanently marked trees by two experienced professional foresters. Error rates were approximately equal between observers. Measurement error rates of 5% of tree diameter or greater may be expected in dbh measurements on as many as 5% of measured trees.

Elzinga, Caryl L.; Shearer, Raymond C. 1997. Vegetation structure in old-growth stands in the Coram Research Natural Area in northwestern Montana. Gen. Tech. Rep. INT-GTR-364. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 22 p. **Abstract**: Forest stand structure, understory composition, and tree seedling composition are described for eight permanent tenth-hectare plots established in Engelmann spruce/subalpine fir, western larch, and interior Douglas-fir forest cover types in northwestern Montana. Sites have been protected as examples of old-growth stands since the establishment of the Coram Research Natural Area in 1937. Plot data clearly illustrate a successional trend toward shade-tolerant conifers, placing old-growth stands at risk of loss from succession or catastrophic fire. Management issues associated with use of prescribed fire to maintain old-growth characteristics in natural areas are discussed.

Embry, Robert Samuel, Jr. 1960. A soil-site study of western larch (*Larix occidentalis*, Nuttall) in Montana. Missoula, MT: Montana State University. 47 p. Thesis. **Abstract**: The purpose of this study was to determine if there were any soil physical properties or physiographic features that might be used as an index to predict the growth of western larch (*Larix occidentalis*, Nutt.) in Montana.

Evenden, Angela G. 1995. *Larix lyallii* and *Larix occidentalis* within USDA Forest Service Research Natural Areas. In: Schmidt, Wyman C.; McDonald, Kathy J., Ecology and management of *Larix* forests: a look ahead: proceedings of an international symposium; 1992 October 5-9; Whitefish, MT. Gen. Tech. Rep. INT-319. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 483-485. **Abstract**: This article contains a list of Research Natural Areas (RNAs) on National forest System lands in Idaho, Montana, Oregon, and Washington representing subalpine forests dominated by western larch (L*arix occidentalis*) and subalpine larch (*Larix lyalli*). The National Forest, size, elevational range, and associated tree species of each RNA are included.

Evenden, Angela G.; Moeur, Melinda; Shelly, J. Stephen; Kimball, Shannon F.; Wellner, Charles A. 2001. Research natural areas on national forest system lands in Idaho, Montana, Nevada, Utah, and western Wyoming: a guidebook for scientists, managers, and educators. Gen. Tech. Rep. RMRS-GTR-69. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 84 p. **Abstract**: This guidebook is intended to familiarize land resource managers, scientists, educators, and others with Research Natural Areas (RNAs) managed by the USDA Forest Service in

the Northern Rocky Mountains and Intermountain West. This guidebook facilitates broader recognition and use of these valuable natural areas by describing the RNA network, past and current research and monitoring, management, and how to use RNAs.

Farnes, Phillip E.; Shearer, Raymond C.; McCaughey, Ward W.; Hansen, Katherine J. 1995. Comparisons of hydrology, geology, and physical characteristics between Tenderfoot Creek Experimental Forest (east side) Montana, and Coram Experimental Forest (west side) Montana. Final Report RJVA-INT-92734. Bozeman, MT: Montana State University, College of Letters and Sciences, Department of Earth Sciences. 19 p. **Abstract**: Physical features, precipitation rates and patterns, temperature, streamflow patterns, and runoff are compared between Tenderfoot Creek Experimental Forest and Coram Experimental Forest.

Federal Committee on Ecological Reserves. 1977. Coram Research Natural Area. In: A directory of research natural areas on Federal lands of the United States of America. Washington, DC: U.S. Department of Agriculture, Forest Service: 123. **Abstract**: This directory provides basic establishment, location, size, ownership, and descriptive information for the Research Natural Areas on Federal Lands of the U.S. Coram Experimental Forest is included.

Fellin, David G. 1980. A review of some interactions between harvesting, residue management, fire, and forest insects and diseases. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: symposium proceedings; 1979 September 11-13; Missoula, MT. Gen. Tech. Rep. INT-90. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 335-414. **Abstract**: Many species of insects and diseases create residues that predispose forests to fire. Conversely, natural factors such as fire, wind-throw, and other agents create forest residues that predispose forests to diseases and insects, including bark and cambium beetles, wood borers, and others. Man-made residues also predispose forests to insects and disease.
Harvesting practices, residue management, and fire management not only influence the behavior and impact of forest insects, but also can be used to suppress some insect and disease populations. These practices also have a profound influence--mostly negative--on forest floor and forest soil arthropods, many of which (in concert with wood-destroying fungi) are involved in both the micro- and macro-deterioration and dispersion of forest residues. Opinions vary concerning the value of removing residues through prescribed fire to manage forest insects and diseases. Harvesting, residue management, and fire management are inextricably tied to forest succession.
The interactions between harvesting, residues, fire, insects, and diseases have many implications for the resource manager. Future research should provide a better understanding of these interactions and will likely enhance our opportunity to reduce the negative impacts of many species of indigenous insects and diseases in managed forests.

Fellin, David G. 1980. Effect of silvicultural practices, residue utilization, and prescribed

fire on some forest floor arthropods. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: symposium proceedings; 1979 September 11-13; Missoula, MT. Gen. Tech. Rep. INT-90. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 287-316. **Abstract**: The combined effects of two silvicultural practices--shelterwood and clearcutting--and two residue management practices--intense fiber removal (utilization) and residue removal by prescribed fire--on forest floor arthropods (macrofauna) are discussed. Arthropods most abundant on the study area and most affected by treatments were spiders (Arachnida:Araneida), ants (Hymenoptera: Formicidae), and beetles (Coleoptera), especially the families Carabidae and Staphylinidae.
Although some populations increased between treatments or years, most treatments adversely affected most groups of macrofauna, particularly the second and third year, respectively, after burning and harvesting. Prescribed burning of residues stimulated a resurgence of some groups. The five treatments studied could be ranked in a decreasing impact on forest floor fauna in the following order: shelterwood cutting and leave residues, shelterwood and burn residues, shelterwood and mechanically remove residues (intense fiber utilization), clearcut and burn residues, clearcut and mechanically remove residues. Management implications of the effects of these harvesting and residue treatments on surface arthropods are discussed.

Fellin, David G. 1980. Populations of some forest litter, humus, and soil arthropods as affected by silvicultural practices, residue utilization, and prescribed fire. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: symposium proceedings; 1979 September 11-13; Missoula, MT. Gen. Tech. Rep. INT-90. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 317-334. **Abstract**: The combined effects of two silvicultural practices--shelterwood and clearcutting--and two residue management practices--intense fiber removal (utilization) and residue removal by prescribed fire--on forest litter, humus, and soil arthropods (mesofauna) are discussed. Arthropods most abundant on the study area and most affected by treatment were mites (Arachnida, Acarina) and springtails (Insecta, Collembola). These and other arthropods collected are listed and their seasonal and vertical distribution presented. Preliminary results of these four treatments are presented, and the management implications of the harvesting and residue utilization treatments discussed.

Fellin, David G.; Schmidt, Wyman C. 1967. Spruce budworm larvae sever stems of western larch shoots in Montana. Journal of Forestry. 65(4): 258-260. **Abstract**: Spruce budworm larvae are severing stems of terminal and lateral shoots of young western latch in some western Montana forests. Rapid juvenile height growth and excellent form--two highly desirable characteristics of larch--are jeopardized. Severance of terminal shoots is producing trees with multiple leaders and crooked boles. Severance of lateral shoots is less common and less serious. The long-range impact of this budworm damage on larch regeneration is being studied.

Fellin, David G.; Schmidt, Wyman C. 1973. How does western spruce budworm feeding

affect western larch? Gen. Tech. Rep. INT-7. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 25 p. **Abstract**: This pictorial describes how western spruce budworm larvae feed on young western larch and the trees' responses to this damage. Larvae feed not only on the current year's foliage-their usual diet on most coniferous hosts- but also sever stems of current year's shoots. Multiple-topped, bushlike trees develop in direct response to the amount and type of damage. As a result, trees cannot maintain straight boles and good form. Sustained budworm damage could conceivably influence the management of western larch-one of the more important conifers in the northern Rockies.

Finklin, Arnold I. 1986. A climatic handbook for Glacier National Park—with data for Waterton Lakes National Park. Gen. Tech. Rep. INT-204. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 124 p. **Abstract**: This publication presents climatic details for the Glacier National Park-Waterton Lakes National Park area in northwestern Montana-Alberta; data and analysis mainly cover the Montana area. The content, including numerous tables and graphs, is intended to provide information to aid fire management planning and other wildland resource activities. Data are summarized and analyzed from year-round climatological stations, fire-weather stations, and additional sources. Weather and climatic elements are examined individually. Combinations of temperature, relative humidity, and windspeed data are included for the fire season. In addition, the relationship of climatic conditions to topography, weather correlations between stations, persistence of weather, and climatic trends are examined.

Franklin, Jerry F. 1977. The biosphere reserve program in the United States. Science. 195(4275): 262-267. **Abstract**: The objective of the biosphere reserve program is to identify and protect representative and unique segments of the world's biotic provinces as major centers for biotic and genetic preservation, ecological and environmental research, education, and demonstration. It is intended to be more than simply another program of preservation layered onto existing parks and reserves. The success of the program will depend in large measure on the overall significance of the selected reserves and the degree to which they are active sites for scientific research and monitoring.

Franklin, Jerry F. 1979. The conceptual basis for selection of US Biosphere Reserves and features of established areas. In: Franklin, Jerry F.; Krugman, Stanley L., coords. Selection, management and utilization of biosphere reserves: proceedings of the United States--Union of Soviet Socialist Republics Symposium on Biosphere Reserves. Gen.Tech. Rep. PNW-82 Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station: 3-27. **Abstract**: This publication is directed to the analysis of the selection, management, and utilization of Biosphere Reserves as viewed by scientists from the United States and the Union of Soviet Socialist Republics. Soviet papers focus on types of research and monitoring programs that should be developed on Biosphere Reserves, with emphasis on their use in pollutant monitoring. The nature of the U.S. Biosphere Reserves and their current and potential value for research, education, and biological preservation is considered in the

U.S. papers. An additional paper provides an international perspective on U.S. and Soviet collaboration in the field of Biosphere Reserves. Characteristics of Soviet Biosphere Reserves are described in an appendix.

Franklin, J. F.; Krugman, S. L., coords. 1979. Selection, management, and utilization of biosphere reserves: proceedings of the United States-Union of Soviet Socialist Republics Symposium on Biosphere Reserves. Gen.Tech. Rep. PNW-82 82 p. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. **Abstract**: This publication is directed to the analysis of the selection, management, and utilization of Biosphere Reserves as viewed by scientists from the United States and the Union of Soviet Socialist Republics. Soviet papers focus on types of research and monitoring programs that should be developed on Biosphere Reserves, with emphasis on their use in pollutant monitoring. The nature of the U.S. Biosphere Reserves and their current and potential value for research, education, and biological preservation is considered in the U.S. papers. An additional paper provides an international perspective on U.S. and Soviet collaboration in the field of Biosphere Reserves. Characteristics of Soviet Biosphere Reserves are described in an appendix.

Gannon, Amy; Sontag, Scott, comps. 2007. Montana forest insect and disease conditions and program highlights. Report 08-1. U.S. Department of Agriculture, Forest Service, Northern Region, Forest Health Protection; Montana Department of Natural Resources and Conservation, Forestry Division. 80 p. **Abstract**: This report summarizes the major forest insect and disease conditions in Montana during 2007 and was jointly prepared by the Montana Department of Natural Resources and Conservation, Forestry Division and USDA Forest Service (FS), Forest Health Protection (FHP), State and Private Forestry, Northern Region. Information for this report was derived from ground and aerial surveys within Reporting Areas across parts of Montana. A Reporting Area includes all federal, state, and private land ownerships within a particular geographic boundary.

Gardner, Rulon B. 1978. Cost, performance, and esthetic impacts of an experimental forest road in Montana. Res. Pap. INT-203. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 35 p. **Abstract**: An experimental logging road designed to minimize environmental and esthetic impact was constructed in northwest Montana. The road was single-lane (14-foot finished surface, 3-foot ditch), constructed along the contour. Esthetically, the single-lane experimental road was judged far superior to existing roads on the forest.

Gardner, Rulon B. 1980. Skyline logging productivity under alternative harvesting prescriptions and levels of utilization in larch-fire stands. Res. Pap. INT-247. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 35 p. **Abstract**: Larch- fir stands in northwest Montana were experimentally logged to determine the influence of increasingly intensive levels of utilization upon rates of yarding production, under three different silvicultural prescriptions. Variables influencing rate of production were also identified.

Gibson, David F. 1978. Interactive computer graphics for planning cable logging operations. Transactions of the American Society of Agricultural Engineers. 21(2): 202-208. **Abstract**: A computerized planning and evaluation system for cable logging operations is described. Interactive graphics are employed. The engineer can view the area to be logged, select locations of corridors, and query the system for various output options such as system mechanics and time to log for any particular logging plan.

Gibson, Ken; Aquino, Leah. 2006. Bark beetle conditions--Northern Region. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Forest Health Protection, Missoula Field Office. 52 p. **Abstract**: This report details bark beetle activity throughout the Northern Region. For each reporting area, bark beetle effects on their respective hosts are noted. Areas affected, estimate of impacts, and beetle population trends are given.

Gisborne, H. T. 1929. A forest fire explosion. The Frontier. 10(1): 13-16. **Abstract**: This article gives a firsthand account of the Half-Moon Fire, Montana's largest human-caused fire at the time. This 90,000 acre fire spanned Teakettle Mountain, to Belton, and Glacier National Park.

Habeck, James R. 1988. Old growth forests in the Northern Rocky Mountains. Natural Areas Journal. 8(3): 202-211. **Abstract**: Old-growth forests still remain in significant amounts in the northern Rocky Mountains on federal forest lands; old growth in private ownership has mostly been destroyed. The perpetuation of viable populations of wildlife species that are dependent on old-growth conditions has become the focal point in developing old-growth management plans for federal forests located in the northern Rocky Mountains. However, old-growth forests have their own intrinsic ecological value independent of wildlife considerations and deserve conservation in a system of land allocations that represents the range of ecosystems found in the northern Rockies.

Harvey, Alan E. 1982. The importance of residual organic debris in site preparation and amelioration for reforestation. In: Baumgartner, David M., comp. Site preparation and fuels management on steep terrain: proceedings of a symposium; 1982 February 15-17; Spokane, WA. Pullman, WA: Washington State University, Cooperative Extension: 75-85. **Abstract**: Decayed or decaying wood and other organic materials provide either the environment or the energy source for microorganisms critical to the survival and growth of conifers in the relatively infertile and frequently droughty soils of the central and northern Rocky Mountains. The microorganisms that contribute to decay processes, nitrogen conversions and ectomycorrhizal activities are particularly important to conifers. The purpose of this report will be to briefly review the biological role of organic debris in forest soils, particularly with regard to ectomycorrhizal fungi, as a basis for examining the specific role organic debris may play in reforestation and reforestation problems.

Harvey, A. E.; Jurgensen, M. F.; Larsen, M. J. 1978. Seasonal distribution of ectomycorrhizae in a mature Douglas-fir/larch forest soil in western Montana. Forest

Science. 24(2): 203-208. **Abstract**: Counts of individual ectomycorrhizal root tips from random soil core samples showed that the greatest number occurred during May and June in the organic soil fractions. Soil humus provided the major substrate for ectomycorrhizae throughout the year except during July and August. During this drier period, more active ectomycorrhizal tips occurred in the decayed soil wood. Moisture levels were higher in the decayed wood than the humus at that time. Decayed wood may serve a critical role in supporting ectomycorrhizae in the soils of mature Douglas-fir/larch forests, particularly during periods of limited moisture availability.

Harvey, Alan E.; Jurgensen, Martin F.; Larsen, Michael J. 1978. Role of residue in and impacts of its management on forest soil biology. In: Proceedings of the eighth world forestry congress; 1978 October 16-18; Jakarta, Indonesia. FQL 29-8. [Place of publication unknown]: [Publisher name unknown]: 1615-1626. **Abstract**: This article reviews ways that silvicultural activities affect soil biology. The influence of forest use on soil processes including nitrification, nitrogen fixation, decay, mycorrhizal activities, and disease activity are reviewed. Additionally, management of forest residues under different conditions is discussed.

Harvey, Alan E.; Jurgensen, Martin F.; Larsen, Michael J. 1980. Biological implications of increasing harvest intensity on the maintenance and productivity of forest soils. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: symposium proceedings; 1979 September 11-13; Missoula, MT. Gen. Tech. Rep. INT-90. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 211-220. **Abstract**: The microbiological populations of a forest soil are largely responsible for its relative quality and productivity, within limitations of climate and geology. Organisms that contribute to decay processes, nitrogen conversions (particularly fixation) and ectomycorrhizal activity provide soils with important biological characteristics. All of these organisms are dependent on organic matter (biomass) input as an energy source or, after it has decayed, as an organic substrate with specific chemical and physical characteristics. Thus, there is an interdependence between above-ground (organic matter input) and below-ground (nutrient and moisture availability) processes, and this interdependence can strongly influence site productivity. Wood can be a particularly critical and functional soil organic component; its relative importance varies with site. Its relative input to a given site and the quantity of organic reserves on that site help determine how much wood fiber can be removed without risk to future soil quality. There is an opportunity for residues management to enhance sites with inherent limitations to organic matter production and for fire management to protect sites where there are high fire risks to available organic reserves.

Harvey, Alan E.; Jurgensen, Martin F.; Larsen, Michael J. 1980. Clearcut harvesting and ectomycorrhizae: survival of activity on residual roots and influence on a bordering forest stand in western Montana. Canadian Journal of Forest Research. 10(3): 300-303. **Abstract**: Low numbers of active ectomycorrhizal roots persisted until July in forest stands that had been clearcut the preceding October. Two years after clearcutting, active ectomycorrhizal roots supported by an adjacent, uncut stand were found only

1.5m into a clearcut, broadcast burned area. Effects of the clearcut burn reduced ectomycorrhizal activity for at least 7.6m into the adjacent uncut stand. Taking advantage of the residual ectomycorrhizal mycelium in fall clearcuts requires that outplanting must be accomplished before July of the following season. Active fungal mycelium from roots of an adjacent stand will be of limited help to the rapid establishment of ectomycorrhizae on tree regeneration in broadcast burned clearcuts.

Harvey, Alan E.; Jurgensen, Martin F.; Larsen, Michael J. 1981. Organic reserves: importance to ectomycorrhizae in forest soils of western Montana. Forest Science. 27(3): 442–445. **Abstract**: The important attributes contributed to forest soils by organic matter make it imperative to determine the quantity and type required to sustain good forest tree growth. Quantitative measurement of soil humus, decayed wood, and charcoal as related to numbers of active ectomycorrhizal root tips (in random soil cores from old-growth sites in western Montana) showed both positive and negative relationships with organic matter. Increased quantities of organic material, to 45 percent by volume of the top 30 cm of soil, were associated with increased numbers of ectomycorrhizae. At 45 percent organic matter or above, numbers of ectomycorrhizae decreased. Study results also showed association with soil organic matter had a relatively greater positive effect on ectomycorrhizae of the dry site than the moist sites.

Harvey, Alan E.; Jurgensen, Martin F.; Larsen, Michael J.; Graham, Russell T. 1987. Relationships among soil microsite, ectomycorrhizae, and natural conifer regeneration of old growth forests in western Montana. Canadian Journal of Forest Research. 17(1): 58-62. **Abstract**: Successful establishment, root distribution, growth, and ectomycorrhizal development of conifer regeneration in three old-growth forests in western Montana showed site-specific associations with soil microsites containing organic matter. A positive association between decayed wood in the soil and establishment of seedlings occurred on the two drier sites. In general, organic soil components supported most of the root system and ectomycorrhizae on all three sites. Associations between soil organic components and occurrence (establishment) and between organic components and performance (growth) were site specific. No observable evidence of feeder root mortality attributable to soil-inhabiting pathogens was present in any soil component. Roots of competing understory species were notably absent in decayed soil wood.

Harvey, Alan E.; Jurgensen, Martin F.; Larsen, Michael J.; Graham, Russell T. 1987. Decaying organic materials and soil quality in the Inland Northwest: a management opportunity. Gen. Tech. Rep. INT-225. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 15 p. **Abstract**: Organic debris, including wood residue, is important to the development and function of forest soil. Organic matter stores nutrients and moisture plus it provides important habitats for microbes beneficial to tree growth. To protect long-term forest soil productivity, organic horizons and their parent materials should be maintained.

Harvey, Alan E.; Jurgensen, Martin F.; Larsen, Michael J.; Schlieter, Joyce A. 1986. Distribution of active ectomycorrhizal short roots in forest soils of the Inland Northwest:

effects of site and disturbance. Res. Pap. INT-374. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 8 p. **Abstract**: An examination of the distribution of active ectomycorrhizal short roots among soil components of eight old-growth stands representative of the important timber growing lands of the Inland Northwest revealed a disproportionate concentration in surface organic materials. A similar concentration in the forest floor was present in six second-growth stands of various ages from the subalpine fir and Douglas-fir habitat series of western Montana. Exceptions to this trend were noted only in an extremely dry, old-growth, ponderosa pine stand and a highly disturbed site regenerating to a pure stand of young western larch. Even in these exceptional cases, ectomycorrhizal activities were concentrated in shallow mineral horizons relatively rich in organic materials. There was considerable variation in the quantity of soil organic materials on the 14 sites. In general, harsh and disturbed sites tended to have the least. The relative proportions of soil organic components (litter, humus, decayed wood) changed significantly both within and between sites. Distribution of active ectomycorrhizal short roots among those components during the early summer months was also significantly different, both within and between sites. Approximately 75 percent of active ectomycorrhizal short roots occurred in organic materials that represented only the first 4 cm of the soil depth. This disproportionate role of surface organic materials In supporting critical symbiotic processes emphasizes the need to carefully manage this important soil resource in forested ecosystems throughout the Inland West.

Harvey, Alan E.; Larsen, Michael J.; Jurgensen, Martin F. 1976. Distribution of ectomycorrhizae in a mature Douglas-fir/larch forest soil in western Montana. Forest Science. 22(4): 393-398. **Abstract**: The top 38 cm (15 inches) of a western Montana forest soil was 60 percent mineral, 23 percent humus, 15 percent decayed wood, and 2 percent charcoal. Most (to 95 percent) of the active ectomycorrhizae were associated with the organic fractions. Five percent of all active ectomycorrhizae occurred in the mineral soil fraction, 66 percent in the humus, 21 percent in the decayed wood, and 8 percent in the charcoal. Thus, the organic reserves in this forest soil were the most important substrates for ectomycorrhiza formation. Therefore, the parent materials (leaves, litter, and woody residues) for soil organic reserves may require management during timber harvesting and prescribed burning to prevent a subsequent loss in the capacity of soils of this type (limestone base) to support ectomycorrhizal associations in mature Douglas-fir/larch forests.

Harvey, Alan E.; Larsen, Michael J.; Jurgensen, Martin F. 1979. Comparative distribution of ectomycorrhizae in soils of three western Montana forest habitat types. Forest Science. 25(2): 350-358. **Abstract**: Soil core samples from three western Montana forest sites representing a range of moisture, productivity, and dominant tree species (Douglas-fir, subalpine fir, and hemlock) were analyzed for differences in quantities and types of soil organic matter and the distribution of active (physiologically functioning) ectomycorrhizae in the soil profiles. The lowest levels of soil organic matter and ectomycorrhizal activity occurred in the Douglas-fir and subalpine fir sites. Most of the ectomycorrhizae occurred in the soil organic matter at all three sites, primarily in humus (O2 layer) or in brown cubical decayed wood distributed throughout the soil

profiles. In the Douglas-fir site, decayed soil wood was the most frequent substrate for active ectomycorrhizae. In soils of the subalpine fir and hemlock sites, humus was the most frequent substrate for ectomycorrhizae. Consistently high moisture levels in the organic materials, particularly decayed wood, were associated with this phenomenon.

Harvey, A. E.; Larsen, M. J.; Jurgensen, M. F. 1979. Fire-decay: interactive roles regulating wood accumulation and soil development in the Northern Rocky Mountains. Research Note INT-263. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 4 p. **Abstract**: Decay and fire play interactive roles in recycling wood and other organic materials in forest ecosystems; and contribute to the development of high quality soils in the Northern Rocky Mountains. Decayed wood, charcoal, and other decomposed organic matter are the principal media for ectomycorrhizal and nonsymbiotic nitrogen fixing microbes. The activities of these microbes are critical to the growth of forest trees. The balance between decay and fire, as it affects the amount, distribution, and type of organic matter, controls the ability of forest soils to support the growth of trees.

Harvey, Alan E.; Larsen, Michael J.; Jurgensen, Martin F. 1980. Partial cut harvesting and ectomycorrhizae: early effects in Douglas-fir-larch forests of western Montana. Canadian Journal of Forest Research. 10(3): 436-440. **Abstract**: Numbers of ectomycorrhizae were assessed 3 years after harvesting approximately 50% of the overstory in two Douglas-fir-larch stands in western Montana, one was subjected to intensive residue removal, the other broadcast burned 1 year after harvest. Numbers of active ectomycorrhizal root tips were significantly reduced in the broadcast burned stand compared to either the intensively utilized stand or to an adjacent, undisturbed stand. This indicates that on difficult-to-regenerate sites, particularly where soil organic matter is low, it may be advantageous to dispose of slash created in partial cuts by means other than burning.

Harvey, Alan E.; Larsen, Michael J.; Jurgensen, Martin F. 1980. Ecology of ectomycorrhizae in northern Rocky Mountain forests. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: symposium proceedings; 1979 September 11-13; Missoula, MT. Gen. Tech. Rep. INT-90. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 189-208. **Abstract**: Activity of ectomycorrhizal symbionts depends on the nature of the soil and vegetation, as controlled by climate and natural or man-caused disturbances over time. Organic materials in the form of litter, humus, decayed wood or charcoal that occur in layers or mixed in the mineral soil are key factors governing ectomycorrhizal activities in forest soils. Importance of these organic fractions to ectomycorrhizal activity can be predicted, based on their quantity and distribution in the forest floor, the season, and the relative position of the site along a temperature-moisture gradient. Organic materials are most important in the harshest soils. This appears to result directly from their ability to buffer wide variations of pH, moisture and temperature. Because the ectomycorrhizal association depends on host trees, manipulations of the stand also provide direct control of ectomycorrhizal activity.

Harvey, A. E.; Larsen, M. J.; Jurgensen, M. F. 1981. Forest management implications of improved residue utilization: biological implications in forest ecosystems. In: Harvesting and utilization opportunities for forest residues in the Northern Rocky Mountains: symposium proceedings; 1979 November 28-30; Missoula, MT. Gen. Tech. Rep. INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 259-267. **Abstract**: Various forms of residue provide parent materials for the development and function of the organic mantle of forest soils. Organic matter provides either the environment or the energy source for a variety of microorganisms which are critical to continued site productivity. Of the many organic materials added to forest soils during a stand rotation, the woody component is, in many respects, the most important. To protect the productive potential of a forest soil, a continuous supply of organic materials must be provided.
Intensive wood utilization may interfere with the supply of appropriate quantities and types of organic materials being cycled on certain sites. Providing adequate organic supplies could, therefore, impose constraints on harvesting intensity and residue utilization standards. Current research has provided some insights into this potential problem in the northern Rocky Mountains. Research indicates no serious shortage of organic residues with current management practices on productive sites in the northern Rocky Mountains. Substantial increases in utilization intensity, extremely hot wildfire, or excessive site preparation could reduce stand productivity, particularly on harsh, cold or dry sites.

Harvey, A. E.; Larsen, M. J.; Jurgensen, M. F. 1981. Rate of woody residue incorporation into Northern Rocky Mountain forest soils. Res. Pap. INT-282. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 5 p. **Abstract**: The important properties contributed to forest soils by decayed wood in the Northern Rocky Mountains make it desirable to determine the time required to reconstitute such materials in depleted soils. The ratio of fiber production potential (growth) to total quantity of wood in a steady state ecosystem provides estimates varying from approximately 100 to 300 years, depending on habitat type, for replacement of decayed soil wood. Radiocarbon dating of decayed wood in various stages of incorporation into the soil ranged from 100 to 550 years, depending on site and depth in soil. Species identification of decayed wood indicated that Douglas-fir residue is the most persistent woody material in these Northern Rocky Mountain soils.

Higgins, Stewart S.; Black, R. Alan.; Radamaker, Gary K.; Bidlake, William R. 1987. Gas exchange characteristics and water relations of *Larix occidentalis*. Canadian Journal of Forest Research. 17(11): 1364-1370. **Abstract**: Photosynthetic, transpirational, and stomatal responses to light, temperature, humidity, and plant moisture stress were measured for greenhouse-grown seedlings of *Larix occidentalis* Nutt. Light saturation was 550 μmol photons•m^{-2}•s^{-1}; light and CO_2 compensation points were 26 μmol photons•m^{-2}•s^{-1} and 59 μL CO_2•L^{-1}, respectively. Light-saturated photosynthetic rate was over 7 μmol CO_2•m^{-2}•s^{-1} with a temperature optimum between 18 and 23 °C. Photosynthesis, transpiration, and stomatal conductance to water vapor declined as xylem pressure potential decreased from −1.5 to less than −2.5 MPa; above −1.5 MPa no effect was observed. Stomatal conductance declined with increasing leaf

to air vapor density difference. Stomatal conductance increased with increasing irradiance. Nighttime stomatal conductance was about 50% of the daytime maximum conductance regardless of xylem pressure potential. When plants were well watered, the ratio of xylem pressure potential to transpiration (XPP/E) decreased by 1.5×10^{-3} MPa•(μg H2O•cm^{-2}•s^{-1})$^{-1}$ with each mg H2O•cm^{-2} that had been transpired. After 7 days of drought, however, XPP/E decreased at 7.9 × 10−3 MPa•(μg H2O•cm^{-2}•s^{-1})$^{-1}$ per mg H2O•cm^{-2}. These characteristics are compared with other conifers and are used to suggest differences between growth patterns of *L. occidentalis* and sympatric species.

Hungerford, Roger D. 1980. Microenvironmental response to harvesting and residue management. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: symposium proceedings; 1979 September 11-13; Missoula, MT. Gen. Tech. Rep. INT-90. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 37-73. **Abstract**: The concept of energy balance is useful in analyzing the environmental changes and in predicting biological responses that follow timber harvesting and residue management. The physical properties of the surface have a large effect on the surface environment. Surface conditions such as radiation load and temperature have reached lethal levels following harvesting on several sites. Harvesting also aggravates and creates frost pockets that severely limit seedling establishment. Some predictive models are discussed that aid in prediction of environmental conditions and relate to biological implications. Methods of using residue manipulation to alter the microenvironment are suggested.

Hungerford, Roger D. 1984. Native shrubs: suitability for revegetating road cuts in northwestern Montana. Res. Pap. INT-331. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 13 p. **Abstract**: Four years after planting. Wood's rose (82 percent), red-osier dogwood (94 percent), and thimbleberry (73 percent) had the highest survival of the 18 species of native shrubs planted on steep road cuts in northwestern Montana. Two penstemon species and Wood's rose demonstrated good growth and regeneration 9 years after planting. Several of the species tested can be valuable for revegetating road cuts. stabilizing slopes, and improving their appearance. Species suitability is rated and important attributes are given for the species that rated the highest.

Hungerford, Roger D.; Babbitt, Ronald E. 1987. Overstory removal and residue treatments affect soil surface, air, and soil temperature: implications for seedling survival. Res. Pap. INT-377. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 19 p. **Abstract**: Potentially lethal ground surface temperatures were measured at three locations in the Northern Rocky Mountains but occurred more frequently under treatments with greater overstory removal. Observed maximum and minimum temperatures of exposed surfaces are directly related to the thermal properties of the surface materials. Survival of planted seedlings was consistent with the pattern of potentially lethal temperatures. Care in manipulating overstory canopies and residues can enhance the potential for tree

seedling survival.

Hungerford, Roger D.; Nemani, Ramakrishna R.; Running, Steven W.; Coughlan, Joseph C. 1989. MTCLIM: a mountain microclimate simulation model. Res. Pap. INT-414. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 52 p. **Abstract**: A model for calculating daily microclimate conditions in mountainous terrain is presented. Daily air temperature, shortwave radiation, relative humidity, and precipitation are extrapolated from data measured at National Weather Service stations. The model equations are given and the paper describes how to execute the model. Model outputs are compared with observed data from several mountain sites.

Hungerford, Roger D.; Schlieter, Joyce A. 1984. Weather summaries for Coram Experimental Forest, northwestern Montana-- an international biosphere reserve. Gen. Tech. Rep. INT-160. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 34 p. **Abstract**: This report presents weather data summaries (1934-82) for most of the stations within the Coram Experimental Forest. Several adjacent long-term stations are also included for comparison. These data provide excellent opportunities for interpreting results of silvicultural and other biological research, particularly in describing climatological variations associated with forest growth and productivity. Topographic features, periods of record, types of data collected, habitat types, and vegetation conditions are included for each weather station.

Hutto, Richard L.; Young, Jock S. 1999. Habitat relationships of landbirds in the Northern Region, USDA Forest Service. Gen. Tech. Rep. RMRS-GTR-32. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 72 p. **Abstract**: A series of first-generation habitat-relationships models for 83 bird species were detected in a 3-year study on point counts conducted in association with the USDA Forest Service's Northern Region Landbird Monitoring Program. The models depict probabilities of detection for each of the bird species on 100-m-radius, 10-minute point counts conducted across a series of major vegetation cover types. Based on these models, some bird species appear to be restricted in their habitat distribution to: (1) postfire, standing-dead forests, (2) relatively uncut, older forests, (3) harvested forest types, (4) marshes, (5) riparian environments, and (6) grasslands and sagebrush. Such restricted distributions highlight the need to provide adequate amounts of these cover types to maintain viable species populations. Many bird species were relatively abundant in harvested forests, suggesting a need for nesting success studies because timber harvesting creates unnatural cover types that may elicit settling responses by species that are "programmed" to respond to similar naturally occurring cover types. Thus, these unnatural cover types could be acting as "ecological traps," where species are being attracted to sites where suitability is relatively poor. These preliminary results demonstrate the utility of a landbird monitoring program, and suggest that agencies such as the Forest Service should consider broadening the indicator species concept to monitor groups of species (such as landbirds and butterflies) that can be easily sampled with a single field method. The list of species covered by this program is indeed large

enough and ecologically broad enough to help managers predict and monitor the effects of management activities on almost all the major vegetation types in the region. The detail and region-specific nature of this information can be matched by no other database in existence on landbirds, and the information should prove useful to land managers in planning areas that might consist of alternative cover types.

Jurgensen, M. F.; Arno, S. F.; Harvey, A. E.; Larsen, M. J.; Pfister, R. D. 1979. Symbiotic and nonsymbiotic nitrogen fixation in northern Rocky Mountain forest ecosystems. In: Gordon, J. C.; Wheeler, C.R.; Perry, D. A., eds. Symbiotic nitrogen fixation in the management of temperate forests: proceedings of a workshop; 1979 April 2-5; [Corvallis, OR]. Corvallis, OR: Oregon State University, Forest Research Laboratory: 294-308. **Abstract**: Recent development of forest habitat-type classifications for the northern Rocky Mountains has provided a data base from which information on N-fixing plants could be obtained. Detailed vegetation analysis from over 2,000 pole-sized and larger stands indicate that five genera and 7 species of non-leguminous N-fixing plants, and eight genera and 25 species of leguminous plants are present in forests of Montana and central Idaho. No information is available on the actual contribution of these plants to the nitrogen economy. Scattered distribution and low numbers of N-fixing plants in most older stands make sizable annual N additions unlikely; however, appreciable N gains may accrue during early forest succession in certain habitat types. Nonsymbiotic fixation rates in forest soils of this region are low, but would appear to be the only biological source of added nitrogen in many forest stands. Management possibilities exist for increasing nitrogen additions to northern Rocky Mountain forests through both symbiotic and nonsymbiotic N-fixation.

Jurgensen, M. F.; Harvey, A. E.; Graham, R. T.; Page-Dumroese, D. S.; Tonn, J. R.; Larsen, M. J.; Jain, T. B. 1997. Impacts of timber harvesting on soil organic matter, nitrogen, productivity, and health of Inland Northwest Forests. Forest Science. 43(2): 234-251. **Abstract**: Soil organic components are important factors in the health and productivity of Inland Northwest forests. Timber harvesting and extensive site preparation (piling, windrowing, or scalping) reduces the amount of surface organic material (woody residues and forest floor layers) over large areas. Some wildfires and severe prescribed burns can have similar consequences. Such organic matter reductions can have important implications for soil chemical, biological and physical properties. A number of studies have linked substantial reduction in mycorrhizae development and tree growth to high levels of soil disturbance, or removal of organic horizons. Timber harvesting also removes a large percentage of coarse woody debris, which has unknown ramifications on soil productivity. Current woody residue guidelines in this region recommend leaving <10 to 125 Mg ha^{-1} on site to replace woody materials lost during harvesting operations. Large amounts of soil nitrogen (>500 kg ha^{-1}) can also be lost from timber harvesting and site preparation, especially when using prescribed fire. The time required to replace this lost nitrogen may range from <10 to >275 yr, and depends on the severity of site treatments, presence or absence of nitrogen-fixing plants, and amounts of atmospheric deposition. Maintaining adequate amounts of organic matter on some forest sites in the Inland Northwest may temporarily increase the risk of wildfire or favor the activity of certain insects or disease fungi. However,

carefully planned prescribed burns and mechanical site preparation can be practiced on most sites with relatively low impacts on soil organic levels, while accomplishing the important forest management objectives of fuel reduction, seedbed preparation, and reducing competing vegetation. Organic matter management will be the most difficult on very dry sites, with their historically low soil organic and nitrogen content, and high fire potential. The maintenance of adequate soil organic matter levels is critical for sustaining forest health and productivity under the variable moisture and temperature conditions of this region. Thus, soil organic components will become more important in the future as ecosystem management systems are developed for western forests.

Jurgensen, Martin F.; Harvey, Alan E.; Larsen, Michael J. 1981. Effects of prescribed fire on soil nitrogen levels in a cut-over Douglas-fir/western larch forest. Research Paper INT-275. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 p. **Abstract**: The effects of a prescribed broadcast fire on soil nitrogen (N) levels and related soil properties were determined following the clearcutting of a 250-year-old Douglas-fir/ western larch stand in northwestern Montana. Soil N losses from burning amounted to slightly over 90 Ib/acre (100 kg/ha), all from the surface organic layers. This was 6 percent of the total N originally present in the surface 12 inches (30 cm) of soil. In contrast, soil ammonium concentration increased within 2 days following the fire. Rapid nitrification also occurred after a 3-week lag period. The higher nitrate levels were associated with increased populations of nitrifying bacteria. Both soil ammonium and nitrate concentrations returned to preburn levels by the end of the following summer. Soil acidity was decreased after the burn and had not yet returned to original levels in the organic horizons 4 years later. Organic matter content of the mineral soil was not affected by the fire. No long-term depletion of soil N reserves would result from this prescribed fire. Plant reestablishment on the site benefited by increased soil N availability.

Jurgensen, M. F.; Larsen, M. J.; Harvey, A. E. 1977. Effects of timber harvesting on soil biology. In: Forests for people, a challenge in world affairs: proceedings of the Society of American Foresters, 1977 National Convention; 1977 October 2-6; Albuquerque, NM. Washington, DC: Society of American Foresters: 244-250. **Abstract**: This article reviews the effects of timber harvesting on soil biology. Timber harvesting influences: (1) soil nutrient levels and availability, (2) decay of woody plant material, and (3) activities of plant pathogens. Most of the information on the biological consequences of timber harvesting is derived from a few studies investigating treatments designed to give the highest possible impact to the site. The infinite variations in harvesting techniques, stand age and condition, post-harvest treatment, soil and climatic differences which characterize forest conditions make it difficult to draw general conclusions.

Jurgensen, M. F.; Larsen, M. J.; Harvey, A. E. 1977. A soil sampler for steep, rocky sites. Res. Note INT-217. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 5 p. **Abstract**: A portable, hand-operated soil core sampler has been developed for sampling soils on steep, rocky sites. The sampler provides a 10- by 30-cm (4- by 11.8-in) soil core and can be built by

most machine shops. Construction drawings and material specifications are available from the Forest Products Laboratory, Madison, Wisconsin 53705.

Jurgensen, M. F.; Larsen, M. J.; Harvey, A. E. 1979. Forest soil biology–timber harvesting relationships: a perspective. Gen. Tech. Rep. INT-69. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 12 p. **Abstract**: Timber harvesting has a pronounced effect on the soil microflora by removing essential woody food supplies and by changing soil chemical and physical properties. Greater activity of microorganisms following logging operations may affect site quality because of increased availability of soil nutrients and accelerated nutrient movement through the soil profile. Soil micro-organisms that function in the cycling of nitrogen generally are stimulated by timber removal, particularly if fire is used as part of postharvest site preparations. The effect of harvesting on the incidence of disease is a potential problem, but seems to be more related to the levels and types of logging residues on the site than to changes in soil properties. Decayed wood, as both a physical and chemical component of soil, appears to be an important factor in stand development and productivity on dry sites in the northern Rocky Mountains. The long-term implications of reducing the amounts of woody materials returned to the soil by increasing residue utilization is unknown. At present, no detrimental impact on site quality can be directly attributed to harvesting effects on soil micro-organisms; however, this may change as forest management goals emphasize more intensive use of existing stands.

Jurgensen, Martin F.; Larsen, Michael J.; Harvey, Alan E. 1980. Microbial processes associated with nitrogen cycling in northern Rocky Mountain forest soils. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: symposium proceedings; 1979 September 11-13; Missoula, MT. Gen. Tech. Rep. INT-90. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 175-188. **Abstract**: The soil microflora is of critical importance for the cycling of nitrogen (N) in forest ecosystems. Forest management practices such as timber harvesting, residue removal and prescribed burning greatly affect the activity of these microorganisms. N fixation by free-living soil bacteria in the Northern Rocky Mountain region was reduced following harvesting. This was particularly true in the surface organic horizons and appeared related to low moisture levels on the surface of cleared sites. Decaying wood incorporated in the soil was a major site of N fixation. The establishment of N-fixing plants, such as *Alnus*, *Ceanothus*, *Lupinus*, and *Astragalus* on logged areas could more than compensate for the lower N fixation rates by soil bacteria. However, the occurrence of these plants is habitat-type related, and most of the sites studied did not have a significant N-fixing plant component. Increases in ammonium and nitrate concentrations occurred in the soil following logging, especially when the sites were burned. Such increases in available soil N levels could be beneficial for subsequent regeneration establishment and growth. However, both ammonium and nitrate concentrations returned to their original levels within several years after cutting. Higher nitrate concentrations after harvesting could increase leaching losses of N from the site. Changes in soil organic matter content must be considered when evaluating the effects

of harvesting methods on soil N strata.

Jurgensen, M. F.; Larsen, M. J.; Spano, S. D.; Harvey, A. E.; Gale, M. R. 1984. Nitrogen fixation associated with increased wood decay in Douglas-fir residue. Forest Science. 30(4): 1038-1044. **Abstract**: Nitrogen fixation rates, as estimated by the acetylene reduction technique, were determined for four decay stages of down Douglas-fir logs on two old-growth sites in northwestern Montana. Acetylene reduction rates increased as wood decay progressed, but were not affected by site location. Wood carbohydrate, soluble sugar, total and soluble nitrogen, and moisture content also varied among decay stages. Acetylene reduction rates were positively correlated with wood moisture content and nitrogen concentration, and negatively correlated with carbohydrate level. The annual nitrogen additions to the sites from nitrogen fixation in decaying Douglas-fir logs were small, 0.72 kg/ha/yr on the moister site and 0.26 kg/ha/yr on the drier site. These differences in nitrogen inputs were related to differences in residue loading between sites. Although small, such nitrogen gains may be significant over the rotation life of a stand.

Keane, Robert E. 2008. Biophysical controls on surface fuel litterfall and decomposition in the northern Rocky Mountains, USA. Canadian Journal of Forest Research. 38(6): 1431-1445. **Abstract**: Litterfall and decomposition rates of the organic matter that comprise forest fuels are important to fire management, because they define fuel treatment longevity and provide parameters to design, test, and validate ecosystem models. This study explores the environmental factors that control litterfall and decomposition in the context of fuel management for several major forest types in the northern Rocky Mountains (Idaho and Montana), USA. Litterfall was measured for more than 10 years using semiannual collections of six fine fuel components (fallen foliage, twigs, branches, large branches, logs, and all other canopy material) collected from a network of 1 m^2 litterfall traps installed at 28 plots across seven sites. Decomposition of foliage, twigs, branches, and large branches were measured using litter bags installed on five of the seven sites. Measured litterfall and decomposition rates were correlated with major environmental and vegetation variables using regression analysis. Annual foliage litterfall rates ranged from 0.057 $kg.m^{-2}.year^{-1}$ for dry *Pinus ponderosa* Dougl. ex Laws. stands to 0.144 $kg.m^{-2}.year^{-1}$ on mesic *Thuja plicata* Donn ex D. Don stands and were correlated with the vegetation characteristics of leaf area index, basal area, and tree height ($r > 0.5$), whereas decomposition rates were correlated with the environmental gradients of temperature and relative humidity ($r > 0.4$).

Keane, Robert E. 2008. Surface fuel litterfall and decomposition in the northern Rocky Mountains, U.S.A. Res. Pap. RMRS-RP-70. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 22 p. **Abstract**: Surface fuel deposition and decomposition rates are important to fire management and research because they can define the longevity of fuel treatments in time and space and they can be used to design, build, test, and validate complex fire and ecosystem models useful in evaluating management alternatives. We determined rates of surface fuel litterfall and decomposition for a number of major forest types that span a wide range of biophysical conditions in the northern Rocky Mountains, USA. We measured fuel

deposition for more than 10 years with semi-annual collections of fallen biomass sorted into six fuel components (fallen foliage, twigs, branches, large branches, logs, and all other canopy material). We gathered this material using a network of seven to nine, 1-m^2 litter traps installed at 28 plots that were established on seven sites with four plots per site. We measured decomposition for only fine fuels using litter bags installed on five of the seven sites and monitored for biomass loss from the bags each year for 3 years. Deposition and decomposition rates are summarized by plot, cover type, and habitat type series. We also present various temporal and spatial properties of litterfall and decomposition fluxes across the six fuel components.

Keane, Robert E.; Ryan, Kevin C.; Running, Steven W. 1996. Simulating effects of fire on northern Rocky Mountain landscapes with the ecological process model FIRE-BGC. Tree Physiology. 16(3): 319. **Abstract**: A mechanistic, biogeochemical succession model, FIRE-BGC, was used to investigate the role of fire on long-term landscape dynamics in northern Rocky Mountain coniferous forests of Glacier National Park, Montana, USA. FIRE-BGC is an individual-tree model—created by merging the gap-phase process-based model FIRESUM with the mechanistic ecosystem biogeochemical model FOREST-BGC—that has mixed spatial and temporal resolution in its simulation architecture. Ecological processes that act at a landscape level, such as fire and seed dispersal, are simulated annually from stand and topographic information. Stand-level processes, such as tree establishment, growth and mortality, organic matter accumulation and decomposition, and undergrowth plant dynamics are simulated both daily and annually. Tree growth is mechanistically modeled based on the ecosystem process approach of FOREST-BGC where carbon is fixed daily by forest canopy photosynthesis at the stand level. Carbon allocated to the tree stem at the end of the year generates the corresponding diameter and height growth. The model also explicitly simulates fire behavior and effects on landscape characteristics. We simulated the effects of fire on ecosystem characteristics of net primary productivity, evapotranspiration, standing crop biomass, nitrogen cycling and leaf area index over 200 years for the 50,000-ha McDonald Drainage in Glacier National Park. Results show increases in net primary productivity and available nitrogen when fires are included in the simulation. Standing crop biomass and evapotranspiration decrease under a fire regime. Shade-intolerant species dominate the landscape when fires are excluded. Model tree increment predictions compared well with field data.

Klade, Richard J. 2006. The Northern Rocky Mountain Station, 1926-1953. In: Building a research legacy. The Intermountain Station 1911-1997. Gen. Tech. Rep. RMRS-184. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 33-56. **Abstract**: Includes highlights of the history of organizations that preceded formation of the Intermountain Forest and Range Experiment Station in 1954. Provides detailed accounts of Intermountain Station research and administrative accomplishments, some of the people who led activities, and changes in the organization from 1954 through 1997 when the Intermountain and Rocky Mountain Stations merged to become the Rocky Mountain Research Station. Many significant Station publications are indicated by title in the text, and the references list includes other publications that provide additional historic background on research programs and

results.

Klade, Richard J. 2006. A quick trip through the last two decades. In: Building a research legacy. The Intermountain Station 1911-1997. Gen. Tech. Rep. RMRS-184. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 223-247. **Abstract**: This chapter provides a timeline for historical events and changes at the Intermountain Station in the years before its merger with the Rocky Mountain Station. Included are highlights of the history of organizations that preceded formation of the Intermountain Forest and Range Experiment Station in 1954. Provides detailed accounts of Intermountain Station research and administrative accomplishments, some of the people who led activities, and changes in the organization from 1954 through 1997 when the Intermountain and Rocky Mountain Stations merged to become the Rocky Mountain Research Station. Many significant Station publications are indicated by title in the text, and the references list includes other publications that provide additional historic background on research programs and results.

Klages, Murray G. 1974. Clay minerals of Montana soils. Proceedings of the Montana Academy of Sciences. 34: 12-18. **Abstract**: The Plant and Soil Science Department of the Agricultural Experiment Station has conducted soil clay mineral studies over many years. The analyses were made because of the importance of clay minerals in soil formation and classification and in soil physical and chemical properties but were not a part of a systematic study of Montana soils. Thus, procedures have not been uniform and not all parts of the State have received equal attention. Nine studies are summarized in this paper and their results compiled into a clay minerals map. The studies include soils from 74 locations in 24 counties. The Soil conservation Service also has unpublished clay mineral studies in the State. The Montana Bureau of Mines and Geology has published a study of soil clays in glacial Lake Missoula. Results from these agencies are not reported in this paper, but they were reviewed; and they support the map in a general way. Five of the nine studies reported here have been published. The reader can refer to those publications for more details. Procedures for the other four studies were generally similar and are described only where there were important differences. Geology of soil parent materials was taken from the map published by Ross et al unless noted otherwise.

Klages, M. G.; McConnell, R. C.; Nielsen, G. A. 1976. Soils of the Coram Experimental Forest. Res. Rep. 91. Bozeman, MT: Montana State University, Montana Agricultural Experiment Station. 43 p. **Abstract**: Soils of Coram Experimental Forest were mapped and classified. Soil pits were dug to aid in the description, classification and sampling; physical and chemical soil properties were analyzed from samples.

Korol, Ronni L. 2001. Physiological attributes of 11 Northwest conifer species. Gen. Tech. Rep. RMRS-GTR-73. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 9 p. **Abstract**: The quantitative description and simulation of the fundamental processes that characterize forest growth are increasing in importance in forestry research. Predicting future forest growth, however, is

compounded by the various combinations of temperature, humidity, precipitation, and atmospheric carbon dioxide concentration that may occur. One method of integrating new management objectives and potential climate scenarios is to model ecosystems mechanistically. General application of ecosystem process models has been difficult. In particular, obtaining initial physiological parameters from current techniques that rely on instantaneous gas exchange measurements can be both expensive and challenging. Frequently, data necessary to parameterize ecosystem process models are not readily available. This report provides model parameters for 11 conifer species of the Inland Northwest. Field measurements of A, A_{max}, g, g_{max}, c_i, predawn water potentials, analysis of leaf nitrogen concentration, carbon isotope discrimination (Δ), and values of c_i, and intrinsic water use efficiency (A/g) inferred from the carbon composition ($\delta^{13}C$) are presented. The relationship of wet leaf weight to dry leaf weight is also presented. The data in this report can be used to calibrate and constrain physiological parameters for modeling physiological processes of 11 conifer species in the Inland Northwest.

Lange, David E.; Lapp, Joyce. 1999. Native plant restoration on the Going-to-the-Sun Road, Glacier National Park. In: Holzworth, Larry K.; Brown, Ray W., comps. Revegetation with native species: proceedings, 1997 society for Ecological Restoration annual meeting; 1997 November 12-15; Ft. Lauderdale, FL. Proc. RMRS-P-8. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 22-27. **Abstract**: Since 1991, 53 acres of roadside vegetation and soil were removed along sections of the historic Going-to-the-Sun Road during road rehabilitation activities. Restoration strategies used indigenous plant material to re-establish plant cover, prevent erosion, compete with exotics, and improve aesthetics. From several hundred collections, simple seed mixes were created that included early colonizers and late seral species. Native forbs, shrubs, and trees were propagated as bareroot and containerized material. Grass was grown as seed and increased to larger quantities with offsite seed production plantings. Revegetation incorporated a combination of plant and soil salvage, seeding, in planting, and natural regeneration. Our monitoring program was used to assess results and to help make decisions about species selection, seeding rates, successional strategies, and realistic objectives for restoration.

Lanner, Ronald M. 1995. The role of epicormic branches in the life history of western larch. In: Schmidt, Wyman C.; McDonald, Kathy J., Ecology and management of *Larix* forests: a look ahead: proceedings of an international symposium; 1992 October 5-9; Whitefish, MT. Gen. Tech. Rep. INT-319. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 323-326. **Abstract**: As a western larch (*Larix occidentalis*) tree matures, its first-order branches decline, die, and are replaced by clustered epicormics that form a replacement crown, these epicormics grow from dormant buds at first-order branch-bases, appearing at successively higher positions in the crown, eventually making up entire crowns of old trees. Crown replacement is a normal life-history trait which prolongs the life span, not an injury response. It occurs in *Larix, Pseudotsuga, Abies, Picea, Tsuga, Sequoia*, and *Sequoiadendron*.

Larsen, M. J.; Harvey, A. E.; Jurgensen, M. F. 1980. Residue decay processes and

associated environmental functions in northern Rocky Mountain forests. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: symposium proceedings; 1979 September 11-13; Missoula, MT. Gen. Tech. Rep. INT-90. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 157-174. **Abstract**: Decaying and decayed wood has received little attention in its relationships to the properties and functions of forest soils, although it is recognized that decay of woody substrates in forested ecosystems constitutes a major pathway for carbon and nutrient recycling. Results from our investigations indicate that brown-cubical decayed wood in soil is more functionally unique than previously thought. Wood in soil exhibits functions and characteristics that are similar to those of other soil components, but in some instances performs more efficiently. Wood in soil is an efficient medium for storing nutrients and water. It also provides a place for growth of tree roots and certain fungi that together form "mycorrhizae" ... structures essential to tree establishment, survival, and growth in western forests. Decayed wood is an important site for the biological fixation of nitrogen gas from the atmosphere. Since soil wood is an important part of soil structure and function, it is necessary to determine how much residue (wood) can be removed for further utilization and product development without precipitating site deterioration. By assessing the impact of increasing levels of utilization before forest harvesting and utilization, long term site deterioration or damage may be avoided.

Larsen, Michael J.; Jurgensen, Martin F.; Harvey, Alan E. 1978. N_2 fixation associated with wood decayed by some common fungi in western Montana. Canadian Journal of Forest Research. 8(3): 341-345. **Abstract**: Decay caused by some common wood-destroying fungi in several associated tree hosts of the Intermountain forests of western Montana was evaluated as a potential environment for the fixation of dinitrogen. Differences in the rates of fixation were demonstrated between various decay stages, tree species, decay fungi, and brown and white rots. Advanced brown-rotted wood was a more favorable system for nitrogen fixation than wood partially brown rotted. Also, brown-rotted substrates proved to be more favorable than did white rotted, particularly *Pseudotsuga menziesii* (Mirb.) Franco wood decayed by *Fomitopsis pinicola* (Swartz ex Fr.) Karst. Data demonstrate that a nitrogenase function coexists naturally with decay fungi in woody substrates and that appreciable and significant amounts of nitrogen are fixed in these substrates.

Larsen, Michael J.; Jurgensen, Martin F.; Harvey, Alan E. 1981. *Athelia epiphylla* associated with colonization of subalpine fir foliage under psychrophilic conditions. Mycologia. 73(6): 1195–1202. **Abstract**: This paper documents the occurrence, association, and apparent effects of *Athelia epiphylla* Pers. on postharvest conifer residue under psychrophilic conditions in a northern Rocky Mountain coniferous forest. In the spring following a variety of autumn, 1974, harvesting practices on selected sites in Montana, intense and widespread fungal activity was noted in close proximity to or under "rotten" snow pack. The conditions afforded an immediate opportunity to assess some effects of psychrophilic microorganism activity on small-dimension materials (leaves, twigs, etc.).

Larsen, M. J.; Jurgensen, M. F.; Harvey, A. E.; Ward, J. C. 1978. Dinitrogen fixation associated with sporophores of *Fomitopsis pinicola*, *Fomes fomentarius*, and *Echinodontium tinctorium*. Mycologia. 70(6): 1217-1222. Fixation of atmospheric dinitrogen by bacteria associated with contextual tissues of sporophores of *Fomitopsis pinicola*, *Fomes fomentarius*, and *Echinodontium tinctorium* is reported. Since nitrification rates are low, the data indirectly support the view that an autolysis-recycling mechanism of nitrogen from large volumes of woody tissue is the principal means by which wood-destroying fungi obtain nitrogen for sporophore production and sporulation.

Lauff, George; Reichle, David. 1979. Experimental Ecological Reserves. Bulletin of the Ecological Society of America. 60(1): 4-11. **Abstract**: The Experimental Ecological Reserve network represents an important national research resource available to the scientific community. A pilot plan for long-term ecological measurements and monitoring program is being developed to provide baseline data sets on the major ecosystems represented. The initial network of Experimental Ecological Reserves, containing 71 sites at 67 locations throughout the United States is located on a map and listed.

LeBarron, Russell K. 1948. Review of published information on the larch-Douglas-fir type. Station Paper No. 15. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 14 p. **Abstract**: This report summarizes available information on the larch-Douglas fir forest type. Utilization, cutting practices, botanical characteristics, regeneration, and management recommendations for western larch and Douglas fir are discussed.

Living in the Landscape. 1998. Voices from the landscape. Kalispell, MT: Living in the Landscape. 95 p. **Abstract**: The celebration "Living in the Landscape, a Flathead community celebration" grew out of a wish to mark significant milestones in 1998 for two distinguished local research sites in Montana: the 50th anniversary of the start of research at Coram Experimental Forest and the 30th year at Miller Creek Demonstration Forest. This area is blessed with world class natural attractions. From the distant reaches of Glacier Nat. Park's alpine highlands, to the shimmering, clear waters of Flathead Lake, this setting nurtures a remarkable diversity of native plants, wildlife, and interesting people. Everyone who wished to do so was invited to contribute written reflections on the Flathead. This book is their gift to us all.

Lusk, H. Gilbert; Hayden, Brace; Syroteuk, Merv; Frith, Larry; Shearer, Raymond C. 1995. Crown of the continent biosphere reserves. In: Condo, Antionette J., comp., Biosphere reserves in action: case studies of the American experience. Department of State Pub. 10241 Washington, DC: U.S. Department of State, Bureau of Oceans and International Environmental Science and Technology: 27-32. **Abstract**: For nearly 20 years, biosphere reserves have offered a unique framework for building the knowledge, skills, and attitudes required for conservation and sustainable use of ecosystems. The 12 case studies in this volume chronicle many of the cooperative efforts to implement the biosphere reserve concept in the United States. One of the case studies presented in this report is about the three biosphere reserves (BR) in the transborder region along the Continental Divide, often referred to as the Crown of the Continent, which include

Glacier National Park, Coram Experimental Forest and Waterton Lakes National Park.

McCaughey, Ward W.; Schmidt, Wyman C.; Schmidt, Jack A. 1995. Effect of 20 years of regulated stand densities on bole form of young western larch. In: Schmidt, Wyman C.; McDonald, Kathy J., Ecology and management of *Larix* forests: a look ahead: proceedings of an international symposium; 1992 October 5-9; Whitefish, MT. Gen. Tech. Rep. INT-319. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 492-495. **Abstract**: Volume equations for western larch (*Larix occidentalis*) have been developed using a variety of bole form equations, but they did not account for spacing effects. This paper describes a study designed to evaluate bole form differences between three spacing levels at four locations in western Montana. Girards and Absolute form quotients were used as measures of bole form.

McCaughey, Ward W.; Schmidt, Wyman C.; Shearer, Raymond C. 1986. Seed-dispersal characteristics of conifers in the inland mountain west. In: Shearer, Raymond C., comp. Proceedings—Conifer tree seed in the inland mountain west symposium; 1985 August 5-6; Missoula, MT. Gen. Tech. Rep. INT-203. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 50-62. **Abstract**: This paper summarizes seed-dispersal characteristics and factors affecting dispersal of the major conifers found throughout the Inland Mountain West. Seed dispersal of these conifers is influenced by a number of physical, climatic, and biotic factors such as seed and wing size, height of cone-bearing trees, distance from seed source, physiographic position, and wind patterns. Birds and mammals also aid in the dispersal of larger seeds, particularly those that are wingless.

McClelland, B. Riley. 1977. Relationships between hole-nesting birds, forest snags, and decay in western larch-Douglas-fir forests of the northern Rocky Mountains. Missoula, MT: University of Montana. 489 p. Dissertation. **Abstract**: Nest tree and site preferences of hole-nesting birds were studied in the western larch –Douglas-fir forest cover type of northwestern Montana. The objectives of the study were to: 1) locate and characterize active nest trees, 2) identify habitat characteristics which have a major influence on the density and distribution of hole-nesting birds, and 3) provide management recommendations.

McClelland, B. Riley. 1979. The pileated woodpecker in forests of the northern Rocky Mountains. In: Dickson, James G.; Conner, Richard N. ; Fleet, Robert R. ; Kroll, James C. ; Jackson, Jerome A., eds. The role of insectivorous birds in forest ecosystems; 1978 July 13-14; Nacogdoches, TX. New York: Academic Press: 283-299. **Abstract**: A study of nesting habitat of the pileated woodpecker (*Dryocopus pileatus*) was conducted in northwestern Montana during 1974 through 1978. Fifty-four trees with active pileated woodpecker nests were located. Most nest cavities were in large western larch (*Larix occidentalis*) snags with broken tops. Mean measurements at nest trees were: dbh = 75 cm (29.5 in), tree height = 28m (92 ft), nest hole height = 15.2 m (50 ft), and basal area of surrounding forest= 25 m^2/ha (109 ft^2/acre). In the northern Rocky Mountains, forests with an old-growth component of western larch, ponderosa pine (*Pinus ponderosa*), or black cottonwood (*Populus trichocarpa*) seem to be essential for long-term support of

pileated woodpeckers. The roles of the pileated woodpecker include: a) pathfinder for non-excavating hole nesters, b) predator on insects, c) and key species in forest management plans.

McClelland, B. R. 1980. Influences of harvesting and residue management on cavity-nesting birds. In: Proceedings of a symposium on environmental consequences of timber harvesting in Rocky Mountain coniferous forests; 1979 September 11-13; Missoula, MT. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 469-496. **Abstract**: Coram Experimental Forest (CEF) plots on which different harvesting prescriptions and residue utilization intensities were applied in 1974 were studied during 1974-1979 to determine impacts on nesting and feeding activities of cavity nesters, especially woodpeckers. Uncut controls on the CEF and on other sites in the Flathead National Forest and Glacier National Park also were studied. Cavity nesters preferred western larch, ponderosa pine, black cottonwood, paper birch, or aspen nest trees with heartwood decay. Forests with a component of old-growth western larch supported the highest density and diversity of cavity nesters. Uncut controls received the highest % of feeding use. Shelterwood cuts and uncut islands within group selection plots received relatively high feeding use. Clearcuts received little use, regardless of the intensity of residue utilization.

McClelland, B. Riley. 1995. Old growth western larch forests: management implications for cavity-nesting birds. In: Schmidt, Wyman C.; McDonald, Kathy J., Ecology and management of *Larix* forests: a look ahead: proceedings of an international symposium; 1992 October 5-9; Whitefish, MT. Gen. Tech. Rep. INT-319. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 376. **Abstract**: This paper discusses the role western larch plays in the habitat requirements for cavity-nesting birds. The pileated woodpecker's importance as a "pathfinder" species, the importance of old-growth western larch, and the need for management strategies that feature optimal ecological values are emphasizes.

McClelland, B. Riley; Frissell, Sidney S. 1975. Identifying forest snags useful for hole-nesting birds. Journal of Forestry. 73(7): 414-417. **Abstract**: Preliminary results of a Montana study in western larch and Douglas-fir forests indicate that large broken-top larch and paper birch are most useful as nesting habitat. Some tentative management guides are suggested.

McClelland, B. Riley; Frissell, Sidney S.; Fischer, William C.; Halvorson, Curtis H. 1979. Habitat management for hole-nesting birds in forests of western larch and Douglas-fir. Journal of Forestry. 77(8): 480-483. **Abstract**: During a 3-year study in western larch (*Larix occidentalis*)-Douglas-fir (P*seudotsuga menziesii*) forests of northwestern Montana, 273 active nest trees of 20 hole-nesting bird species were located. Stands with major components of old-growth western larch, ponderosa pine (*Pinus ponderosa*), or black cottonwood (*Populus trichocarpa*) supported the highest density and diversity of hole-nesters. On commercial forests, managers should maintain units of old growth and prepare silvicultural prescriptions that will provide continuing replacement in the

future.

McClelland, B. Riley; McClelland, Patricia T. 1999. Pileated woodpecker nest and roost trees in Montana: links with old-growth and forest "health". Wildlife Society Bulletin. 27(3): 846-857. **Abstract**: The pileated woodpecker (*Dryocopus pileatus*) is of special interest to wildlife managers, it requires large trees for nesting, and its abandoned excavations are used by many birds and other small animals for nesting, roosting, hiding, and feeding. Prior to our study, little had been published on pileated woodpecker habitat in the northern Rocky Mountains. From 1973 through 1995, we located nest and roost trees of pileated woodpeckers in northwestern Montana forests dominated by western larch (*Larix occidentalis*) and Douglas-fir (*Pseudotsuga menziesii*). Nests (113 in 97 trees) were in western larch (n=52), ponderosa pine (*Pinus ponderosa*, n=18), black cottonwood (*Populus trichocarpa*, n=15), trembling aspen (*Populus tremuloides*, n=7), western white pine (*Pinus monticola*, n=3), grand fir (*Abies grandis*, n=1), and Douglas-fir (n=1). Nest-tree diameter-at-breast-height averaged 73 cm, and height averaged 29 m. Roost trees (n=40) were similar to nest trees, but had more cavity entrances and higher basal area of surrounding forest. Nest trees and roost trees typically were snags (81% and 78%, respectively) with broken tops (77% in both). Old-growth stands containing western larch were common nesting sites for pileated woodpeckers. Old-growth ponderosa pine, black cottonwood, and trembling aspen were locally important, but their distribution was more restricted. Compared to other nest-tree species in Montana, undecayed larch wood is hard, making excavation difficult for woodpeckers. Heartwood decay, which softens the wood, becomes more prevalent as a forest matures and was characteristic of western larch nest trees. In the northern Rocky Mountains, the pileated woodpecker has been used too broadly and simplistically as a management indicator of old growth. A more realistic strategy would nurture western larch old growth, defined ecologically, as an indicator of high-quality nesting habitat for pileated woodpeckers. Large trees, logs, snags, carpenter ants (*Camponotus* spp.), and heartwood decay are intrinsic components of "healthy" old growth that sustains pileated woodpeckers.

McClelland, B. Riley; McClelland, Patricia T. 2000. Red-naped sapsucker nest trees in northern Rocky Mountain old-growth forest. The Wilson Bulletin. 112(1): 44-50. **Abstract**: Throughout western North America, Red-naped Sapsucker (*Sphyrapicus nuchalis*) nests have been previously described primarily in trembling aspen (*Populus tremuloides*) with decay-softened wood. During 1974–1992, we located Red-naped Sapsucker nest trees (n = 125) in northwestern Montana old-growth coniferous forest that included widely scattered paper birch (*Betula papyrifera*). Sapsucker nests were in nine tree species (seven conifers). Most (68%) nest trees were live and 75% had broken tops. Western larch (*Larix occidentalis*) and birch were greatly over utilized compared to their availability. Larch nest trees (n = 84) were large [mean DBH = 69 ± 20.95 (SD) cm]. Mean DBH of birch nest trees (n = 30) was 37 ± 8.42 cm. All Mountain Chickadee (*Poecile gambeli*) nests (n = 36) and 12 of 23 Red-breasted Nuthatch (*Sitta canadensis*) nests were in old sapsucker excavated nest holes. Wood of larch and birch is inherently harder than that of aspen (specific gravity = 0.48, 0.48, and 0.35 respectively), posing a potential obstacle for relatively weak excavators such as

sapsuckers. However, the entire inner wood column of birch is susceptible to decay fungi and the durable bark is thin. In larch sapsuckers mitigated the difficulty by selecting trees with extensive heartwood decay (old larch) and by excavating in the upper bole (mean cavity height = 21.5 m), where the bark is thinner. External evidence of heartwood decay was present in 87% of larch and 86% of birch. Decay incidence increases with age in western larch forests, amplifying their value as habitat for sapsuckers and many other species. Perpetuation of old-growth western larch is an important component in the conservation of biological diversity.

Montana State Office. 1965. Water resources survey: Flathead and Lincoln counties, Montana. Helena, MT: State Engineer's Office. **Abstract**: Water resources data contained in this report are obtained from courthouse records in conjunction with individual contacts with landowners. Data include: land ownership, water right records (decrees and appropriations), and articles of incorporation of ditch companies and any other legal papers in regard to the distribution and use of water. This survey is a comprehensive inventory of water rights as they apply to land and other uses.

Mroz, G. D.; Jurgensen, M. F.; Harvey, A. E.; Larsen, M. J. 1980. Effects of fire on nitrogen in forest floor horizons. Soil Science Society of America Journal. 44(2): 395-400. **Abstract**: The effects of burning no nitrogen (N) losses and transformations in red pine (*Pinus resinosa* Ait.), eastern hemlock [*Tsuga canadensis* (L.) Carr.], and Douglas-fir (*Pseudotsuga menziesii*)/western larch (*Larix occidentalis* Nutt.) forest floor were investigated. Organic horizon samples were burned at 400°C for 30 min in a top-heating oven to simulate field conditions. Measurements taken immediately after burning showed total and available N losses from the O_1 horizons but gains in total and available N in underlying layers. After burning, the litter was incubated for 5 weeks and analyzed for ammonium and nitrate concentrations and changes in acidity. Each forest floor type displayed varying patterns of ammonification, nitrification and immobilization of N. The N changes appeared related to the differing initial N contents of the organic material.

Newman, Howard C.; Schmidt, Wyman C. 1980. Silviculture and residue treatments affect water use by a larch/fir forest. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: symposium proceedings; 1979 September 11-13; Missoula, MT. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 75-110. **Abstract**: Three silvicultural systems—clearcut, shelterwood, and group selection--were coupled with four residues treatments, ranging from intensive to conventional utilization and broadcast burning, to evaluate the environmental effects of harvesting larch/Douglas-fir forests in Montana. Effects of the 12 treatment combinations on accumulated precipitation, water used during the growing season, and soil water status during the year, were evaluated for the first 4 years after harvesting. The study was conducted on a steep east aspect at about 4,500 feet (1370 m) elevation.
Silvicultural treatments increased the amount of precipitation that reached the forest floor, most in clearcuts and group selections and less in shelterwoods. Snow accumulation which accounted for about 50 percent of the annual precipitation,

increased about 80 percent in clearcuts, 50 percent in group selections, and 40 percent in shelterwoods when compared to uncut mature forest. During the growing season, the uncut mature forest used about 75 percent of the total annual precipitation. Differences in water use following harvesting were less than expected. Shelterwoods used about 4 percent, group selections 10 percent, and clearcuts 11 percent less than the uncut control. Rapid revegetation on all harvested areas, the residual stand in the shelterwoods, and soil water deficits in the uncut forest apparently ameliorated some differences between uncut forest and treated areas. As a function of differences in accumulated precipitation, in the soil profile remained highest on clearcuts and lowest in uncut mature forest, with shelterwood and group selections falling between the two. Residue treatments had relatively minor effects on precipitation accumulation, water use, and soil water status. Of these, the two treatments with broadcast burning had the greatest effect.

Page-Dumroese, Deborah; Harvey, Alan; Jurgensen, Martin; Graham, Russell T. 1995. Ectomycorrhizal relationships in western larch ecosystems. In: Schmidt, Wyman C.; McDonald, Kathy J., Ecology and management of *Larix* forests: a look ahead: proceedings of an international symposium; 1992 October 5-9; Whitefish, MT. Gen. Tech. Rep. INT-319. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 342-348. **Abstract**: Ectomycorrhizae depend on soil organic materials for successful colonization and activity in larch ecosystems of the Intermountain West, U.S.A. Western larch (*Larix occidentalis* Nutt.) and three other conifer species were evaluated to assess the role of site disturbances and organic horizons on root growth and ectomycorrhizal activity. All species use organic horizons and principal growth substrates. Use of mineral horizons varies by species. Soil types with the greatest organic matter supported the greatest fungal and root growth.

Page-Dumroese, Deborah; Jurgensen, Martin; Elliot, William; Rice, Thomas; Nesser, John; Collins, Thomas; Meurisse, Robert. 2000. Soil quality standards and guidelines for forest sustainability in northwestern North America. Forest Ecology and Management. 138(1-3): 445-462. **Abstract**: Soil quality standards and guidelines of the USDA Forest Service were some of the first in the world to be developed to evaluate changes in forest soil productivity and sustainability after harvesting and site preparation. International and national development of criteria and indicators for maintenance of soil productivity make it imperative to have adequate threshold variables within the USDA Forest Service. In the Pacific Northwest, soils range from one-textured Andisols to coarse-textured skeletal Inceptisols. Forest types encompass the highly productive coastal rain forest to marginally productive, dry, cold sites in the interior mountains. Constant values to detect detrimental disturbances within the soil quality guidelines are routinely applied across diverse soils and timber types and include diagnostic criteria for evaluating management-caused changes to soil productivity. Research information from short- or long-term research studies supporting the applicability of disturbance criteria is often lacking, or is available from a limited number of sites which have relatively narrow climatic and soil ranges. In this paper we calculated changes in soil carbon, nitrogen, erosion, and cation exchange capacity using threshold variables from the Regional USDA Forest Service Soil Guidelines to

assess their applicability across diverse landscapes. Soils were selected from a climatic and elevational gradient in the Pacific Northwest. Application of selected USDA Forest Service standards indicate that blanket threshold variables applied over disparate soils do not adequately account for nutrient distribution within the profile or forest floor depth. These types of guidelines should be continually refined to reflect pre-disturbance conditions and site-specific information.

Page-Dumroese, Deborah; Jurgensen, Martin F.; Harvey, Alan E. 2003. Fire and fire-suppression impacts on forest-soil carbon. In: Kimble, J. M.; Heath, Linda S.; Birdsey, Richard A.; Lal, R., eds. The potential of US forest soils to sequester carbon and mitigate the greenhouse effect. Boca Raton, FL: CRC Press: 201-210. **Abstract**: This chapter discusses the impact of fire on soil carbon (C) pools, recovery after fire, the effects of a fire suppression policy on soil C, methods to estimate C losses from fire, and the implications of fire management on soil C cycling and sequestration.

Pfister, Robert D.; Kovalchik, Bernard L.; Arno, Stephen F.; Presby, Richard C. 1977. Forest habitat types of Montana. Gen. Tech. Rep. INT-34. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 174 p. **Abstract**: A land-classification system based upon potential natural vegetation is presented for the forests of Montana. It is based on an intensive 4-year study and reconnaissance sampling of about 1,500 stands. A hierarchical classification of forest sites was developed using the habitat type concept. A total of 9 climax series, 64 habitat types, and 37 additional phases of habitat types are defined. A diagnostic key is provided for field identification of the types based on indicator species used in development of the classification.
In addition to site classification, descriptions of mature forest communities are provided with tables to portray the ecological distribution of all species. Potential productivity for timber, climatic characteristics, and surface soil characteristics are also described for each type. Preliminary implications for natural resource management are provided, based on field observations and current information.

Pierce, Sarah Jane. 2003. Establishment and growth of conifer regeneration following harvest and residue treatments in a western larch - Douglas-fir forest. Missoula, MT: University of Montana. 101 p. Thesis. **Abstract**: Forest managers often choose prescriptions that promote natural regeneration of various species that differ in relative shade tolerance. Assessing the response of forest vegetation to alternative treatments in the Inland Northwest is challenging, given that the process takes decades to unfold. In this study, conifer regeneration was examined in a western larch (*Larix occidentalis*)/Douglas-fir (*Pseudotsuga menziesii*) forest 25 years after harvest and residue treatments. Harvest treatments included: clearcut, group selection, and shelterwood. Residue treatments included: moderate utilization burned, standard utilization burned, intensive-fiber utilization unburned, and moderate utilization unburned. Subsequent natural conifer regeneration was sampled across all treatments in 2001. Douglas-fir and Engelmann spruce planted between1976-1979 were remeasured and compared to natural conifer regeneration. In addition, growth of a sub-sample of western larch trees in the shelterwood and clearcut harvests was

examined in relation to measures of overstory and understory competition. Natural regeneration was primarily Douglas-fir in all treatments, though larch saplings were typically among the tallest individuals where they occurred. Natural regeneration densities and stocking levels were highest in the shelterwood harvest treatment, and in the two burned residue treatments. Mean heights of the tallest natural regeneration of each species were greater in the clearcuts and group selections than in the shelterwood harvest treatments, and also greater in the burned than the unburned residue treatments. Planted Douglas-fir and Engelmann spruce total height and growth were greatest in the burned treatments of the clearcuts and group selection. Planted trees were consistently taller than natural regeneration Douglas-fir and spruce. Western larch is surviving under the residual overstory of a shelterwood, though recent growth is lower than in other harvest treatments. Under the residual overstory of the shelterwood, western larch growth was positively correlated with initial tree height, and negatively correlated with canopy cover, stand density index, and tall understory cover. Results suggest that after 25 years, the effects of harvest and residue treatments remain evident in the amount and size of natural regeneration, as well as in the size and survival of planted stock. Further, it appears possible to maintain some component of vigorous young larch recruits in partial retention stands.

Polk, R. Brooks. 1949. A survey of composition trends in cut-over stands of the larch--Douglas-fir cover type of western Montana. Missoula, MT: Montana State University. 99 p. Thesis. **Abstract**: A survey of composition trends in cut-over larch-Douglas-fir stands in western Montana was conducted to examine (1) the response of the forest overstory to past cutting practices and (2) the relative abundance and composition of the young stand as affected by (a) the amount of forest cover, (b) aspect, (c) time of establishment, and (d) the relative height growth of competing species.

Polk, R. Brooks; Boe, Kenneth N. 1951. Succession of trees in cut-over larch–Douglas-fir stands in western Montana. Proceedings of the Montana Academy of Sciences. 10: 31-37. **Abstract**: Objectives were to determine the composition of tree species in cut-over larch- Douglas fir forests as compared with the original stands, and to consider what environmental factors influenced the resulting regeneration. Results suggested that in general larch did not regenerate adequately in cut-over areas as compared to other less-favorable tree species.

Richardson, Sherri. 1997. Trees and logs important for wildlife habitat. Forest Research West. 7-11. **Abstract**: The value of trees and logs for wildlife use and habitat is reviewed. Structures that are used by wildlife include: living trees with decay, hollow trees, trees with brooms, dead trees, and down woody material. Two publications that are referenced and discussed are “Trees and logs important to wildlife in the Interior Columbia River Basin”, and the “Field guide for the identification of snags and logs in the Interior Columbia River Basin”. The author infers that forest management should include objectives that allow these wildlife structures to persist in the ecosystem.

Roe, Arthur L. 1948. A preliminary classification of tree vigor for western larch and

Douglas-fir trees in western Montana. Res. Note No. 66. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. **Abstract**: A vigor classification system is introduced for the western larch and Douglas-fir forest type. Factors affecting vigor include: position of the tree in the stand, size and conditions of the crown, tree age, and disease presence. The author suggests that this vigor classification system will be useful in the selection of fast-growing trees for partial cuttings.

Roe, Arthur L. 1948. Thirty-nine years growth in a cut-over larch stand. Res. Note No. 70. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. **Abstract**: Growth and mortality of residual and regenerating trees was measured on a larch-Douglas fir stand that was selectively harvested. Varying harvest intensities resulted in stands that were displayed varying degrees of ingrowth and residual tree growth. Despite being the preferred timber species, western larch reserve trees were exceeded in volume increment by the younger Douglas-fir residuals.

Roe, Arthur L. 1950. Response of western larch and Douglas-fir to logging release in western Montana. Northwest Science. 24(3): 99-104. **Abstract**: The purpose of the study was to analyze the factors which affect the growth responses of western larch and Douglas-fir following logging. Results suggest that: (a) Maximum growth of individual trees occurred in the lightest reserve stands. (b) Diameter growth rates decreased rapidly with increasing volume of reserve up to 5000 board feet per acre, after which it tended to level off. (c) Western larch made relatively better response than Douglas-fir, but on the average, Douglas-fir continued to make wider growth rings after logging. (d) The best vigor larch, under maximum release from competition, grew at good rates (up to 1.1 in. diameter per decade). Under similar conditions, Douglas-fir grew practically the same. (e) The best vigor larch, under greater competition, grew somewhat more slowly than Douglas-fir. (f) Trees in the three different vigor classes exhibited significantly different rates of growth.

Roe, Arthur L. 1951. Growth tables for cut-over larch--Douglas-fir stands in the upper Columbia Basin. Station Paper No. 30. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 24 p. **Abstract**: Growth tables are presented to predict future growth of reserve stands, determine cutting intensities, and aid in the selection of which trees to cut. Growth tables were based on measurements and analysis of variables including: tree growth rates, environmental factors, tree vigor, and stand density. Instructions for how to use the growth tables are included.

Roe, Arthur L. 1952. Larch–Douglas-fir regeneration studies in Montana. Northwest Science. 26(3): 95-102. **Abstract**: One of the chief forest management goals in the larch-Douglas-fir (*Larix occidentalis-Pseudotsuga taxifolia*) type is to maintain or increase the percentage of larch after cutting. Forest managers generally agree that on typical larch habitats, this species is superior for timber production in many respects to Douglas-fir and other more shade-tolerant associated species. To achieve this goal will

require knowledge of habitat conditions "that favor larch reproduction and survival and development of methods for applying this knowledge in practical silviculture. The purposes of this paper are to review past and current investigations and summarize further investigative work which appears to be needed in order to attain the goal of encouraging regeneration of western larch.

Roe, Arthur L. 1955. Cutting practices in Montana larch–Douglas-fir. Northwest Science. 29(1): 23-34. **Abstract**: Until recent years formal research in the western-Larch–Douglas-fir type has included little more than silvical studies of the principal species. Cutting practices, based mainly upon empirical knowledge, have varied widely in silvicultural and management objectives and in the results obtained. The Northern Rocky Mountain Forest and Range Experiment Station in 1947 began a program of research in Larch–Douglas-fir management. The advantages and disadvantages of different cutting systems are explored.

Roe, Arthur L. 1955. A seedbed preparation test in the larch–Douglas-fir timber type in northwestern Montana. Missoula, MT: Montana State University. 62 p. Thesis. **Abstract**: A test of seedbed preparation was conducted on five-year old seed tree cuttings on the Coram Experimental Forest. Three seedbed preparation methods were tested: 1) mechanical scarification; 2) prescribed broadcast burn; and, 3) understory slashed—destruction of understory trees and shrubs. The study concludes that western larch and Engelmann spruce favor seedbed preparation, while Douglas-fir stocking was not significantly improved by seedbed preparation as compared to the natural forest floor.

Roe, Arthur L. 1956. The effect of competition in old growth western larch–Douglas-fir stands. Proceedings of the Montana Academy of Sciences. 16: 41-45. **Abstract**: Western larch, *Larix occidentalis* Nutt., is usually succeeded by more shade-tolerant species. These shade-tolerant species often form a dense understory in mature and over mature larch stands. Frequently the crowns of mature western larch trees in the overstory in such situations become decadent, resulting in a stag-headed condition as the upper 5 to 20 feet of the crown die back. Some observers have attributed this condition to dwarf mistletoe infection while others have suggested root competition by the understory trees as a possible cause. This paper reports an attempt to investigate quantitatively the effect of root competition by the understory on an overstory of larch and Douglas-fir.

Roe, Arthur L. 1966. A procedure for forecasting western larch seed crops. Res. Note INT-49. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 7 p. **Abstract**: Successful regeneration depends upon good coordination between seed production and seedbed preparation. To aid forest managers in scheduling seedbed preparation, a simple sequential sampling plan for estimating potential cone crops as much as a year in advance of the seed fall was developed and is described herein. With advance knowledge of the cone crop prospects. the manager can schedule seedbed preparation or select an alternative action such as postponing work or substituting planting.

Roe, A. L.; Benson, R. E. 1966. Evaluating growth performance of young stands. Research Note INT-44. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 7 p. **Abstract**: A simple procedure for evaluating the diameter growth of young stands in relation to potential growth is described. A comparison technique is developed which contrasts relative diameter of crop trees to the relative diameter growth of the last decade to show the condition and trend of growth in the stand. The method is objective, easy to use, and has several applications such as: (1) determining relative growth performance of trees and stands, (2) confirming the need for thinning and setting of priority among stands, and (3) determining the growth impact of disease and other growth depressing agents. The technique does not replace more complex, precise methods of growth study.

Roe, Arthur L.; Squillace, A. E. 1953. Effect of cutting methods on logging costs in larch–Douglas-fir. Journal of Forestry. 51(11): 799-802. **Abstract**: Silviculturists tend to overlook financial aspects of cutting methods in their desire for greater understanding of purely biological factors. Reporting in a study made in the Larch–Douglas-fir type in the northern Rocky Mountains, the authors discuss some effects of cutting method upon logging costs.

Running, Steven W.; Hungerford, Roger D. 1983. Spatial extrapolation of meteorological data for ecosystem modeling applications. In: Proceedings of the sixth conference on biometeorology and aerobiology and 16th conference on agriculture and forest meteorology; 1983 April 26-29; Fort Collins, CO. Boston, MA: American Meteorological Society: 192-195. **Abstract**: The objective of this paper is to report our first attempt at predicting important meteorological variables on a forested site, without onsite measurements. Our primary interest is to predict daylight average air temperature and relative humidity, daily incoming shortwave radiation and daily 24 hour precipitation for the annual period of potential photosynthesis for coniferous trees. Midwinter conditions, nocturnal conditions, windspeed and direction were not considered necessary to drive a forest growth model. Additionally, no vertical canopy profiles are considered.

Sax, J. L.; Keiter, R. B. 1987. Glacier National Park and its neighbors: A study of federal interagency relations. Ecology Law Quarterly. 14: 207. **Abstract**: Glacier National Park’s relationships with its neighbors, the Park's success in influencing external activities, and broader lessons relevant to the park protection debate are described. Coram Experimental Forest’s role in the Biosphere Reserve Program is discussed.

Schmidt, Wyman C. 1961. Effects of some treatments on the dormancy of western larch seed. Missoula, MT: University of Montana. 63 p. Thesis. **Abstract**: This thesis compares seed germination rates resulting from nine seed treatments. Results suggest that: 1) steeping the seeds in cold water for 18 days, or soaking the seeds in 3% hydrogen peroxide for 12 hours are acceptable methods for quickly determining the viability of a western larch seed lot; and, 2) sand stratification, steeping, and naked stratification of western larch seed are the treatments most promising for field sowing

application.

Schmidt, Wyman C. 1962. Rapid viability tests for western larch seed. Proceedings of the Montana Academy of Sciences. 21: 26-32. **Abstract**: Time required for viability tests of western larch (*Larix occidentalis* Nutt.) seed can be shortened by use of proper treatments. Tests show that by cold-soaking the seeds in water or soaking them in hydrogen peroxide prior to incubation, 98 percent of germinative capacity can be reached in as short a time as 28 days.

Schmidt, Wyman C. 1966. Growth opportunities for young western larch. Res. Note INT-50. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 4 p. **Abstract**: Young western larch stands commonly overstock and have as many as 30,000 to 40,000 trees per acre. A typical 9-year-old larch stand showed that individual tree growth and crown development were far better where stocking rates were not this heavy. Dominant larch grew twice as much in diameter and one -third more in height on plots having 5,000 trees per acre as they did on plots with 35,000 trees per acre. Very early thinning is recommended for heavily overstocked larch stands.

Schmidt, Wyman C. 1969. Seedbed treatments influence seedling development in western larch forests. Res. Note INT-93. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 7 p. **Abstract**: Studies in 12- to 15- year- old western larch stands at Coram Experimental Forest in northwestern Montana show that condition of the seedbed at the time of seedling establishment strongly influences seedling development. Larch regenerates abundantly, grows rapidly, and becomes dominant where prescribed burning or mechanical scarification has reduced the amount of competing vegetation. In contrast, Douglas- fir is less sensitive to seedbed conditions for both establishment and growth. With reduced competition from larch, it subsequently dominates stands where seedbeds had little or no preparation.

Schmidt, Wyman C. 1978. Some biological and physical responses to forest density. In: Eighth world forestry congress; 1978 October 16-18; Jakarta, Indonesia. FQL 25-2. 12. **Abstract**: Forestry activities such as thinning can impact the forest environment in a number of positive ways. Using western larch (*Larix occidentalis* Nutt.) as an example, this paper illustrates that stand culture not only accelerates and distributes growth on selected trees, but it affects other forest factors such as water yield and insect relationships. For example, reducing stand densities decreased the amount of water used by the regulated stands as much as 20% compared to the nonregulated stands, making more water available for streamflow. Stand density regulation also affected the incidence of defoliator insects and the ability of trees to cope with the insect-feeding activities. Trees in the stands with the lowest stand densities recuperated the most rapidly after the insect populations declined. Thus, regardless of the primary objective of stand culture — whether to improve tree growth, manipulate water use, reduce insect susceptibility, or to regulate some other forests value — it will likely impact the environment, and it can be in a positive fashion.

Schmidt, Wyman C. 1980. Understory vegetation response to harvesting and residue management in a larch/fir forest. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: symposium proceedings; 1979 September 11-13; Missoula, MT. Gen. Tech. Rep. INT-90. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 221-248.
Abstract: This paper reports the response of understory shrubs and herbs to combinations of three silvicultural harvest cutting systems--clearcut, shelterwood, group selection-and four residues treatments--intermediate utilization of harvest residues followed by broadcast burning, conventional-utilization-and-broadcast-burn, intense removal of all woody residues, and understory-protected treatments. Volume, cover, and biomass of shrubs and herbs were evaluated before, and at 2 years and 4 years after harvesting.
All treatments substantially reduced the volume and biomass of live shrubs to as little as 3 percent of the preharvest volume on burned treatments. However, all vegetation responded rapidly under all treatments, in some cases approaching preharvest levels in as few as 4 years. Herbs responded earlier and more to treatments than did the shrubs. Total biomass of live understory vegetation (not including trees) averaged over 5,000 kg/ha (4,500 pounds/acre) in the mature forest, reached about half that 2 years after harvesting, and about three-fourths of that 4 years after harvesting.

Schmidt, Wyman C. 1989. Management of young *Larix occidentalis* forest in the Northern Rocky Mountains of the United States. In: Wollmerstädt, J.; Thomasius, Harald, Treatment of young forest stands: proceedings, International Union of Forestry Research Organizations, Working Party S1.05-03; 1989 June 19-23; Dresden, East Germany. Dresden: Technische Universitaet: 246-253.
Abstract: Stand density strongly affects tree growth, animal damage, and water use in young western larch (*Larix occidentalis*) forests of the northern Rocky Mountains of the United States. Continuous 20-year records of naturally regenerated stands that were thinned to a wide range of densities at age 9 shows that these young forests were very responsive to different stand density levels. Diameter and height were very different after 20 years of stand density regulation with the largest trees produced in the least dense plots. Tree survival generally was high in thinned stands, but bears (*Ursus* spp.) were a problem; they damaged the largest trees in stands with the fewest trees. Water use, in this area where water is usually limiting, was greatest in the densest stands.

Schmidt, Wyman C. 1995. Around the world with *Larix*: an introduction. In: Schmidt, Wyman C.; McDonald, Kathy J., Ecology and management of *Larix* forests: a look ahead: proceedings of an international symposium; 1992 October 5-9; Whitefish, MT. Gen. Tech. Rep. INT-319. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 6-18.
Abstract: This paper describes the global distribution of larch forests. The 10 species (and several hybrids) of larch occupy a wide variety of ecological conditions across the Northern Hemisphere. The10 most commonly recognized larch species and their general distribution are listed and described.

Schmidt, Wyman C. 1998. Stand density in relation to biological functions in young

Western larch forests. In: Bamsey, Colin R., ed. Stand density management: planning and implementation: proceedings of a conference; 1997 November 6-7; Edmonton, Alberta, Canada. Edmonton, Alberta: Clear Lake Ltd.: 101-111. **Abstract**: Western larch is a versatile and valuable species in the U.S. and Canadian West. Like most other seral species, it is a good seed producer that claims receptive sites soon after fires, harvesting, or other disturbances over much of its natural range. Its rapid juvenile growth provides a competitive edge over most of its associated species, but it normally overstocks to the point that individual tree growth is inhibited by intertree competition early in its life. This paper describes the development of young western larch under a wide range of regulated and natural stand conditions. It demonstrates larch's rapid growth potential, describes its phenology, soil water use, cone production, wood density, mortality and damage factors such as snow and frost, budworm, larch casebearer, diseases, and bear. Dispersed locations of the study provided the opportunity to monitor different growth performances and the various perturbations that occur during a 30-year period at four widely separated study sites.

Schmidt, Wyman C.; Carlson, Clinton E.; Byler, James W. 1992. A wedding of new perspectives and research in the inland west: something old, something new, something blue. In: National silviculture workshop; 1991 May 6-9; Cedar City, UT. Gen. Tech. Rep. INT-US. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 14-18. **Abstract**: A wedding is the analogy used to describe some of the processes that should be considered in matching research objectives with New Perspectives concepts. The status of planning aimed at implementing this "marriage" is described in terms of the "old," "new," and "blue." Researchers need to examine old data in a new light and blend in the more recent, new, and sophisticated data into meaningful packages that will help implement New Perspectives. Research and management are cautioned about the "blue" aspects-insect and disease problems that can be associated with various silvicultural objectives under New Perspectives. Some of the Intermountain Research Station's New Perspectives planning is described.

Schmidt, Wyman C.; Fellin, David G. 1973. Western spruce budworm damage affects form and height growth of western larch. Canadian Journal of Forest Research. 3(1): 17-26. **Abstract**: An unusual feeding behavior of the western spruce budworm (*Choristoneura occidentalis* Freeman) reduced height growth and deformed young western larch (*Larix occidentalis* Nutt.). On western larch, budworm larvae did not confine their feeding to foliage, their usual diet on other conifers, they also fed on and severed stems of current-year terminal and lateral shoots. A 5-year study in young larch stands showed that: (1) amount and severity of budworm damage increased annually; (2) all trees were damaged sometime during the study; (3) severance of the terminal shoot was the most serious type of budworm damage to larch; (4) severances reduced net height growth at least one-fourth and resulted in forked; bushy-topped trees; and (5) specific forks in the tree did not persist more than 5 years because of the strong apical dominance characteristic of larch.

Schmidt, Wyman C.; Fiedler, Carl E.; McCaughey, Ward W. 1995. Vegetation responses to silviculture and woody residue treatments in a western larch forest.

Schmidt, Wyman C.; McDonald, Kathy J., Ecology and management of *Larix* forests: a look ahead: proceedings of an international symposium; 1992 October 5-9; Whitefish, MT. Gen. Tech. Rep. INT-319 Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 375. Abstract. **Abstract**: This abstract describes a 10-year response to the harvest cutting treatments: (1) clearcut, (2) shelterwood, and (3) group selection with residues disposal treatments. Residue treatments included: (1) moderate level of woody residues followed by broadcast burning, (2) heavy amount of residues followed by broadcast burning, (3) intense removal of all residues, and (4) understory tree protected with moderate removal of woody residues. Results suggest that understory response to the various treatment combinations was rapid for the first 2 to 4 years followed by a gradual approach toward mature forest conditions.

Schmidt, Wyman C.; Friede, J. L. 1996. Experimental forests, ranges, and watersheds in the northern Rocky Mountains: a compendium of outdoor laboratories in Utah, Idaho, and Montana. Gen. Tech. Rep. INT-GTR-334. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 117 p. **Abstract**: This is a compendium of experimental forests, ranges, watersheds, and other outdoor laboratories, formally established by the Forest Service and Agricultural Research Service of the U.S. Department of Agriculture, and the universities in Utah, Idaho, and Montana. The purposes, histories, natural resource bases, data bases, past and current studies, locations, and who to contact for information are given for these areas that represent ecosystems ranging from deserts to cold subalpine forests.

Schmidt, Wyman C.; Gourley, Mark. 1992. Black bear. In: Black, Hugh C., Silvicultural approaches to animal damage management in Pacific Northwest forests. Gen. Tech. Rep. PNW-GTR-287 Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 309-331. **Abstract**: Black bears can be a significant forest management problem in young to intermediate-age forests of the Pacific Northwest and the northern Rocky Mountains. Bears peel bark from the lower bole of trees and feed on the inner bark and cambium layers. This peeling totally or partially girdles trees, kills some, and provides an entrance point for disease in trees that survive. Bears' favorite trees are Douglas-fir in the forests west of the Cascade Range and western larch in the northern Rockies, but they also feed , to a lesser extent, on associated tree species. Most damage occurs in 15- to 25-year-old coastal forests and 15- to 50-year-old forests of the northern Rockies. Rapidly growing, vigorous trees are favorite targets for bears-usually in moderately to lightly stocked stands. Bear damage mostly occurs in May and June when the wood-sugar content of trees is high. Damage is sporadic and apparently results from learned behavior passed from sow to cub. Silvicultural practices that may help reduce the problem include management for greater species diversity, delayed thinning and fertilizing where bear damage is severe, stands maintained at higher densities, and management objectives and practices adjusted to compensate for losses caused by bears. Direct control of problem bears is the most common method of reducing tree damage. Direct control includes hunting, snaring, relocation, and supplementary feeding. Snaring is the most successful of these methods of control, because it targets specific bears that cause the problem, not the

entire bear population. Many questions remain to be answered before a totally satisfactory solution to the bear-damage problem is reached. That solution probably will involve some combination of reasonable adjustments in silvicutural practices to reduce favorable feeding conditions for bears and some selective control of bears. This chapter includes a list of questions concerning this subject that remained unanswered.

Schmidt, Wyman C.; McCaughey, Ward W.; Schmidt, Jack A. 1995. Western larch growth and pertubations in stands regulated for 30 years. In: Schmidt, Wyman C.; McDonald, Kathy J., Ecology and management of *Larix* forests: a look ahead: proceedings of an international symposium; 1992 October 5-9; Whitefish, MT. Gen. Tech. Rep. INT-319 Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 281. Abstract. **Abstract**: This abstract describes a long-term, permanent plot study that was established to determine the effects of different levels of regulated stand densities on western larch individual tree and stand growth. Also examined was the relationship of these different stand densities to perturbations such as insect, animal, snow, and other types of damage to the trees. Results suggest that larch diameter growth was very responsive to stand density, with the greatest individual tree growth in the least dense stands.

Schmidt, Wyman C.; McDonald, Kathy J. comps. 1995. Ecology and management of *Larix* forests: a look ahead: proceedings of an international symposium. Gen. Tech. Rep. INT-319; 1992 October 5-9; Whitefish, MT. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 521 p. **Abstract**: This proceedings is a product of the first comprehensive and international examination of *Larix* species of the world. It reports most of the papers and posters that were presented at the international symposium “Ecology and management of *Larix* forests: a look ahead”. Topics covered include: *Larix* ecology and management, physiology, regeneration processes, silviculture, damage agents, genetics, breeding, and provenance testing. Also included is a special section on *Larix occidentalis*.

Schmidt, Wyman C.; Schmidt, Jack A. 1979. Recovery of snow-bent young western larch. Gen. Tech. Rep. INT-54. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 13 p. **Abstract**: Heavy winter snowfalls are common in the subalpine forests of the Northern Rockies. These forests are generally well adapted to winter snows. But occasionally unseasonal, heavy, wet snows damage these forests. In June 1966, a heavy wet snow flattened many young stands in the Flathead area of northwestern Montana. Included was a 13-year-old western larch stand on one of our stand development study areas on Coram Experimental Forest. Photographic evaluations of this stand over an 11-year period following the snowfall showed that: (1) all trees in the sample, regardless of severity of the snow damage, eventually recuperated; (2) slightly snow-bent trees returned to vertical within 2 years, moderate and heavily snow-bent trees within 4 years, and severely snow-bent trees within 6 years; (3) the most apparent aftereffects were crooks in the tree boles, with the extent of crook deformities directly related to the severity of the snow bend: (4) dominant and nondominate trees recovered at about the same rate. These results illustrate phenomenal recuperative abilities of vigorous young

larch and demonstrate to the manager that snow bend doesn't always reduce his management options.

Schmidt, Wyman C.; Seidel, Kenneth W. 1988. Western larch and space: thinning to optimize growth. In: Schmidt, Wyman C., Proceedings--future forests of the mountain west: a stand culture symposium; 1986 September 29-October 3; Missoula, MT. Gen. Tech. Rep. INT-243. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 165-174. **Abstract**: Space determines the future of many organisms, and western larch is one of them. Larch is an important pioneer species in the Inland Mountain West of the United States and Canada, well adapted to regenerating sites disturbed by fire, harvesting, or other activities. This paper summarizes information on how space allotted to larch trees affects growth response at very early as well as intermediate stages. Western larch benefits greatly when given adequate space to grow. Spacing is most effective in very young stands. Diameter is most responsive and is directly related to intensity of thinning, but height response is more variable and less conclusive. Basal area increases rapidly to about age 40, slows, and levels off after age 100, and it is related to stand density. Cubic volume yield is relatively constant over a wide range of density, but merchantable volume is generally increased by thinning.

Schmidt, Wyman C.; Shearer, Raymond C. 1973. Western larch. In: Silvicultural systems for the major forest types of the United States. Agric. Handb. 445 Washington, DC: U.S. Department of Agriculture, Forest Service: 37-38. **Abstract**: The current trend toward the establishment and care of forests for a wide combination of uses requires flexibility in forest culture and a knowledge of the silvicultural choices available to the resource manager. This publication summarizes for each of 37 major forest types in the United States the silvicultural systems that appear biologically feasible on the basis of present knowledge. Supporting information is given on the occurrence of the 37 forest types, the cultural requirements of the component species, and the biological factors that control the choice of silvicultural options. The text is arranged in regional sections suitable for reprinting.

Schmidt, Wyman C.; Shearer, Raymond C. 1990. *Larix occidentalis* Nutt. Western Larch. In: Burns, Russell M.; Honkala, Barbara H., tech. coords. Silvics of North America. Volume 1. Conifers. Washington, DC: U.S. Department of Agriculture, Forest Service: 160-172. **Abstract**: This chapter reviews the geographic range, climate conditions, soils and topography, and associated forest cover that support western larch. Life history including reproduction, growth, seed production, seedling development, rooting habit, ecology, and competitive strategy are reviewed.

Schmidt, Wyman C.; Shearer, Raymond C. 1999. *Larix occidentalis* Nutt., western larch. Burns, Russell M. ; Honkala, Barbara H., Silvics of North America. Agric. Handb. 654 1. Washington, DC: U.S. Department of Agriculture, Forest Service: 160-172. **Abstract**: This chapter reviews the geographic range, climate conditions, soils and topography, and associated forest cover that support western larch. Life history including reproduction, growth, seed production, seedling development, rooting habit, ecology,

and competitive strategy are reviewed.

Schmidt, Wyman C.; Shearer, Raymond C.; Naumann, John R. 1983. Western larch. In: Bums, Russell M., tech. comp. Silvicultural systems for the major forest types of the United States. Agric. Handb. 445 (Rev.) Washington, DC: U.S. Department of Agriculture, Forest Service: 56-58. **Abstract**: The current trend toward the establishment and care of forests for a wide combination of uses requires flexibility in forest culture and a knowledge of the silvicultural choices available to the resource manager. This publication summarizes the silvicultural systems that appear biologically feasible, on the basis of present knowledge, for each of 48 major forest types in the United States. Supporting information is given on the occurrence of the 48 forest types, the cultural requirements of the component species, and the biological factors that control the choice of silvicultural options.

Schmidt, Wyman C.; Shearer, Raymond C.; Roe, Arthur L. 1976. Ecology and silviculture of western larch forests. Tech. Bull. 1520. [Washington, DC]: U.S. Department of Agriculture, Forest Service. 96 p. **Abstract**: Summarizes and consolidates ecological and silvicultural knowledge of western larch forests. Describes economic, biological, and environmental values; tree regeneration and stand management opportunities; and growth and yield estimates.

Schweitzer, Dennis L.; Ullrich, James R.; Benson, Robert E. 1976. Esthetic evaluation of timber harvesting in the northern Rockies: a progress report. Res. Note INT-203. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 11 p. **Abstract**: Panels of judges have been evaluating the esthetic dimension of harvested areas in the Northern Rockies. Studies conducted in Wyoming and Montana agree with intuition in that forest scenes are generally liked less as the evidence of man's activities increases.

Scott, Glenda; Chew, Jimmie D. 1997. Demonstrating vegetation dynamics using SIMPPLLE. In: Communicating the role of silviculture in managing the national forests: Proceedings of the national silviculture workshop; 1997 May 19-22; Warren, PA. Gen. Tech. Rep. NE-238. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 65-75. **Abstract**: Understanding vegetation dynamics, both spatially and temporally, is essential to the management of natural resources. SIMPPLLE has been designed to help us quantify and communicate these concepts: What levels of process, i.e., fire or insect and disease, to expect; how they spread; what the vegetative distribution and composition is over time; and how silvicultural treatments affect the processes driving vegetative change. SIMPPLLE is applied in two forest types and used to communicate interaction of processes and vegetative patterns on specific landscapes and evaluate silvicultural strategies. Impacts on species, stand structure and probability of fire are displayed and compared to desired landscape conditions.

Shearer, Raymond C. 1959. Seed dispersal and seedling establishment on clearcut blocks in the larch–Douglas-Fir type in northwestern Montana. Logan, UT: Utah State

University. 72 p. Thesis. **Abstract**: This paper discusses block clearcutting as a means of harvesting timber and reestablishing larch as the dominant species. The block clearcutting study is located on the Coram Experimental Forest in northwestern Montana. The objectives of the study were to: 1. Determine the maximum and optimum sized openings which can be regenerated successfully within five years on this area. 2. Obtain seed dispersal information over the clearcut blocks for the major species represented in the residual timber. 3. Evaluate regeneration by seedbeds. 4. Determine the possible reasons for seed loss and seedling mortality from a study of literature. The information contained in this paper attempts to explain the significance of the data gathered from three clearcut blocks on the Coram Experimental Forest.

Shearer, Raymond C. 1959. Western larch seed dispersal over clearcut blocks in northwestern Montana. Proceedings of the Montana Academy of Sciences. 19: 130-134. **Abstract**: Data on dispersal of western larch seed through a 6-year experimental period were obtained from clearcut areas on the Coram Experimental Forest. Two seed crops during the 6- year period were good, two were poor, and two were near failures. Seed soundness as determined by cutting test s varied from 42.4 % to 4.9%. Highest soundness occurred in years of abundant seed production and lowest soundness in poor seed years. 92% of the total sound seed was dispersed by the good seed crops into the cut-over areas, 6% from the poor seed crops, and 2% from the near-failure crops. Seed dispersal declined rapidly from timber edge to 6 chains, then decreased slowly to the center of the 60-acre block. Virtually no seeds were dispersed past 4 chains from timber edge during poor seed years. Seed soundness declined with increased distance from the seed source. Most of the seed was dispersed uphill, probably by thermal slope winds occurring on hot, dry days. Enough seed is disseminated throughout square, clear-cut blocks as large as 60 acres during an abundant seed year to provide for adequate restocking.

Shearer, Raymond C. 1961. First-year mortality of coniferous seedlings in the western larch-Douglas-fir type. Proceedings of the Montana Academy of Sciences. 20: 18-19. **Abstract**: Seeds of western larch, Douglas-fir, Engelmann spruce, and subalpine fir were sown in the spring of 1959. The amount and cause of mortality was measured on watered, weeded, shaded, and nontreated quadrats. Germination began in late May and continued at a low rate until the soil surface became dry. Initial seedling loss began soon after germination started. Biotic agents, mainly fungi, birds, and rodents, caused most of the early losses and ceased in early July as soil moisture decreased and seedling tissue hardened. From mid-July until mid-August heat and drought were the main physical agents causing mortality.

Shearer, Raymond C. 1967. Insolation limits initial establishment of western larch seedlings. Res. Note INT-64. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 p. **Abstract**: During a 2 -year study of spot seeding of western larch (*Larix occidentalis* Nutt.), insolation was the chief cause of death. Effects of insolation were most pronounced on seedlings less than 3 months old on west- and south-facing slopes. Insolation was most severe in early summer if soils were dry. Soil surface temperatures of 130° F. and higher consistently

killed seedlings. Successful seeding practices are noted and recommended.

Shearer, Raymond C. 1970. Problems associated with western larch planting stock. In: Proceedings of the joint meeting of the Western Forest Nursery Council and the Intermountain Forestry Nurseryman's Association; 1970 August 4-6; Coeur d'Alene, ID. [Place of publication unknown]: [Publisher name unknown]: 27-29. **Abstract**: This paper discusses planting and nursery storage strategies for western larch. Studies at Coram Experimental forest showed that seedlings that were machine planted had higher survival, vigor, and growth than seedlings that were planted by hand. Furthermore, survival was highest when seedlings were planted before bud break. Observations from another study suggest that planting stock of western larch should be stored on shelves with good air circulation to prevent higher temperatures and premature bud break.

Shearer, Raymond C. 1971. Silvicultural systems in western larch forests. Journal of Forestry. 69(10): 732-735. **Abstract**: Western larch (*Larix occidentalis* Nutt.), one of the most valuable and attractive species in the northern Rocky Mountains, grows in association with most native conifers in this region. Larch is extremely intolerant of shade and requires nearly full sunlight and well distributed and exposed mineral soil for good seedling establishment and growth. Because of these silvical requirements, larch stands are usually harvested and regenerated by clearcutting, seed tree, or shelterwood systems. Seedbed preparation is normally accomplished by scarification or prescribed burning. However, due to multiple use considerations, these silvicultural practices should be modified on some areas. This paper discusses some of the effects of various silvicultural systems in western larch stands.

Shearer, Raymond C. 1980. Western larch. In: Eyre, F. H., ed., Forest cover types of the United States and Canada. Washington, DC: Society of American Foresters: 93-94. **Abstract**: The distribution, life history, ecology, disturbance and disease agents of western larch are reviewed.

Shearer, Raymond C. 1980. Regeneration establishment in response to harvesting and residue management in a western larch-Douglas-fir forest. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: symposium proceedings; 1979 September 11-13; Missoula, MT. Gen. Tech. Rep. INT-90. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 249-269. **Abstract**: Natural regeneration lagged on all sites on a recent logging study; regardless of previous residue utilization standards or understory and seedbed treatments. Two factors have reduced regeneration potential: (1) little mineral soil was exposed either during timber harvest or as a result of prescribed burning, and (2) in 1974 (year of logging) western spruce budworm destroyed nearly all cones except western larch.
Seed dispersal usually occurred via thermal slope winds with uphill motion, beginning in September. However, in 1976 most seed was dispersed by erratic winds associated with a dry cold front in October. Less than 10 percent of the sound seed dispersal in the fall survived until germination. Germination and seedling survival of western larch,

Douglas-fir, lodgepole pine, Engelmann spruce, and subalpine fir was substantially higher on burned seedbeds than on unburned seedbeds. Subalpine fir was the only species that germinated relatively well on unburned duff. Surface temperatures were not critical on any treatment (except on charred surfaces the first year following prescribed burning), because competing vegetation quickly shaded all cutover areas. Douglas-fir and Engelmann seedlings planted during 1976-1978 have become established on all treatments. The effects of residue utilization on understory and seedbed treatments may be more important in the later growth of conifers than in the establishment stage.

Shearer, Raymond C. 1986. Western larch cones and seeds—current Intermountain Research Station studies. In: Landis, Thomas D., tech. coord. Proceedings: Combined Western Forest Nursery Council and Intermountain Nursery Association meeting; 1986 August 12-15; Tumwater, WA. Gen. Tech. Rep. RM-137. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 4-10. **Abstract**: In 1985, two studies involving western larch cone and seed production were begun. The first determines the influence of spacing on seed cone production of 30- to 32-year-old larch in western Montana. The second identifies factors limiting western larch cone production in forest stands of Idaho and Montana.

Shearer, Raymond C. 1990. Research studies of the clearcutting regeneration harvest method. In: Miller, Richard G.; Murphy, Dennis D., comps. Genetics/silviculture workshop proceedings; 1990 August 27-31; Wenatchee, WA. Washington, DC: U.S. Department of Agriculture, Forest Service: 168-181. **Abstract**: Clearcutting or one of its variations has been used to successfully regenerate 44 of the 47 major forest cover types in the United States. A wide range of studies have been superimposed on some clearcuts and results from this research are used to formulate and justify management decisions. Biological and physical factors, or combinations of these factors, can limit the probability of success; sometimes within the most easily regenerated forest types. Often, regeneration success is not the issue that prevents the use of clearcutting, but the visual impacts, concerns for biodiversity, or other perceived problems. Managers expect research to fill gaps in knowledge and provide a defensible and scientific basis for decisions. Information is needed in each of the forest cover types to define: the minimum size opening and treatments required to maintain seral species in stands, the long-term implications of repeated clearcutting or the absence of a form of clearcutting on sites, and factors that inhibit the regeneration potential. Also, we need to understand the consequences of limiting or eliminating clearcutting in terms of changes in plant and animal composition, long-term impacts from disease and insects, wildlife habitat, water yield and quality, timber growth and yield, recreation, and fire management.

Shearer, Raymond C. 1996. Coram Experimental Forest: a "jewel" in the Crown of the Continent ecosystem. American Conifer Society Bulletin. 13(2): 56-58. **Abstract**: This article briefly describes the landscape, climate, ecosystem, and history of Coram Experimental Forest

Shearer, Raymond C. 1996. Coram Experimental Forest. In: Schmidt, Wyman C.;

Friede, J. L., comps. Experimental forests, ranges, and watersheds in the northern Rocky Mountains: a compendium of outdoor laboratories in Utah, Idaho, and Montana. Gen. Tech. Rep. INT-GTR-334 Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 73-80. **Abstract**: The purpose, history, forest description, data bases, past and current studies, location, and contact for information for Coram Experimental Forest are given.

Shearer, Raymond C. 1998. Coram Experimental Forest: fifty years of research. In: Interpreting the landscape through science: symposium proceedings; 1998 May 15-16; Kalispell, MT. Kalispell, MT: Living in the Landscape Office: 20-23. **Abstract**: The history of research conducted at Coram Experimental Forest is reviewed. Coram Experimental Forest was established to study the ecology and management of western larch. Research began with site preparation techniques and seed dispersal in the 1940s, followed by regeneration cuttings (1950s), young stand management (1960s), forest residue utilization (1970s), forest processes (1980s), and education and conservation (1990s).

Shearer, Raymond C. [1989]. Coram Experimental Forest--a manipulated biosphere reserve. In: Milove, Diana, ed. Crown of the continent—a perspective under the Man and Biosphere Program proceedings; 1989 August 8-10; West Glacier, MT. U.S. Department of the Interior, Glacier National Park: 6. **Abstract**: This note describes Coram Experimental Forest and its role as a research area and a Biosphere Reserve. Also described is the history and types of research conducted at Coram Experimental Forest.

Shearer, R. C.; Carlson, C. E. 1993. Barriers to germination of *Larix occidentalis* and *Larix lyallii* seeds. In: Edwards, D.G.W., comp. Dormancy and barriers to germination: proceedings of an international symposium of IUFRO Project Group P2.04-00 (Seed Problems); 1991 April 23-26; Victoria, BC, Canada. Victoria, B.C.: Forestry Canada, Pacific Forestry Centre: 127-132. **Abstract**: *Larix occidentalis* Nutt. (western larch) and *Larix lyallii* Pari. (alpine larch) grow in the upper Columbia River Basin of North America. Western larch often is a major component at low to moderate elevation forests while alpine larch is found only at timberline in some of the high mountains. Both species are monoecious, and flower buds develop throughout the crown. Western larch seed cone buds open throughout April to early May and the cones mature in August; and in May and mid September for alpine larch. Developing strobili can survive spring frosts as low as -4°C in western larch and -10°C in alpine larch. Major barriers to quality western larch seeds occur during cone development. Mature dominant and codominant trees produce megasporangia every year, but frost or insects or both often reduce the potential by 75% soon after bud burst. Then, mature cones usually have less than 20% filled seeds; the remainders are mostly empty or damaged by insects. Seed dormancy was easily overcome in 38 tests by stratification for 30 days at 1oC in the dark. Germinative energy averaged 75% at 7 days and germinative capacity averaged 94% at 13 days. Previous attempts to germinate alpine larch seeds under laboratory conditions were mostly unsuccessful. But about 95% of the seeds with embryos germinated after stratifying in moist peat in leach tubes for 30 days in the dark at 2oC and then

incubating them at 22oC with 16 hours of fluorescent light and 8 hours of dark. Germinative energy was 70% at 10 days and germinative capacity was 90% at 16 days. Soil chemistry may be important in preparing alpine larch seeds for germination.

Shearer, Raymond C.; Halvorson, Curtis H. 1967. Establishment of western larch by spring spot seeding. Journal of Forestry. 65(3): 188-193. **Abstract**: A 3-year experiment to determine feasibility of spot seeding western larch in spring yielded information on favorable aspect and dates for planting, effectiveness of two seed treatments in increasing germination, and means for preventing loss to rodents. Sowing stratified seed on bare soil on north-facing slopes soon after snow-melt produced best germination and survival. Seed soaked in hydrogen peroxide and seed that had no pretreatment germinated poorly. Seedling survival was low on south-and west-facing slopes regardless of seed pretreatment. Drought, insolation, frost heaving, and fungi caused most seedling mortality. Losses to rodent depredations were insignificant and hardly justified use of control measures.

Shearer, Raymond C.; Kempf, Madelyn M. 1999. Coram Experimental Forest: 50 years of research in a western larch forest. Gen. Tech. Rep. RMRS-GTR-37. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 66 p. **Abstract**: 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.

Shearer, Raymond C.; Potter, Rachel W.; Kurth, Laurie L.; Asebrook, Jennifer M. 1996. Cooperation enhances vegetation efforts in Glacier National Park. Park Science--Integrating Research and Resource Managment. 16(1): 20-21. **Abstract**: Work conducted in the experimental portion of one biosphere reserve (i.e. Coram Experimental Forest) has augmented protection of the core area of another biosphere reserve (Glacier National Park). The Man and the Biosphere Program promotes cooperative studies such as this, which enables input from several specialists and

results in sound resource management decisions. Significant applicable information was obtained that the park could not have generated alone, due to the lack of subject expertise or ability to conduct manipulative experiments. Not only did Glacier National Park receive information that directed efficient and effective revegetation, but our basic silvicultural knowledge increased for several conifer species.

Shearer, Raymond C.; Schmidt, Jack. A. 1982. Reforesting a burned shrubfield and clearcut on a steep slope in a western larch forest of northwest Montana. In: Baumgartner, David M., ed. Site preparation and fuels management on steep terrain: proceedings of a symposium; 1982 February 15-17; Spokane, WA. Pullman, WA: Washington State University, Cooperative Extension: 159-165. **Abstract**: A 14-year-old shrubfield and an adjacent new clearcut in a western larch forest were successfully prescribed burned and reforested. The shrubfield originated after a 1952 prescribed fire failed to reduce the duff layer on a 60 percent north-facing slope within a 60-acre (24-ha) clearcut on the Coram Experimental Forest. Natural regeneration was poor except on skid roads. In 1966 the shrub field was sprayed with Tordon 101, the mature forest above the shrubfield was clearcut and slashed, and both areas were burned on August 23.
Regeneration established following a combination of natural and direct seeding and planting. By October 1981, both the old shrubfield and 1966 clearcut were well stocked (78 and 91 percent) with conifers, mostly western larch, Douglas-fir, and Engelmann spruce. The average number of seedlings per acre 0.5 ft (0.2 m) or taller was 765 (1,890/ha) on the shrubfield and 1,559 (3,852/ha) on the 1966 clearcut. About 2,000 smaller seedlings per acre (4,900/ha) were also present on both areas. Average height, crown length, crown width, and diameter at breast height are given for the tallest tree on each stocked plot. Total height of the tallest tree of each species on the plots averaged: 10.9 ft (3. 3 m) for larch; 3.8 ft (1.2 n) for Douglas-fir; and 2.6 ft (0.8 m) for spruce.

Shearer, Raymond C.; Schmidt, Jack A. 1991. Natural and planted regeneration of interior Douglas-fir in western Montana. In: Baumgartner, David M.; Lotan, James E., eds. Proceedings of interior Douglas-fir: the species and its management symposium; 1990 February 27-March 1; Spokane, WA. Pullman, WA: Cooperative Extension, Washington State University: 217-226. **Abstract**: Throughout the range of interior Douglas-fir both natural and artificial means are used to regenerate disturbed areas. Three study sites in western Montana (Coram Experimental Forest, Miller Creek Demonstration Forest, and Newman Ridge study area), document the establishment and early growth of natural and planted Douglas-fir regeneration. Harvest methods were clearcutting at each study site, and shelterwood and group selection (small openings) cutting at Coram. Site treatments were prescribed burning and no burning at Coram and prescribed burning only at Miller and Newman. Natural regeneration began from seed from onsite or nearby trees. Plantations originated from 2-0 bare root seedlings grown at the USDA Forest Service's Coeur d'Alene Nursery and were planted for several consecutive years following treatment. Stocking, number of trees per acre, total height, and average annual height for Douglas-fir are shown in this paper. Douglas-fir natural regeneration predominated on most cutover areas--a result of the high proportion of Douglas-fir seed source, seed production while site was receptive, good seed dispersal,

and reasonable seedling survival. Douglas-fir planted within four years following site treatment were significantly taller and the average annual height growth was greater than the tallest Douglas-fir natural regeneration after 15-20 years. Although individual tree height growth was greater, some Douglas-fir plantations had high mortality.

Shearer, Raymond C.; Schmidt, Jack A. 1995. Natural regeneration after harvest and residue treatment in a western larch forest of northwestern Montana, U.S.A. In: Schmidt, Wyman C.; McDonald, Kathy J., Ecology and management of *Larix* forests: a look ahead: proceedings of an international symposium; 1992 October 5-9; Gen. Tech. Rep. INT-319. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 169. **Abstract**: This abstract describes a study designed to measure the establishment of natural regeneration following harvest cutting and forest residue reduction treatments on the Coram Experimental Forest. Each of three harvest methods (shelterwood, clearcut, and group selection) received four levels of timber and residue utilization treatments. Stocking levels of regenerating western larch, Douglas-fir, Engelmann spruce, western hemlock, western redcedar, and lodgepole pine from immediate post-treatment to 18 years post-treatment is reported. Western larch established quickly on exposed soils, but virtually stopped establishing a few years post-treatment, while Douglas-fir regenerated prolifically a few years after treatment occurred.

Shearer, Raymond C.; Schmidt, Jack A. 1999. Natural regeneration after harvest and residue treatment in a mixed conifer forest of northwestern Montana. Canadian Journal of Forest Research. 29(2): 274-279. **Abstract**: In 1974, two clearcuts, two shelterwoods, and two sets of eight group selections (equally divided between two elevation zones) were harvested on the Coram Experimental Forest in northwestern Montana. Four levels of tree and residue utilization were compared. Moist fuels on approximately half of each area were poorly burned by prescribed fires in September 1975. Natural regeneration on these treatments was compared in 1979, 1987, and 1992. Regeneration of western larch (*Larix occidentalis* Nutt.) began in 1975 on soil exposed during yarding of logs and continued mostly in 1977 and 1979 on these scarified sites and other burned areas. Competing vegetation curtailed establishment of larch seedlings much past 1979 on these sites. Few Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) regenerated before 1979 but aggressively established through 1992. Engelmann spruce (*Picea engelmannii* Parry) and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt) regeneration began in 1979 and is increasing slowly throughout the area. Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and western red cedar (*Thuja plicata* Donn.) also slowly regenerate moister areas of the lower elevation units.

Shearer, Raymond C.; Schmidt, Jack A.; Schmidt, Wyman C. 1995. Appendix B: International *Larix* arboretum, Coram Experimental Forest Headquarters, Hungry Horse, Montana, U.S.A. In: Schmidt, Wyman C.; McDonald, Kathy J., Ecology and management of *Larix* forests: a look ahead: proceedings of an international symposium; 1992 October 5-9; Whitefish, MT. Gen. Tech. Rep. INT-319. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 518-521. **Abstract**: The *Larix* Symposium provided the impetus to establish an arboretum that

features all *Larix* species of the world. This International *Larix* Arboretum, established next to the headquarters of the Coram Experimental forest and near the Hungry Horse Ranger Station was dedicated October 2, 1992, with a tree-planting ceremony that had international participation. This symbol of global cooperation will not only provide a visual demonstration of larch international, but it is designed to provide opportunities for species comparisons and genetics research.

Shearer, Raymond C.; Schmidt, Wyman C. 1987. Cone production and stand density in young *Larix occidentalis*. Forest Ecology and Management. 19(1-4): 219-226. **Abstract**: Research began in 1985 to investigate the influence of spacing on cone production of 30- and 32-year old western larch (*Larix occidentalis* Nutt.) in western Montana, U.S.A. These natural stands are on two moderately productive sites (Site Index 18 m at 50 years) at Coram, on a less productive site (SI 16 m) at Cottonwood, and on a more productive site at Pinkham (SI 21 m). In 1961, four 0.4-ha plots at each of the four sites were thinned to average spacing of 2.0, 2.4, 3.4, and 4.6 m. In addition, at each Coram site, a 6.1-m average spacing and an unthinned (control) were installed. The crowns of 10 taller trees in each treatment and control were examined for 1985 seed and pollen cones and for open seed cones that were still attached from previous years. Numbers of seed and pollen cones generally increased as average spacing increased. Unthinned trees had neither new seed, new pollen, nor old seed cones. The least productive site produced the fewest seed and pollen cones, while the mòderate and most productive sites produced the most seed and pollen cones. At Coram, some trees in the 2.4-m and wider spacings were damaged by bears (*Ursus* sp.) partially stripping bark at the base of the trees. All damaged trees produced seed cones, but not all undamaged trees produced seed cones.

Shearer, Raymond C.; Schmidt, Wyman C. 1988. Cone production and stand density in young western larch. In: Schmidt, Wyman C., Proceedings--future forests of the mountain west: a stand culture symposium; 1986 September 29-October 3; Missoula, MT. Gen. Tech. Rep. INT-243. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 399-400. **Abstract**: This paper describes research on the influence of stand density (spacing) on the frequency and amount of seed cone production on four larch stands in western Montana.

Shearer, Raymond C.; Stoehr, Michael U.; Webber, Joe E.; Ross, Stephen D. 1999. Seed cone production enhanced by injecting 38-year-old *Larix occidentalis* Nutt. with $GA_{4/7}$. New Forests. 18(3): 289-300. **Abstract**: The influence of injecting 38-year-old *Larix occidentalis* with gibberellin $A_{4/7}$ ($GA_{4/7}$) on seed and pollen cone production was studied in western Montana, U.S.A. Two natural stands thinned to several spacings in 1961 were chosen. The two widest spacings were used. In 1991, 60 trees selected for study at each site were randomly divided into two groups of similar DBH, half as controls and half injected in June 1991 with a solution of $GA_{4/7}$ in ethyl alcohol. The volume injected was adjusted to the DBH of each tree (60 mg per 5 cm diameter). In June 1994, half the trees treated with $GA_{4/7}$ in 1991 and half the untreated trees were injected with $GA_{4/7}$ in the same manner as before. In 1992 and 1995, seed cone production increased on $GA_{4/7}$-treated trees compared to the controls. Pollen cone

production was significantly increased by $GA_{4/7}$ treatment but only at one site. Delayed effects of $GA_{4/7}$ on seed cone production was not evident in subsequent years after treatment. Foliar and shoot damage on treated trees was attributed to $GA_{4/7}$ treatment but most trees recovered completely the following year. Finally, $GA_{4/7}$ treatment did not affect cone length, potential seed per cone or filled seed per cone.

Shearer, Raymond C.; Tackle, David. 1960. Effect of hydrogen peroxide on germination in three western conifers. Res. Note No. 80. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 4 p. **Abstract**: Seeds of western larch (*Larix occidentalis*), Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), and subalpine fir (A*bies lasiocarpa*) germinate very slowly in standard germination tests without pretreatment. This research found that using hydrogen peroxide (H_2O_2) instead of water as the wetting agent hastened the germination of western larch and Douglas-fir, but not of subalpine fir.

Sneck, Kathleen M. Davis. 1977. The fire history of Coram Experimental Forest. Missoula, MT: University of Montana. 134 p. Thesis. **Abstract**: This thesis documents the fire history and assesses the role of fire in the western larch/Douglas-fir forest of the Coram Experimental Forest in northwestern Montana. Primary attention was given to the frequency, areal spread, relative severity, and effects of fires prior to the advent of active suppression efforts in order to determine the natural occurrence and influence of fire.

Society of American Foresters. 1954. Type 212, larch--Douglas-Fir. Type 213, grand fir--larch--Douglas-fir. Type 214, ponderosa pine--larch--Douglas-fir. In: Forest cover types of North America (exclusive of Mexico). Washington, DC: Society of American Foresters: 46-47. **Abstract**: Describes the composition, distribution, and ecology of larch cover types.

Spano, S. D.; Jurgensen, M. F.; Larsen, M. J.; Harvey, A. E. 1982. Nitrogen-fixing bacteria in Douglas-fir residue decayed by *Fomitopsis pinicola*. Plant and Soil. 68(1): 117-123. **Abstract**: Colonizing populations of nitrogen-fixing bacteria were measured in various decay stages of Douglas-fir logs infested with *Fomitopsis pinicola*. Numbers of nitrogen-fixers and N-fixation rates in the wood increased as decay progressed. These increase in bacterial populations and N-fixing activity appeared related to increases in wood moisture content. Bacteria resembling *Clostridium pasteurianum*, *Clostridium butyricum*, and *Klebsiella/Enterobacter* spp. were isolated from the various wood decay stages.

Stark, N. 1980. Light burning and the nutrient value of forage. Res. Note INT-280. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 7 p. **Abstract**: Slash burning in a clearcut under conditions producing very light to light burn intensities (<150^{o}F or 66^{o}C) for a short duration did stimulate resprouting, but resulted in almost no enrichment of biologically essential nutrients in the foliage. Burns of this low temperature range are not suitable for improving the quality and quantity of browse. Exceedingly dry soil conditions during the

summer months appear to have resulted in low nutrient contents in clip plots where plants were crowded and dense, but not in controls where spacing was wider.

Stark, N. 1983. The nutrient content of Rocky Mountain vegetation: a handbook for estimating nutrients lost through harvest and burning. Missoula, MT: University of Montana, Montana Forest and Conservation Experiment Station. 81 p. **Abstract**: Samples of forest components that are normally burned or removed during harvest were collected at the Coram Experimental Forest and the Lubrecht Experimental Forest and analyzed for elemental content. The elements calcium, copper, iron, potassium, magnesium, manganese, nitrogen, sodium, phosphorus and zinc in standard fuel-size categories were analyzed to help assess how much of these nutrients would be lost during harvesting or fires of different intensities. The data can be used to describe the essential nutrient content in forest biomass and for modeling. The proportioned weights and nutrient contents of vegetation examine in other studies can be related to the nutrient content of vegetation reported here. Estimates can be made of nutrient losses caused by harvesting and slash burning. Many of these procedures are complex, but the measurements and calculations can be invaluable when dealing with problem soils.

Stark, Nellie M. 1979. Nutrient losses from timber harvesting in larch/Douglas-fir forest. Res. Pap. INT-231. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 41 p. **Abstract**: Nutrient levels as a result of experimental clearcutting, shelterwood cutting, and group selection cutting--each with three levels of harvesting intensity--were studied in a larch-fir forest in northwest Montana, experimentally logged with a skyline system. None of the treatments altered nutrient levels in an intermittent stream, nor were excessive amounts of nutrients lost in soil below the root zone. Under conditions on this site, skyline logging did not result in surface erosion or nutrient losses that would affect forest management.

Stark, Nellie M. 1980. The impacts of utilization on nutrient cycling. In: Environmental consequences of timber harvesting in Rocky Mountain coniferous forests: symposium proceedings; 1979 September 11-13; Missoula, MT. Gen. Tech. Rep. INT-90. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 123-136. **Abstract**: Studies of the impacts of fire and logging in western Montana have shown that only the hottest fires are likely to have long-lasting nutrient losses. Fires with surface soil temperatures of about 572 F (300 C) can be used indefinitely on a 50-year rotation with no significant loss of long-term productivity on the richer forest soils. A method of estimating the nutrient storage capacity of soil can be used to help select management treatments that avoid excessive losses of biologically essential nutrients from fire or fertilization. Harvest of wood and bark in clearcuts on two forests did not remove more nutrients than could be returned through precipitation in 70-100 years. Intensive harvests should not remove more nutrients in fiber than can be returned from precipitation, soil solution available nutrients, pollen and normal decay in 70 years time. This means that only wood, bark, and branches can be harvested safely. Harvest should not be subsidized by the nutrients released from weathering during a particular rotation or the site will never improve in productive capabilities. Results are not pertinent to nitrogen or phosphorous.

Stoleson, Scott H.; King, David I.; Tomosy, Monica. 2011. Avian research on U.S. Forest Service Experimental Forests and Ranges: emergent themes, opportunities, and challenges. Forest Ecology and Management. 262(1): 49-52. **Abstract**: Since 1908, U.S. Forest Service Experimental Forests and Ranges have been dedicated to long-term interdisciplinary research on a variety of ecological and management questions. They encompass a wide diversity of life zones and ecoregions, and provide access to research infrastructure, opportunities for controlled manipulations, and integration with other types of long-term data. These features have facilitated important advances in a number of areas of avian research, including furthering our understanding of population dynamics, the effects of forest management on birds, avian responses to disturbances such as fire and hurricanes, and other aspects of avian ecology and conservation. However, despite these contributions, this invaluable resource has been underutilized by ornithologists. Most of the Experimental Forests and Ranges have had no ornithological work done on them. We encourage the ornithological community, especially graduate students and new faculty, to take advantage of this largely untapped potential for long-term work, linkage with long-term data sets, multiple disciplines, and active forest management.

Tackle, David. 1962. Infiltration in a western larch–Douglas fir stand following cutting and slash treatment. Res. Note 89. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 7 p. **Abstract**: Opportunity to explore the relative changes in infiltration capacity produced by logging and slash treatment in a western larch (*Larix occidentalis*)-Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) stand was provided in 1952 following the installation of a harvest cutting study in western Montana. Five year records show that immediate and variable reductions in infiltration capacity occur on broadcast burned, scarified, and tractor skid road surfaces; but improvement can be expected within a few years, except on surfaces that have been compacted excessively.

Tippets, David W. 1995/1996. Larch: when affection may not be enough to save the species. Flathead National Forest focus. Winter: 4, 8. **Abstract**: Western larch forests require fire, sunlight, and bare soil to persist. The historic role of fire in maintaining larch forests is described. The author suggests that appropriate management is necessary to conserve larch forests.

Tippets, David W. 1996. Western larch: flames, sunlight, and soil. Forestry Research West. May: 13-19. **Abstract**: Fire history and management in western larch forests is reviewed. Native American burning, fire exclusion, fire regimes, and research and management in larch stands are discussed.

Tobalske, Bret W. 1991. Bird populations, logging, and red-naped sapsuckers habitat suitability based on fledging success. Missoula, MT: University of Montana. 62 p. Thesis. **Abstract**: Ten species of breeding birds differed in abundance between harvested and adjacent uncut areas following a winter (1988-89) seed tree removal on Coram Experimental Forest in northwestern Montana. There was high variation in

abundance of bird species relative to logged or unlogged stand condition. Foliage-foraging species and tree gleaners were less abundant in harvested areas, whereas flycatching species and ground foragers were more common. Of the nesting guilds, conifer tree-nesting species were least abundant in clearcuts, and ground nesters were more common within the cutover habitats.
Red-naped Sapsuckers (*Sphyrapicus nuchalis*) were abundant in logged stands with trees left standing. The number of sapsucker young fledged per nest was positively correlated with the percent of home territory logged and the number of birch and aspen from 10-30 cm dbh within the home territory.
When mitigation for tree-dependent species is an objective, forest managers should retain within cutting units broadleaf trees including paper birch, quaking aspen, and black cottonwood, and snags of all tree species.

Tobalske, Bret W. 1992. Evaluating habitat suitability using relative abundance and fledging success of red-naped sapsuckers. The Condor. 94(2): 550–553. **Abstract**: The relative abundance of red-naped sapsuckers (*Sphyrapicus nuchalis*) in logged and recently logged coniferous forest was examined. To determine whether such modified habitats provide suitable nesting opportunities for this species, an analysis of fledging success was also conducted. Results suggest that the relative abundance of red-naped sapsuckers and mean number of fledged per nest did not differ between logged and unlogged stands. The author cautions however, that, although red-naped sapsuckers nested successfully in logged areas, unlogged coniferous forest surrounding the cutting units was probably essential to adult survival and productivity.

Tobalske, Bret W.; Hutto, Richard L.; Shearer, Raymond C. 1990. The effects of timber harvesting on the reproductive success of red-naped sapsuckers (*Sphyrapicus nuchalis*): planned research. Northwest Environmental Journal. 6(2): 398-399. **Abstract**: This article reviews research that compared the relative abundance of red-naped sapsuckers (*Sphyrapicus nuchalis*) in logged and recently logged coniferous forest and proposes new research that compares the success of red-naped sapsucker nests in logged habitat to those in contiguous old-growth forest.

Tobalske, Bret W.; Shearer, Raymond C.; Hutto, Richard L. 1991. Bird populations in logged and unlogged western larch/Douglas-fir forest in northwestern Montana. Res. Pap. INT-442. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 12 p. **Abstract**: We detected differences in population sizes of 10 species of breeding birds between harvested and adjacent uncut areas following a winter (1988-89) seed tree removal on Coram Experimental Forest in northwestern Montana. Cutting units were relatively small, and live paper birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), and black cottonwood (*Populus trichocarpa*) trees as well as conifer and broad leaf snags were left standing within the cutting units. During the summers of 1989 and 1990, tree swallows (*Tachycineta bicolor*) were abundant in clearcuts and not detected in unlogged stands. Similarly, dark-eyed juncos (*Junco hyemalis*) and pine siskins (*Carduelis pinus*) were more common within clearcut and partially cut habitats than within uncut stands. Golden-crowned kinglets (*Regulus satrapa*), Swainson's thrushes (*Catharus ustulatus*),

varied thrushes (*Ixoreus naevius*), and Townsend's warblers (*Dendroica townsendl*) were less abundant in the cut areas. Ruby-crowned kinglets (*Regulus calendula*) and fox sparrows (*Passerella iliaca*) were least abundant in both clearcut and contiguous old-growth stands. Chipping sparrows (*Spizella passerina*) were common in logged stands and interspersed, unlogged forest, and relatively rare in contiguous old growth. Foliage-foraging species and tree gleaners were less abundant in harvested areas, while flycatching species and ground foragers were more common there. Of the nesting guilds, conifer tree-nesting species were least abundant in clearcuts, and ground nesters were more common within the cutover habitats. The variation in relative abundance among bird species in logged and unlogged stands points out that management of forest resources for birds should focus on diverse community-level habitat needs. If mitigation for tree-dependent species is an objective, we recommend retaining within cutting units broadleaf trees including paper birch, quaking aspen, and black cottonwood, and snags of all tree species. Slash piles may also contribute to the suitability of logged habitat for certain bird species, and future research should attempt to quantify this factor.

Tobalske, Bret W.; Shearer, Raymond C.; Hutto, Richard L. 1995. Maintaining bird diversity in western larch/Douglas-fir forests. In: Schmidt, Wyman C.; McDonald, Kathy J., comps. Ecology and management of *Larix* forests: a look ahead: proceedings of an international symposium; 1992 October 5-9; Whitefish, MT. Gen. Tech. Rep. INT-319. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 505-507. **Abstract**: Bird occurrences were evaluated under four stand conditions in western larch/Douglas-fir forests: clearcut, partial cut, unlogged (fragmented), and contiguous forest. Frequencies were noted for foraging guilds, tree gleaners, flycatchers, nesting guilds, tree drillers, and primary cavity nesters. Managers should consider a diversity of habitat conditions if maintaining habitat for bird species is an objective.

Touzeau, Roy Frederick. 1977. Scaling perceptions and preferences of forest scenes from the Coram Experimental Forest: an application of multidimensional scaling. Missoula, MT: University of Montana. 325 p. Dissertation. **Abstract**: Despite recent concern for the forest environment, little quantitative work has been done to determine which forest attributes influence preferences for various forest scenes. Previous attempts have been inadequate to identify individual differences in the selection of forest attributes on which preferential judgments are based. This research was designed to determine (1) specifically what attributes observers attend to when making perceptual or preferential judgments of forest scenes, and (2) whether or not individuals differ in their preferences for various forest attributes.
Four experiments were conducted each using a different data collection technique and a slightly different set of stimuli. The stimuli were color slides and 4x4 prints of forest areas which had been subjected to various degrees of logging activity. Slides were presented three at a time (i.e. in triads) for experiments I, II and III. Observers first ranked the three slides for preference; then gave their judgments of similarity. In experiment I, nine stimuli were presented using the complete method of triads. In experiment II, a set of 15 stimuli were presented using triadic presentations based on an

incomplete block design with three replications. In experiment III, a set of 25 stimuli were presented using triadic presentation with one replication. The data for experiment IV were collected using prints.
Dissimilarities data collected were analyzed using the computer programs POLYCON and INDSCAL. Preference data were analyzed using the programs PREFMAP and MDPREF. Major methodological results include (1) better scaling resulted from the use of the most heterogeneous stimulus set (slides of both cut and uncut areas); (2) the method of data collection used in experiment II provided the best scaling results for large stimulus sets; and (3) the use of prints provided the poorest data for scaling. The results related to perceptions and preferences are as follows. Dissimilarities judgments seemed based on the factors of (1) degree of logging; (2) number of prominent trees; and (3) the amount of brush or slash. Preferences depended on the factors of (1) degree of logging and (2) amount of brush or slash. Substantial individual differences in preferences also obtained. The differences between observers' preferences seemed to depend on both the degree of cutting and the amount of brush or slash, i.e. some observers preferred cut areas in which slash had been removed while others preferred uncut areas.

Turner, Monica Goigel; Gregg, William P., Jr. 1983. The status of scientific activities in United States Biosphere Reserves. Environmental Conservation. 10(3): 231-237.
Abstract: The United States Biosphere Reserve network was begun in 1974, and currently numbers 38 sites. An investigation into the status of scientific activities in US Biosphere Reserves was conducted in 1981 to determine how well the network was meeting the multiple objectives of the Man and the Biosphere Programme. A survey questionnaire was administered to all US Biosphere Reserves, covering the adequacy of available data-bases, the types of research conducted, the perceived anthropogenic threats, funding, support, facilities, and educational programmes. Based on predominant management emphasis, Biosphere Reserves were designated as experimental or observational (i.e. conservational) for the purpose of analysis of the data.
The results of our survey indicate that baseline scientific data, such as aerial photography, bibliographies, weather data, flora and fauna checklists and keys, and topographic maps, are generally available for most of the US Biosphere Reserves; environmental monitoring activities are more comprehensive than ecological research activities, but topic emphasis varies with the management's orientation of the Reserves. Experimentally-oriented Reserves tend to emphasize biological productivity, succession, silviculture, and forest restoration and management, while observationally-oriented Reserves tend towards descriptive studies.
In almost all scientific activities, experimental Reserves were scored higher than observational (‘conservation’) Reserves in terms of general value; they have also received significantly more funding for scientific research. In all Reserves, most natural resources are considered to be effectively protected. Observational Reserves report a greater number of anthropogenic threats, including air and water pollution, exotic species, operations problems, resource removal, and visitor impacts; but they are addressing a greater proportion of these threats than are experimental Reserves. Most Reserves communicate natural history and other scientific information to the public, but

many do not discuss MAB or its goals. Almost all the 38 US Biosphere Reserves are used for professional training and have basic support-facilities for field-work. Recommendations made for improving the effectiveness of US Biosphere Reserves include: strengthening communications among Reserves within the network; initiating more cooperative studies at all geographic levels; intensifying scientific research in observational ('conservation') Reserves; improving the status of ecological research on aquatic systems and soils, and at the ecosystem level in all Reserves; also designing studies which focus on Man as an integral part of the system and how Mankind might exist in improved concert with The Biosphere. The designation of a multiple-site Biosphere Reserve bearing the name of the biogeographic region in which it occurs, is now being used both to conserve a region's representative ecosystems and to foster cooperation among sites. We believe this is a workable approach and an important first step in implementing these recommendations regionally and, so far as they prove practicable, ultimately globally.

U.S. Department of Agriculture, Forest Service. 1981. Harvesting and utilization opportunities for forest residues in the Northern Rocky Mountains: symposium proceedings. 1979 November 28-30; Missoula, MT. Gen. Tech. Rep. INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 294 p. **Abstract**: Research reported in this symposium investigates alternative timber harvesting and processing practices that can achieve more intensive timber utilization. Major subjects include detailed evaluation of the resource; investigation of product, processing, and market opportunities; and development of harvesting and handling methods.

U.S. Department of Commerce. 1964. Climatological data, Montana. 67(6). Asheville, NC: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Satellite, Data and Information Service, National Climatic Data Center: 115-140. **Abstract**: Climatological tables are provided for June, 1964.

U.S. Department of Commerce. 1966. Climatological data, Montana. 69(6). Asheville, NC: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Satellite, Data and Information Service, National Climatic Data Center: 109-131. **Abstract**: Climatological tables are provided for June, 1996.

U.S. Department of Commerce. 1989. Climatological data, Montana. 92(1). Asheville, NC: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Satellite, Data and Information Service, National Climatic Data Center: 1-44. **Abstract**: Climatological tables and figures are provided for January, 1989.

U.S. Department of Commerce. 1989. Climatological data, Montana. 92(2). Asheville, NC: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Satellite, Data and Information Service, National Climatic Data Center: 1-44. **Abstract**: Climatological tables and figures are provided for February, 1989.

U.S. Department of Commerce. 1995. Climatological data, Montana. 98(1). Asheville,

NC: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Satellite, Data and Information Service, National Climatic Data Center: 1-44. **Abstract**: Climatological tables and figures are provided for January, 1995.

U.S. National Committee for Man and the Biosphere. 1990. The United States Man and the Biosphere Program. Dept. of State Pub. 9798. Washington, DC: U.S. Department of State, Bureau of Oceans and International Environmental Science and Technology. 24 p. **Abstract**: This brochure describes the establishment, mission, collaboration, and support of the U.S. Man and the Biosphere Program (MAB). The program directorates including high latitude ecosystems, human dominated systems, marine and coastal ecosystems, temperate ecosystems, and tropical ecosystems are described.

Wicker, Ed F.; Hawksworth, Frank G. 1991. Upward advance, intensification, and spread of dwarf mistletoe in a thinned stand of western larch. Res. Note RM-504. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 4 p. **Abstract**: From 1978 to 1988 western larch (*Larix occidentalis*) in a thinned, 35-year-old stand in the Coram Experimental Forest, Flathead National Forest in northern Montana, grew an average of 37 cm per year in height. This growth rate was over 4 times the rate of upward advance of dwarf mistletoe (*Arceuthobium laricis*) in these trees, which was only 9 cm per year. Current levels of dwarf mistletoe infection are 100 low (dwarf mistletoe ratings of only 1 or 2) to reduce tree height or diameter growth, although spread from inoculated trees to previously uninfected ones has occurred at all three spacing levels tested. These findings are discussed in relation to management of dwarf mistletoe in young monocultures of western larch.

Wicker, Ed F.; Wells, James M. 1983. Intensification and lateral spread of *Arceuthobium laricis* in a young stand of western larch with stocking control. Canadian Journal of Forest Research. 13(2): 314-319. **Abstract**: Initial intensification and lateral spread of *Arceuthobium laricis* (Piper) St. John were measured for three levels of stocking, 1680, 549, and 272 stems/ha (2.4 × 2.4, 4.3 × 4.3, and 6.0 × 6.0m spacing) of young, single-layer, western larch (*Larix occidentalis* Nutt.) monoculture, following artificial inoculation. Intensification was slow for the first 6 years following inoculation, but showed 5- to 10-fold increases in treatment means for the next 3-year period. Lateral spread from the inoculated trees to neighboring suscepts was not observed during the first 6 years, but was observed in all three treatments between years 7 and 9 and averaged 3.5–4.9m for the three spacing treatments. Maximum lateral spread during the period was 6.4m. We conclude that *A. laricis* can intensify rapidly on young western larch once an inoculum source is established. The lowest stocking level (highest spacing level, 6 × 6m) used in this study did not prevent lateral spread of the pathogen. These data attest to the value of prevention or early detection and removal of infections for the protection of western larch stands from subsequent losses.

Wonn, Hagan T. 1998. Height:diameter ratio and tree stability relationships for four Northern Rocky Mountain tree species. Missoula, MT: University of Montana. 24 p. Thesis. **Abstract**: High height: diameter ratios can affect tree and stand stability by

increasing susceptibility to wind breakage and snow bending. Height: diameter ratio was shown to be a good predictor of snow and wind damage, while live crown ratio was not a good predictor. A threshold height: diameter ratio was established for ponderosa pine (*Pinus ponderosa*), western larch (*Larix occidentalis*), Douglas-fir (*Pseudotsuga menziesii* var. g*lauca*), and lodgepole pine (*Pinus contorta* var. *latifolia*) in the northern Rocky Mountains. When these species exceed height: diameter ratios of 80:1, likelihood of damage is high. Previous spacing trials are used to determine optimal spacings to maintain stable height: diameter ratios for western larch and ponderosa pine. The PROGNOSIS model was also used to determine spacing guidelines, but did not adequately represent stand average height: diameter trends.

Wonn, Hagan T.; Hara, Kevin L. 2001. Height:diameter ratios and stability relationships for four northern Rocky Mountain tree species. Western Journal of Applied Forestry. 16(2): 87-94. **Abstract**: Ratios of tree height to diameter have been used to predict susceptibility to storm damage for many years. In this study, individual trees damaged by recent snow and wind events in western Montana were sampled in 1997 and 1998 to determine their height:diameter ratios in comparison to nearby undamaged trees. Four species were sampled: ponderosa pine (*Pinus ponderosa*), western larch (*Larix occidentalis*), interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), and lodgepole pine (*Pinus contorta* var. *latifolia*). Ratios of 80:1 (both measures in equal units) provided a stability threshold for all four species. Trees with higher ratios were more prone to damage than trees with lower ratios. Height:diameter ratios from trees grown in spacing trials were used to examine spacings that avoided development of unstable trees. Wide spacings or early thinnings provide the best means of avoiding major losses to snow and wind damage. The growth and yield model Prognosis was unable to predict height:diameter ratios for developing stands.

Wright, David K.; Glasgow, Lance S.; McCaughey, Ward W.; Sutherland, Elaine K. 2011. Coram Experimental Forest 15 minute streamflow data, [Online]. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station (Producer). Available:http://dx.doi.org/10.2737/RDS-2011-0019 [2011, December 2]. **Abstract**: This data product contains 15 minute streamflow for two flumes in the Coram Experimental Forest from 2004-2010. The two flumes are located on the Lunch Fork of Abbot Creek and Abbot Creek above Lunch Fork.