

## APPENDIX C

### LIVESTOCK GRAZING, FIRE REGIMES, AND TREE DENSITIES

Grazing occurs on 91% of all federal lands in the 11 contiguous western states (Armour et al, 1991). The negative effects of livestock grazing in a variety of native ecosystems have been documented in several excellent reviews (Fleishner 1994; Kauffman and Krueger 1984; Skovlin 1984; Thurow 1991) and in a recent report to the Interior Columbia Basin Ecosystem Management Project by Belsky and Blumenthal (1995). These papers, plus others that cover the effects of grazing on forests in western states, illustrate the transformations that have occurred throughout the west, including in the previously open, park-like ponderosa pine and mixed-conifer forests, which once stretched from British Columbia to Mexico.

A great deal of evidence exists suggesting that livestock grazing has contributed to increases in the distribution and density of many woody species across the western United States (see reviews by Arnold 1950; Ellison 1960; Bahre 1991; Archer and Smeins 1991). Scientists have found that livestock grazing causes increased tree densities in two ways:

- ! livestock consume and lower the density of grasses that would otherwise compete with tree seedlings for space, water and nutrients, and
- ! livestock remove the herbaceous understory which provides fuel for 'cool' surface fires that kill regenerating trees.

In addition, cattle and sheep directly facilitate conifer invasions into western grasslands by:

- ! exposing mineral soils and/or destroying cryptogamic (biotic) soil crusts and thereby creating mineral seedbeds, and
- ! inducing arroyo formation, which dries out meadows and promotes pine invasion.

Aldo Leopold (1924) was among the first to recognize that livestock grazing can result in reduced fire frequency. Indeed, some foresters of the day encouraged grazing (and in many cases still do) so that herbaceous fuel loads would be reduced and denuded areas could act as firebreaks (Leopold, 1924). Leopold's suspicions were borne out later as tree densities across the west began to increase concomitant with widespread livestock grazing (Cooper 1960; Madany and West 1983; Peet 1988; Belsky and Blumenthal 1995).

Shade increased with increasing forest density, fostering the growth of more shade-tolerant and fire-sensitive species such as Douglas-fir, noble fir and white fir. Forest stands previously dominated by fire-tolerant species such as ponderosa pine and western larch shifted to dominance by Douglas-fir and true fir, a process that was exacerbated by selective logging (Zimmerman and Neuenschwander 1984;

Habeck 1990; Morgan 1994). In all cases, the new stands of poles and saplings were forced into intense competition with each other, and the ability of young trees to withstand attacks by forest pests and diseases was compromised (Weaver 1950; Hessburg 1994; Morgan 1994). These pests and diseases became proportionately more prevalent in the denser stands appearing across the west.

In a series of papers published in the 1940s and '50s, Harold Weaver, mentioned earlier, also recognized the connection between livestock grazing and ponderosa thickets. He wrote that overgrazing was "of great significance in development of such stands, through breaking up of original sod cover and preparation of mineral seedbeds." Weaver warned that the future of these forests was in jeopardy, asking "Shall we attempt to reduce the hazard in the dense stands, or shall we ask for larger and ever larger [fire suppression] budgets?" Today's "crisis" is a result of the Forest Service choosing the latter course.

Cooper (1960) echoed Weaver's concerns, stating that "The overuse and mismanagement which followed introduction of livestock into the West produced profound changes, some of them permanent, in the plant cover. In particular, overgrazing has often been assigned as the primary cause of the overabundance of young pines." Similarly, Ellison (1960) and Archer and Smeins (1991) described the process whereby grazing allows the introduction of woody plants, shrubs, and trees into rangelands and forests. Ellison surmised that the transition from prairie to forest in the Middle West may have been caused by a factor seldom suggested or studied: overgrazing by domestic livestock.

### *The Critical Studies*

In 1923 Aldo Leopold wrote "Whether grass competitors or fire was the principle deterrent to timber reproduction is hard to answer because the two factors were always paired, never isolated." The question of which variable, grazing or active fire suppression, is the primary cause of overstocking long vexed scientists because it was (and still is) difficult to find an ungrazed forest for a control site. We know of three field studies that were ultimately able to isolate the "paired" variables: these studies (Rummell 1951; Madany and West 1983; Zimmerman and Neuenschwander 1984) identified grazing as the principle factor in causing forest overstocking. A further study described the complex interactions needed to produce increased tree densities once grazing had been introduced (Savage and Swetnam 1990).

Rummell (1951) studied two neighboring and ecologically similar ponderosa pine forests in central Washington. One had been grazed by livestock for 40 years while the other had never been grazed by livestock. Neither had experienced a fire for at least 125 years. Rummell characterized the ungrazed forest as "one of the few [remaining] relicts of virgin ponderosa pine forest and range" with "an almost unbelievably lush mat" of pine grass. Significantly, very little pine reproduction was found: only 85 trees less than 4 inch dbh per acre.<sup>1</sup> In sharp contrast, the grazed forest had little grass, and a density of

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<sup>1</sup> N.B. - Total number of Ponderosa/acre (all diameter classes) in Rummell's "open and parklike" area = 115; Doug fir = 18; western larch = 0.4 and grand fir = 1. Total number of trees per acre is then 134.4. This number is much

3,291 trees less than 4 inch dbh per acre (2,033 ponderosa pines, 1,016 Douglas firs, and 242 western larch).

Rummell concluded that the high density of herbaceous understory vegetation on the ungrazed forest contributed substantially to the low tree reproduction rate. Overall, "heavy grazing of the herbaceous understory vegetation, rather than exclusion of fire, appeared to be the prime factor in explaining the dense tree reproduction" on the grazed forest (emphasis added).

A similar study was conducted in 1983 on three areas in Zion National Park "almost identical biotically and environmentally." They had similar fire histories but markedly different grazing histories. The Horse Pasture Plateau was heavily grazed until about 1960, while Greatheart and Church Mesas - isolated by cliffs and slickrock - were never grazed and approximated pre-settlement conditions. Both areas were dominated by ponderosa pine and Gambel oak, and both had a similar history of browsing by large ungulates.

The authors characterized the study area as "uniquely suited to allow independent assessment of the relative importance of fire cessation and livestock grazing in the conversion of savannas to forests." They stated that the visual contrast between the areas was obvious, with dense thickets of ponderosa, Gambel oak, and Rocky Mountain juniper saplings prevalent on the grazed plateau and largely absent on the ungrazed mesas. They noted that fire was excluded from all the study areas but stated that decreased fire frequency alone is not the essential factor needed to cause these physiognomic changes. The

"presence of savanna conditions on Church and Greatheart Mesas despite long fire-free intervals is the strongest evidence yet for our contention...The fact that there were no thickets of "dog-hair" ponderosa pine on either mesa despite a comparable absence of fire, implicates livestock grazing as the critical factor (emphasis added)."

Fire, they say, "may have been the most important secondary factor for the maintenance of savanna conditions (emphasis added)." They went further, concluding that:

"Our findings challenge the widely accepted notion that the high frequency of fires in ponderosa pine savanna was the prime cause for the prevention of succession to denser stands of ponderosa pine or to shade-tolerant but fire-sensitive conifers... However important fire may be for management and maintenance of ponderosa pine communities, the key factor in the widespread conversion of savanna to forest seems to have been livestock grazing (emphasis added)."

The study showed that after the removal of livestock from Horse Pasture Plateau in 1960, the establishment rate for ponderosa pine dropped significantly. Importantly, this indicates that with the removal of cattle, the potential for forest restoration, via an increase in grass cover and a decrease in

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greater than the accepted Forest Service portrayal of 15-50 trees/acre for pre-settlement conditions in the SW Region.

tree density, is possible.

The third study, by Zimmerman and Neuenschwander (1984), looked at grazed and ungrazed ponderosa pine and Douglas-fir stands in the foothills of the Bitterroot Mountains of Idaho. The authors found the grazed stands of both species to have more young trees than ungrazed stands. As did the previous authors, Zimmerman and Neuenschwander concluded that "livestock grazing was probably the principal factor in creating and maintaining conditions that favored increased tree regeneration." They also predicted that if the grazed stands did not burn, they would "stagnate, causing reductions in growth rates and increased susceptibility to damage from insects and disease." This study, like the one in Zion National Park, is significant because the results suggest that if grazing is excluded and cool fires allowed to burn, the forests can once again approach their original healthy state.

### *Conclusion*

While information linking livestock grazing to high stand density has been available for nearly a century, it appears to have been forgotten. Or, at least, the implications have not been expressed in Forest Service policy for any of the varied western forest types. Indeed, a review of recent Forest Service publications could find little mention of grazing as a factor in decreased forest health (Belsky and Blumenthal, 1995); instead the blame seems to fall almost exclusively on past fire suppression policies. The Forest Service's current move toward an active prescribed burning program is welcome (providing it is an appropriate program, i.e. no spring burning, etc), but such a program cannot be successful if the current level of grazing is maintained. The two are mutually exclusive.

It is imperative that whatever the next stages of the forest health debate include, the role of livestock grazing as a causal and perpetuating factor in forest health problems be recognized and addressed. This is not only a historical problem: as long as livestock are present, the problem will remain. Furthermore, it is clear that grazing is not just a range issue. It is a silvicultural problem and, given that the Forest Service must legally consider all relevant scientific information, it must be analyzed in timber sales, salvage sales, juniper control and other silvicultural activities.

### *A PARTIAL GRAZING/FOREST HEALTH BIBLIOGRAPHY*

(Including Literature Cited)

Allen, B.H., and J.W. Bartolome. 1989. Cattle grazing effects on understory cover and tree growth in mixed conifer clearcuts. *Northwest Science* 63:214-220.

Archer, S. and F.E. Smeins. 1991. Ecosystem-level processes. Pages 109-139 in R.K. Heitschmidt and J.W. Stuth, editors. *Grazing management: an ecological perspective*. Timber Press, Portland, Oregon.

Armour, C.L., D.A. Duff, and W. Elmore. 1991. The effects of livestock grazing on riparian and stream ecosystems. *Fisheries* 16(1):7-11.

- Arnold, Joseph F., 1950. Changes in Ponderosa Pine Bunch grass Ranges in Northern Arizona Resulting from Pine Regeneration and Grazing. *J. Forestry* 48: 118- 126.
- Bahre, Conrad Joseph, 1991. *A Legacy of Change - Historic Human Impact on Vegetation of the Arizona Borderlands*. Tucson, University of Arizona Press 231p.
- Bahre, Conrad J., 1985. Wildfire in Southeastern Arizona Between 1859 and 1890. *Desert Plants* 7(4):190-194
- Baumgartner, D. and J.E. Lotan, eds. 1987. *Proceedings of a symposium: ponderosa pine - the species and its management*. Spokane, Washington.
- Belsky, Joy and Dana Blumenthal. 1995. *Ecological Assessment of Livestock Grazing in Forests of the Western Interior United States*. Paper prepared for the Interior Columbia Basin Ecosystem Management Project (US Forest Service). Submitted 14 April 1995. Submitted to *Conservation Biology*.
- Blackburn, W.H. 1984. Impacts of grazing intensity and specialized grazing systems on watershed characteristics and responses. Pages 927-983 in *Developing strategies for rangeland management*. Westview Press, Boulder, Colorado.
- Blackburn, Wilbert H. and Paul T. Tueller, 1970. Pinyon and Juniper Invasion in Black Sagebrush Communities in East-Central Nevada. *Ecology* 51(5) pp. 841-848.
- Brawn, J.D. and R.P. Balda. 1988. The influence of silvicultural activity on ponderosa pine forest bird communities in the Southwestern United States. IN *Bird Conservation*, Vol. 3, G.A. Jackson, ed. International Council for Bird Protection and the University of Wisconsin Press.
- Campbell, R.R. 1954. Fire in relation to forest grazing. *Unasylva* 8:154-158.
- Chandler, R.F. Jr. 1940. The influence of grazing upon certain soil and climatic conditions in farm woodlands. *Journal of the American Society of Agronomy* 32:216-230
- Clary, W.P., 1975. *Range Management and its Ecological Basis in the Ponderosa Pine Type of Arizona: The Status of Our Knowledge*. USDA Forest Service Research Paper RM-158 35p. Rocky Mt. For and Range Exp. Stn., Fort Collins, Colo. 80521
- Cooper, C.F., 1960. Changes in Vegetation, Structure, and Growth of Southwestern Pine Forests since White Settlement. *Ecol. Monog.* 30(2): pp. 129-164
- Cottam, W.P. 1976. *The impact of man on the flora of the Bonneville Basin*. Research Paper Number 76-1, Department of Geography, University of Utah, Salt Lake City, Utah, USA.

- Covington, W. W. and M. Moore, 1994. Southwestern Ponderosa Forest Structure. *Journal of Forestry*, January 1994. p. 39-47
- Covington, W.W. and M.M. Moore, 1992. Post-settlement Changes in Natural Fire Regimes: Implications for Restoration of Old Growth Ponderosa Pine Forests. In *Old Growth forests in the Southwest and Rocky Mountain regions: Proceedings of a workshop*, p. 81-99. USDA For Serv. Gen Tech. Rep. RM-213. 201p.
- Covington, W.W. and L.F. DeBano. 1988. Effects of fire on pinyon-juniper soil. IN *Management of Southwestern Natural Resources*, USDA Forest Service.
- Covington, W.W. and S.S. Sackett. 1988. Fire effects on ponderosa pine soils and their management implications. in *Management of Southwestern Natural Resources*, USDA Forest Service.
- Currie, P.O. 1987. Grazing in ponderosa pine forests. Pages 193-200 in D. Baumgartner, and J.E. Lotan, eds. *Proceedings of a symposium: ponderosa pine - the species and its management*. Spokane, Washington.
- Currie, P.O. and H.L. Gary. 1978. Grazing and logging effects on soil surface changes in central Colorado's ponderosa pine type. *Journal of Soil and Water Conservation* 4:176-178.
- Eissenstat, D.M., J.E. Mitchell, and W.W. Pope. 1982. Trampling damage by cattle on northern Idaho forest plantations. *Journal of Range Management* 35(6):715-716.
- Ellison, Lincoln, 1960. Influence of Grazing on Plant Succession of Rangelands. *The Botanical Review* V26(1) Jan-Mar 1960 p. 1-78
- Evanko, A.B., and R.A. Peterson. 1955. Comparisons of protected and grazed mountain rangelands in southwestern Montana. *Ecology* 36:71-83. Evans, R.A. 1988. *Management of Pinyon-Juniper Woodlands*. Gen. Tech. Rep. INT-249. USDA-FS.
- Faulk, O.B. 1970. *Arizona: A Short History*. University of Oklahoma Press, Norman, OK.
- Filip, G.M. 1994. Forest Health decline in central Oregon: a 13-year case study. *Northwest Science* 68(4): 233-240.
- Fitzgerald, R.D., R.J. Hudson, & A.W. Bailey. 1986. Grazing preferences of cattle in regenerating aspen forest. *J. of Range Manage.* 39(1):13-18.
- Fitzgerald, R.D. and A.W. Bailey. 1984. Control of aspen re-growth by grazing with cattle. *J. of Range Manage.* 37(2):156-158.
- Fleischner, Thomas L. 1994. *Ecological Costs of Livestock Grazing in Western North America*.

Conservation Biology 8(3): 629-644.

- Galbraith, W.A. and E.W. Anderson. 1991. Grazing history of the Northwest. *Rangelands* 13(5):213-218.
- Gillen, R.L., W.C. Krueger, and R.F. Miller. 1984. Cattle distribution on mountain rangeland on northeastern Oregon. *Journal of Range Management* 37(6):549-553.
- Graham, R. T. and J.L. Kingery. 1990. Seedling damage and mortality of conifer plantations on transitory ranges in northern and central Idaho. Pages 209-213 in R.L. Davis and R.E. Marsh, eds., *Proceedings of the 14th Vertebrate Pest Conference*. University of California, Davis, California.
- Graham, Russell T, James Kingery and Leonard A. Volland. 1992. Livestock and Forest Management Interactions. in *Silvicultural Approaches to Animal Damage Management in Pacific Northwest Forests*. GTR PNW-287. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.
- Gruell, G.E. 1985. Fire on the early western landscape: an annotated record of wildland fires 1776-1900. *Northwest Science* 59:97-104.
- Habeck, J.R. 1990. Old-growth ponderosa pine-western larch forests in western Montana: ecology and management. *Northwest Environmental Journal* 6:271-292.
- Hall, F.C. 1976. Fire and vegetation in the Blue Mountains -implications for land managers. *Proceedings of the Tall Timbers Fire Ecology Conference* 15:155-170.
- Hall, F.C. 1994. Historical and present conditions of the Blue Mountain forests. *Blue Mountain Natural Resource News*. U.S. Forest Service, Pacific Northwest Research Station, Portland, Oregon. March: 1-2.
- Halloin, L. 1991. Plantation grazing - a feasibility review. Washington State Department of Natural Resources, Pullman, Washington.
- Harrington, G.N. 1991. Effects of soil moisture on shrub seedling survival in a semi-arid grassland. *Ecology* 72(3):1138-1149.
- Harrington, M.G. and S.S. Sackett. 1988. Using fire as a management tool in Southwestern ponderosa pine. IN *Management of Southwestern Natural Resources*, USDA Forest Service.
- Harris, D.R. 1966. Recent plant invasions in the arid and semi-arid Southwest of the United States. *Annals of the Association of American Geographers* 56:408-422. Harris, G.A. 1991. Grazing lands of Washington State. *Rangelands* 13(5):222-227.

- Harris G.A. and M. Chaney. 1984. Washington State grazing land assessment. Washington State Cooperative Extension. Pullman.
- Hastings, J.R. and R.M. Turner. 1965. *The Changing Mile*. University of Arizona Press, Tucson.
- Heitschmidt, R.K. and J.W. Stuth, eds. 1991. *Grazing management: an ecological perspective*. Timber Press, Portland, Oregon.
- Hill, R.R. 1917. Effects of grazing upon western yellow pine production in the National Forests of Arizona and New Mexico. USDA Bulletin 580.
- Humphrey, R.R. 1956. History of Vegetation Changes in Arizona. *Arizona Cattlelog* 11:32- 35.
- Humphrey, R.R. 1958. The desert grassland: A history of vegetational change and an analysis of causes. *Botanical Review* 24:193-252.
- Humphrey, R.R. 1987. *90 Years and 535 Miles: Vegetation Changes Along the Mexican Border*. Albuquerque. University of New Mexico Press.
- Irwin, L.L., J.G. Cook, R.A. Riggs, and J.M. Skovlin. 1994. Effects of long term grazing by big game and livestock in the Blue Mountains forest ecosystems. General Technical Report PNW-325. U.S. Forest Service, Pacific Northwest Research Station, Portland, Oregon.
- Jameson, D.A. 1968. Species interactions of growth inhibitors in native plants of northern Arizona. Forest Service Research Note RM-113, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO, USA
- Johnson, W.M. 1956. The effect of grazing intensity on plant composition, vigor, and growth of pine-bunchgrass ranges in central Colorado. *Ecology* 37(4):790-798.
- Johnson, C.G. Jr., R.R. Clausnitzer, P.J. Mehringer, and C.D. Oliver. 1994. Biotic and abiotic processes of eastside ecosystems: the effects of management on plant and community ecology, and on stand and landscape vegetation dynamics. General Technical Report PNW-GTR 322. U.S. Forest Service, Pacific Northwest Research Station, Portland, OR.
- Karl, M.G. and P.S. Doescher. 1993. Regulating competition on conifer plantations with prescribed cattle grazing. *Forest Service* 39:405-418
- Kauffman, J.B., W.C. Krueger, and M. Vavra. 1983. Effects of late season cattle grazing on riparian ecosystems and streamside management implications...a review. *Journal of Range Management* 37(5): 430-438.
- Koehler, D.A., S.D. Thomas, H.D. Russell, and J.A. Mastel. 1989. Multi-resource management of

- ponderosa pine forests. General Technical Report RM-185. U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.
- Krueger, W.C. and A.H. Winward. 1974. Influence of cattle and big game grazing on understory structure of a Douglas fir-ponderosa pine-Kentucky bluegrass community. *Journal of Range Management* 27(6):450-453.
- Larson, M.M. and G.H. Schubert. 1969. Root competition between ponderosa pine seedlings and grass. General Technical Report RM-54. U.S. Forest Service, Rocky Mountain Forest and Range Experimental Station, Fort Collins, CO.
- Laudenslayer, W.F., H.H. Darr, and S. Smith. 1989. Historical effects of forest management practices in eastside pine communities in northeastern California. Pages 260-34 in A. Teclé, W.W. Covington, and R.H. Hamre, technical coordinators. General Technical Report RM-85. U.S. Forest Service Forest and Range Experimental Station, Fort Collins, Colorado.
- Lehmkuhl, J.F., P.F. Hessburg, R.L. Everett, M.H. Huff and R.D. Ottmar. 1994. Historical and current forest landscapes of eastern Oregon and Washington. Part 1: Vegetation pattern and insect disease hazards. General Technical Report PNW-GTR-328. U.S. Forest Service, Pacific Northwest Research Station. Portland, OR.
- Leninger, W.C., and S.H. Sharrow. 1989. Seasonal browsing of Douglas-fir seedlings by sheep. *Western Journal of Applied Forestry*. 4(3):73-76.
- Leopold, A. 1924. Grass, brush, timber and fire in southern AZ. *Journal of Forestry* 22:1-10.
- Mack, R.N. and J.N. Thompson. 1982. Evolution in steppe with few large, hooved mammals. *American Naturalist* 119(6):757-772.
- Madany, M.H. 1981. Land use-fire regime interacts with vegetation structure of several montane forest areas of Zion National Park. Thesis. Utah State University, Logan, Utah.
- Madany, M.H. and N.E. West, 1983. Livestock Grazing-Fire Regime Interactions within Montane Forests of Zion National Park, Utah. *Ecology*, 64(4). pp 661-667.
- Martin, J.W. and R.M. Turner. 1977. Vegetational change in the Sonoran Desert region, Arizona and Sonora. *Journal of the Arizona Academy of Sciences*.
- McPherson, G.R. and H.A. Wright. 1989. Effects of cattle grazing and Juniper canopy cover on herb cover and production in western Texas. *American Midland Naturalist* 123(1):144-151.
- Miller, R.F. and W.C. Krueger. 1976. Cattle use on summer foothill rangelands in northeastern Oregon. *Journal of Range Management* 29(5):367-371.

- Mitchell, John E. and Duane R. Freeman. 1993. Wildlife-livestock-fire interactions on the North Kaibab: A Historical Review. General Technical Report RM-222. USDA Forest Service Rocky Mountain Forest and Range Experimental Station, Fort Collins, CO. 12p.
- Morgan, Penelope, 1994. Dynamics of Ponderosa and Jeffrey Pine Forests in Flammulated, Boreal and Great Gray Owls in the U.S.. Forest Service General Technical Report RM-253, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO, USA
- O'Laughlin, J., J.G. MacCracken, D.L. Adams, S.C. Bunting, K.A. Blatner, and C.E. Keegan. 1993. Forest health conditions in Idaho. Report Number 11. Idaho Forest, Wildlife and Range Policy Analysis Group, Moscow, Idaho.
- Painter, E.L. and A.J. Belsky. 1993. Application of herbivore optimization theory to rangelands of the western United States. *Ecological Applications* 3:2-9.
- Pearson, G. A. 1923. Natural reproduction of western yellow pine in the Southwest. U.S. Dept. Ag., Bull 1105. 143 pgs.
- Pearson, G.A. 1933. A twenty year record of changes in an Arizona pine forest. *Ecology* 14:272-285.
- Peet, R.K. 1988. Forests of the Rocky Mountains. Pages 63-101 in M.G. Barbour and W.D. Billings, editors. North American terrestrial vegetation. Cambridge University Press. New York, New York.
- Pieper, R.D. and R.D. Wittie. 1988. Fire effects in Southwestern Chaparral and pinyon-juniper vegetation. IN Management of Southwestern Natural Resources, USDA Forest Service.
- Quigley, T.M., H.R. Sanderson, and A.R. Tiedemann, eds. 1989. Managing interior northwest rangelands: the Oregon range evaluation project. General Technical Report PNW-238. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.
- Rasmussen, D.I.. 1941. Biotic communities of the Kaibab Plateau, Arizona. *Ecological Monographs* 11:229-275.
- Rietveld, W.J. 1975. Phytotoxic grass residues reduce germination and initial root growth of ponderosa pine. Forest Service Research Note RM-153, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO, USA
- Roath, L. and W.C. Krueger. 1982. Cattle grazing and behavior on a forested range. *Journal of Range Management* 35(3):332-338.
- Roy, D.F. 1953 Effects of ground cover and class of planting stock on survival of transplants in the

- eastside pine type of California. California Forest and Range Experimental Station Forest Research Note No. 87. 6pp.
- Rummell, Robert S. 1951. Some Effects of Livestock Grazing on Ponderosa Pine Forest and Range in Central Washington. *Ecology* 32(4):594-607.
- Savage, M., and T.W. Swetnam. 1990. Early 19th century fire decline following sheep pasturing in a Navajo ponderosa pine forest. *Ecology* 32(4):594-607.
- Schwan, H.E. 1949. Influence of grazing and mulch on forage growth. *Journal of Range Management* 2:142-148.
- Skovlin, J.M., R.W. Harris, G.S. Strickler, and G.A. Garrison. 1976. Effects of cattle grazing methods on ponderosa pine-bunchgrass range in Pacific Northwest. Technical Bulletin 1531, U.S. Forest Service, Pacific Northwest Research Station, Portland, Oregon.
- Smith, D.W. 1967. Effects of cattle grazing on a ponderosa pine-bunchgrass range in Colorado. Technical Bulletin 1371. U.S. Department of Agriculture, Washington, DC.
- Stebbins, G.L. 1981. Co-evolution of grasses and herbivores. *Annals of the Missouri Botanical Garden*. 68:75-86.
- Stein, S.J. 1988. Explanations of the imbalanced age structure and scattered distribution of ponderosa pine within a high-elevation mixed coniferous forest. *Forest Ecology Management* 25:139-153.
- Swetnam, T.W. and C.H. Baisan, 1995. (in press) In: C.D. Allen (ed.), Proceedings of the 2nd La Mesa Fire Symposium, Mar 29-31, 1994, Los Alamos N.M. National Park Service Technical Report Series
- Tackle, D. and D.F. Roy. 1953. Site Preparation as related to ground cover density in natural regeneration of ponderosa pine. California Forest and Range Exp. Station Technical Paper No. 4. 13 pp.
- Tiedemann, A.R. and H.W. Berndt. 1972. Vegetation and soils of a 30-year elk and deer exclosure in central Washington. *Northwest Science* 46(1):59-66.
- Tisdale, E.W. 1950. Grazing of forest lands in interior British Columbia, *Journal of Forestry* 48:856-860.
- Tuomey, J.W. 1891. I. Notes of Some of the Range Grasses of Arizona. University of Arizona Agricultural Experiment Station Bulletin 2.
- Weaver, H. 1943. Fire as an Ecological and Silvicultural Factor in the Ponderosa Pine Region of the

Pacific Slope J Forestry 41: 7-14

Weaver, H. 1947. Fire - Nature's Thinning Agent in Ponderosa Pine Stands. J. Forestry 45: 437-444.

Weaver, H. 1950. Shoals and Reefs in Ponderosa Pine Silviculture. J. Forestry 48: 21-22.

Weaver, H. 1961. Ecological changes in the ponderosa pine forest of a cedar valley in southern Washington. Ecology 42:416-420.

White, A.W. 1985. Presettlement regeneration patterns in ponderosa pine stands. Journal of Forestry 45:437-444.

Winegar, H.H. 1977. Camp Creek channel fencing - plant, wildlife, soil, and water responses. Rangeland Management Journal 4:10-12.

Wooten, E.O. 1916. Carrying Capacity of Grazing Ranges in Southern Arizona. USDA Bulletin No. 367. Washington, D.C.: GPO.

Wright, H.A. 1988. Role of fire in the management of Southwestern ecosystems. IN Management of Southwestern Natural Resources, USDA Forest Service.

Wright, H.A. and A.W. Bailey. 1982. Fire Ecology, United States and Southern Canada. New York: John Wiley and Sons.

Wright, H.A., L.F. Neuenschwander, and C.M. Britton. 1979. The Role and Use of Fire in Sagebrush-grass and Pinyon-juniper Plant Communities: A state-of-the-art review. USDA Forest Service, Intermountain Forest and Range Experiment Station.

Zimmerman, G.T. and L.F. Neuenschwander. 1984. Livestock grazing influences on community structure, fire intensity, and fire frequency within the Douglas-fir/ninebark habitat type. Journal of Range Management 37(2):104-110.