# FIRE CONDITIONS PRE- AND POSTOCCURRENCE OF ANNUAL GRASSES ON THE SNAKE RIVER PLAIN

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## ABSTRACT

*Fire has been an important factor in the development of the vegetation of the Snake River Plain. Prior to Euro-American influence, fire helped determine the physiognomy and species composition of many communities. The occurrence of fire varied widely depending on the vegetation present, topography, and other factors. This impact can be detected in many historical documents and inferred from species response to fire. On the upper Snake River Plain, fire was frequently reported and was an important factor in vegetation development. On the lower plain, fire appears to have been less common. Low amounts of fine fuel probably limited the extent. During the postsettlement period, the occurrence of fire has increased throughout much of the Snake River Plain. The introduction of annual grasses, particularly cheatgrass* (Bromus tectorum *L.), has altered fuel loads and fuel distribution, which in turn has changed fire intensity and extent. Increased human activity has resulted in greater numbers of ignition sources. The decreased fire-free interval (FFI) has greatly modified the presettlement role of fire and the distribution of many species.*

## INTRODUCTION

The introduction of exotic annual grasses, particularly cheatgrass (*Bromus tectorum* L.) and medusahead (*Taeniatherum caput-medusae* Nevski) into the Snake River Plain may have been the most important event in the natural history of that region since the last glacial period. The associated changes in plant recruitment and fire history, as well as domestic livestock grazing, have completely changed the species composition, physiognomy, and functioning of many vegetation types within the region. The adjustments in biotic community structure following the introduction of the species are continuing to be reflected in the vegetation. Throughout much of the more arid portion of this region, the development of vegetations dominated by one or more annual grasses with frequent fire occurrence is taking place. In this paper we will discuss the occurrence of fire prior to and following the introduction of annual grasses and the subsequent effects on the vegetation. Changes on the Snake River Plain will be emphasized, but information is applicable to adjacent areas of the Great Basin.

In recent years authors have discussed the nature of pristine vegetation on the Snake River Plains and Great Basin based on anecdotal information (Christensen and Johnson 1964; Hull and Hull 1974; Johnson 1986; Vale 1975). These studies have placed primary emphasis on the existing diaries and journals of people entering the region in the early to mid 19th century. The interpretations based on these accounts are highly variable. This is probably expected given the wide variety of vegetation types involved, the long timeframe, and variety of perspectives included in the descriptions and narrations. Most of the observers were from more humid areas of eastern North America, and the arid stark conditions, long distances, lack of water, and strange plants must have made many travelers uneasy. This may have certainly colored many narratives. Most west-bound travelers, leaving Missouri in the spring, did not reach the Snake River Plains until late summer when most of the forage was dormant. Perhaps the first scientist to observe and write about the Snake River Plain in the spring was C. H. Merriam (1890). Also included in these observations are those of the "professional" travelers such as Peter Skeene Ogden, John C. Fremont, Osborne Russell, and John Work who were well equipped and trained for surviving in the region. Due to the amount of time the writers spent in the region and their continual need for water, forage, game, and fuel, these accounts may be our most valuable for the purpose of reconstructing the role of fire in the pristine conditions.

These accounts, supported by old photographs, have also been used to assess the role that fire may have had in the development of vegetation prior to the settlement of the region by Euro-Americans (Gruell 1983; Gruell 1985; Gruell 1986; Gruell and others 1985). In addition, more quantitative approaches to documenting the occurrence of fire have been done for areas that have a tree species that firescars and retains a long-term history (Burkhardt and Tisdale 1969; Burkhardt and Tisdale 1976; Gruell and others 1985; Houston 1973). Because of the reliance on trees to record fire occurrence, these quantitative studies have been done at elevational and precipitation zones that are greater than the area most greatly impacted by the introduced annual grasses. Generally these studies have documented a decrease in fire occurrence and a subsequent increase in the

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woody component of the associated plant community. However, most of the studies did not include the region specifically dominated by cheatgrass and medusahead today. Rather more attention has been given to those areas of the sagebrush-grassland that are on or near the ecotone between sagebrush and woodland or forested vegetation such as western juniper (*Juniperus occidentalis* Hook.), mountain-mahogany (*Cercocarpus ledifolius* Nutt.), ponderosa pine (*Pinus ponderosa* Dougl.), and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco).

## PREOCCURRENCE OF ANNUAL GRASSES

The impression given by the anecdotal accounts for the lower Snake River Plain is that big sagebrush (*Artemisia tridentata* Nutt.) was an overwhelming dominant in the region. We will define the lower Snake River Plain as that portion west of a line from Arco to American Falls, ID. Many individuals describe the appearance, often unfavorably, that sagebrush gave to the landscape. In 1843 near the mouth of Goose Creek, John C. Fremont noted that "the country has a barren appearance, sandy, and densely covered with the artemisias from the banks of the river to the foot of the mountains." Several days later near the present site of Twin Falls he added that "there was no grass here, the soil among the sage being entirely naked" (Fremont 1988). In 1812 describing the area near the present town of Burley, Stuart noted that "the whole face of the country appears level before us, ..., the sage wormwood and saltwood cover a parched soil of sand, dust and gravel" (Spaulding 1953). Townsend (1839) described the area between Blackfoot and Arco as a "wide sandy plain, thickly covered with wormwood."

In 1830, Wislizenus (1912) described the area along the Portneuf River near its confluence with the Snake. "On the east side of the river the plain is barren sandy, and level, and produces only prickleypear, sage and occasional scanty tufts of dry grass. On the west side, the plain is much more extensive stretching often away to 50 and even 60 miles...like the other, barren of vegetation except prickleypear and sage."

Forage for stock was also a concern for most travelers. Many accounts indicate concerns of being able to locate adequate forage for animals. The Oregon and California migration began in 1841. By 1843 tens of thousands of people journeyed along the Oregon Trail annually, and most had stock of some type. The Oregon Trail was not a single track but rather a series of routes. Forage utilization along the trail was undoubtedly high during the years of high migration. Many immigrants were forced to range up to several miles from the trail in order to find adequate feed (Hill 1987). The high utilization makes interpretation of Oregon Trail diaries after 1843 questionable when the authors are discussing vegetation. It was probably very impacted by the mid-1840's. In some locations the evidence of this intense use is still visible on the landscape. However, many accounts that predate the high migration period also express concern for the availability of forage. Near Shoshone Falls, Cross (1851) stated, "They (the mules) were therefore turned out to graze among the sandhills and artemisia, there being scarcely a particle of grass either on the bluff or in the canyon." Stuart in 1812 indicated at Three Island Crossing near present Glenns Ferry, ID, that "scarce and bad indeed is the fodder for our horses" (Spaulding 1953). Limited forage was particularly a concern for those forced to take the route that followed the south bank of the Snake River when high water at Three Island Crossing did not permit fording the river. Forage and water availability were apparently greater along the northern route that followed the lower Boise River. Cross (1851) wrote of the route from Rock Creek to Fort Boise that "the condition of our mules did not justify such long marches; but we were driven to it by compulsion, as neither water nor grass was to be had at any intermediate point." He later stated that the grazing near the mouth of the Malheur River was the best they had seen for some time.

Those able to ford the Snake River at Three Island Crossing found forage conditions more favorable. This was particularly true once the Boise River was reached. Many accounts describe the beauty and lush pasture conditions of the Boise River Valley (Fremont 1988; Haines 1971; Townsend 1839). Bonneville describes the Boise River Valley as the most enchanting he had seen in the far West, presenting the mingled grandeur and beauty of mountain and plain, bright running streams, and vast grassy meadows (Irving 1986). The combination of plentiful forage, water, cottonwood groves, and abundant game and salmon made this area a frequently used rest stop to recover from the hardships of travel across the plain.

Observations on wildfires were uncommon on the lower Snake River Plain. Gruell (1985) documented only five observations of fire in his survey of the historic literature during the 1800-46 period. However, fires did occur. On September 14, 1830, John Work made the following notes on a fire that had occurred 30 km southeast of the present site of Boise: "The country has recently been overrun by fire. Scarcely a spot of grass left for the horses to feed." He continued to cross this burned area for part of the next day (Haines 1971), so it must have been relatively large in size.

The lack of observations of fire on the lower Snake River Plain can probably be explained by the low forage (fine fuels) produced by the vegetation. The region is comprised of several habitat types dominated by an overstory of Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle and Young) (Hironaka and others 1983). During most years, perennial grass (fine fuel) production in these habitat types was probably less than 400 kg/ha (personal communication, M. Hironaka, 1992). While wildfires could occur, even extensive fires under extreme conditions, fires were generally limited by low fuel loading. Fire behavior and fire spread become very erratic when less than 650 kg/ha of fine fuels are present (Beardall and Sylvester 1976; Bunting and others 1987). Once burned, an area was probably unable to sustain a large fire until a new stand of Wyoming big sagebrush became established and contributed to the fuel loading on the site. Prior to the establishment of sagebrush the perennial grasses were too low in density to provide for fire spread under most environmental conditions. Consequently the possibility of frequent reburns was self limiting. Much of the area south of the river is comprised of

Wyoming big sagebrush habitat types as well as one of several salt-desert shrub communities dominated by winterfat (*Ceratoides lanata* [Pursh.] J.T. Howell), saltsage (*Atriplex nuttallii* Wats.), shadscale (*Atriplex confertifolia* [Torr. & Frem.] Wats.), or greasewood (*Sarcobatus vermiculatus* [Hook.] Torr.). These salt-desert communities produce even less fine fuels than the Wyoming big sagebrush communities and rarely burned under pristine conditions.

A recent hypothesis explaining the scarcity of bison (*Bison bison*) west of the Rocky Mountains supports the low fine-fuel concept for the lower Snake River Plain. Van Vuren (1987) has suggested that the distribution of bison was limited by low overall forage conditions. Frequent observations of large numbers of bison prior to 1830 were reported for the upper Snake River Plain and adjacent valleys (Ferris 1983; Haines 1965; Haines 1971; Irving 1986; Ogden 1910; Townsend 1839; Wislizenus 1912). The only location farther west where they were consistently found was in the Raft River Valley. This area was frequently used as a supply point for trapper brigade expeditions into the northern Great Basin (Haines 1971). The great areas once dominated by Wyoming big sagebrush on the lower plain were seldom reported as having large numbers of bison. However, occasional observations were made on the eastern portion of the lower plain. The long severe winter of 1830-31 is generally credited for destroying the Snake River bison herd (Haines 1971). The high winter mortality combined with more efficient hunting methods by Indians, who had acquired the horse and the firearm, and increased hunting pressure from the trapper brigades during the 1810-40 period, probably never allowed the bison to recover. The herd was most likely extinct by 1840, as no references to bison on the Snake River Plain appear in the Oregon Trail diaries.

The upper Snake River Plain and adjacent valleys were distinctly different from the lower plain in characteristics other than the presence of bison. While variable, more grass was consistently reported for this region (Haines 1965; Haines 1971; Irving 1986; Mullan 1855). Ferris (1983) indicated that as one traveled up the Snake River from the mouth of the Portneuf River you crossed "a rich and continuous bottom of excellent grass." Townsend (1839) described the Big Lost River Valley as being "about a mile in width, and covered with excellent grass." The Lemhi Valley, Teton Basin, and south of Monida Pass were also frequently described as having good grazing. Reports of fires prior to 1846 are much more common in the historic literature for the upper Snake River Plain and adjacent valleys (Gruell 1985).

Another area frequently described for its lush valleys was the Camas and Little Camas Prairies 35 km north of Three Island Crossing (Haines 1971; Irving 1986). Fremont (1988) stated, "There is no dispute about the grass, which is almost universal on the hills and mountains, and always nutritious, even in its dry state." He also stated, "Here the vegetation was very much changed, the artemisia disappeared almost completely,...and was replaced by purshia tridentata. These (the hills) were everywhere covered with a fresh and green short grass, like that of early spring. This is the fall or second growth, the dried grass having been burnt off by the Indians; and wherever the fire has passed, the bright-green color is universal." Fires were also reported a number of times in other accounts from this area (Haines 1971). These prairies are higher in elevation and receive greater precipitation, and the uplands are dominated by mountain big sagebrush (*Artemisia tridentata* Nutt. ssp. *vaseyana* [Rydb.] Beetle), not Wyoming big sagebrush. A number of references to wildfires on these prairies can be found in the historic literature. Fires, both wild and prescribed, are common today, and cheatgrass is present but does not dominate.

## POSTOCCURRENCE OF ANNUAL GRASSES

Prior to the 1890's, only a few native grass species occupied the early seral position in disturbed landscapes of the Snake River Plains. Of these, the annual fescues (*Festuca octoflora* Walt. and *F. megalura* Nutt.) were the primary annual grasses. These species would increase for a few years following disturbance, and then be suppressed by perennial species, such as squirreltail (*Sitanion hystrix* [Nutt.] J. G. Smith), Idaho fescue (*Festuca idahoensis* Elmer), bluebunch wheatgrass (*Agropyron spicatum* [Pursh] Scribn. and Smith), rabbitbrush (*Chrysothamnus* spp. Nutt.), and sagebrush. Fire historically occurred in these communities at intervals of 20 to 100 years (Houston 1973; Wright and Bailey 1982; Wright and others 1979), and a successional cycle of early seral perennial to late-seral perennial (sagebrush-bunchgrass) dominance was thought to have occurred. The introduction of cheatgrass and medusahead, both Eurasian winter annuals, has significantly altered the dynamics of these rangeland ecosystems by changing the fire regime and successional patterns.

Cheatgrass, introduced into the Intermountain West in the 1890's, began to appear on the Snake River Plains in the years between 1915 and 1920 (Mack 1981). The primary route of introduction is believed to have been in seed grain, and shipment via railways offered widespread dispersal (Mack 1981). Animals, especially sheep, may have also been important contributors to cheatgrass spread (Yensen 1981). According to accounts, cheatgrass flourished in disturbed areas, such as abandoned farmlands (Piemeisel 1938; Piemeisel 1951), roadsides, and overgrazed range (Mack 1981), and was rapidly distributed across diverse habitats over much of the United States. Cheatgrass was found to provide good forage in the early spring (Harris 1967; Hull and Pechanec 1947), and many ranchers intentionally burned sagebrush rangeland to increase this forage source. However, by maturity its forage value is lowered, and annual yield variation is much greater than for perennial grasses (Hull and Pechanec 1947; Tisdale and others 1969).

Medusahead was introduced into the Western United States in the 1930's and first collected in Idaho in 1946 (Torell and others 1961). It was also probably introduced in seed grain and dispersed via animals. The range of occupation by medusahead is less than that occupied by cheatgrass, as it appears to require more well-developed, finer textured soils (Dahl and Tisdale 1974). Despite the soil limitations, it appears to be moving eastward (Dahl and Tisdale 1974). Throughout the entire plant, medusahead has high silica content (Bovey and others 1961), and thus has low forage quality.

Both cheatgrass and medusahead germinate in the fall after the commencement of the fall rains and are capable of root growth throughout the winter (Hironaka 1961). The amount of growth or tillering by these species depends on the amount of moisture received, but even in low precipitation years both species are capable of forming dense stands and producing viable seed (Tisdale and Hironaka 1981). Upon maturity, medusahead and cheatgrass produce a very fine fuel source, and both may lodge, thus forming a continuous fuel source (Turner and others 1963). The high silica content of medusahead also slows decomposition and thus, over several years, medusahead is capable of forming a dense mat of highly flammable material (Turner and others 1963).

The following two situations are given as examples of the effect that exotic annual grasses have had on communities within the sagebrush-grassland region of the lower Snake River Plains. The upper Snake River Plains receive higher amounts of precipitation and thus do not have the problem with annual grasses, as on the lower Snake River Plains (Bunting and others 1987).

In the first scenario the dominant perennial grasses and forbs have been reduced by overgrazing, while sagebrush and rabbitbrush have increased. Within these communities, the shrub component has formed a dense canopy, and there is little understory vegetation. The closed canopy of these communities is very susceptible to fire. Fire is carried through the community within the canopy, and the overstory species are greatly reduced. If a seed source for annual grasses is present, they will increase following fire. Perennial grass and forb species may maintain prefire population numbers, but more likely will decrease. As annual grass dominance increases, these communities become more susceptible to fire. Within 3 to 6 years following the initial fire, the dried annual grass culms will develop sufficient continuity of fuels to readily support a second fire. Successive fires become common, and each fire reduces the surviving sagebrush and rabbitbrush further. Although resprouting species, such as rabbitbrush, increase with fire, these resprouting species are also lost when the fire-free interval (FFI) is decreased to 5 or less years (Whisenant 1990). In addition, repeated fires with short FFI's deplete the soil seed reserves of sagebrush and other fire-sensitive species.

The second situation occurs in areas where the shrub component has been removed, and annuals and perennial grasses are present. As a fire burns these communities, the perennial species will respond differentially to the fire. Species such as squirreltail are more fire tolerant than the fescues or wheatgrasses (Wright 1971; Wright and Klemmedson 1965; Young and Miller 1985). Perennial forbs are more tolerant of fire in the late summer (Wright and Bailey 1982). Although a reduction in annual grass density occurs after fire, there is a flush of nutrients that the annuals take advantage of, and if adequate moisture is present, they will produce an ample seed crop (Young and Evans 1978). Competition from the cheatgrass and medusahead limits recruitment of perennial grasses, due to the earlier initiation of spring growth of the annual grass seedlings. Thus, over a few years, the annuals will again dominate, litter will accumulate, perennial grasses will be those more tolerant of fire, and the community will be capable of supporting another fire. Throughout this time, the perennial seed bank diminishes. If there are no adult perennial species to produce more seed, the burned community would rely on dispersal from adjoining nonburned communities to provide the seed source necessary for perennial recruitment. But with each fire the area of annual dominance increases, and exogenous seed sources become more dispersed. Also, recent research (Melgoza and Nowak 1991; Melgoza and others 1990) has demonstrated that cheatgrass negatively affects the growth and productivity of established perennial species. Thus, regeneration of the perennial species is limited.

These two examples are likely to occur in years of below-average precipitation ("dry") or above-average precipitation ("wet"). Perennial seedlings are more able to become established in wet years, in spite of increased annual seedlings. Also, during wet years, spread of the annual grasses into the salt-desert shrub communities occurs. Thus, in wet years, these communities, too, become more susceptible to fire.

Although wet years are good for perennial plant establishment, the increased production of the annual grasses results in increased fuel continuity and fine fuel. The annuals become dormant in late summer, and therefore the community has a greater chance for fire. This is reflected in the statistics of the acreage burned within Idaho. Within a 10-year period, 2,412,890 acres (976,879 ha) burned primarily on the Snake River Plains, and until the drought years of 1987 and 1988, the amount of land burned annually had steadily increased in the previous 5 years (Pellant 1990). Production of annual grasses is reduced during drought years, litter accumulation rates are reduced, and the community will become less susceptible to fire. Within annual-dominated rangelands, an FFI of 10 to 12 years, or less, is likely. For these communities to become more resilient to fire, FFI's probably need to be greater than 20 to 50 years, to allow establishment of the sagebrush species occupying the various habitat types on the burned area.

## SUMMARY

The vegetation within the Snake River Plains was historically shrub-bunchgrass communities, with bunchgrasses occupying the interspaces between the shrubs. Fire occurred in the more arid communities only if the sagebrush was sufficiently dense to carry a fire, as the bunchgrasses did not provide adequate continuous fuel. As a result of the introduction of exotic annuals into the Snake River Plains, the historical successional patterns after disturbance were altered. Grazing and agricultural practices have disturbed many habitats, but the primary disturbance in the lower Snake River Plains is fire. Each year more sagebrush rangeland is converted to annual grass rangeland due to wildfires. With each successive fire, annual grass dominance is enhanced, and the FFI is decreased. The landscape has become more homogenous, species diversity has decreased, and burns are larger and more continuous.

## REFERENCES


Beardall, L. E.; Sylvester, V. E. 1976. Spring burning for removal of sagebrush competition in Nevada. Proceedings Tall Timbers Fire Ecology Conference. 14: 539-547.

Bovey, R. W.; LeTourneau, D.; Erickson, L. C. 1961. The chemical composition of medusahead and downy brome. Weeds. 9: 307-311.

Bunting, S. C.; Kilgore, B. M.; Bushey, C. L. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the northern Great Basin. Gen. Tech. Rep. INT-231. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 33 p.

Burkhardt, J. W.; Tisdale, E. W. 1969. Nature and successional status of western juniper vegetation in Idaho. Journal of Range Management. 22: 264-270.

Burkhardt, J. W.; Tisdale, E. W. 1976. Causes of juniper invasion in southwestern Idaho. Ecology. 57: 472-484.

Christensen, E.; Johnson, H. 1964. Presettlement vegetation and vegetation change in three valleys in central Utah. Provo, UT: Brigham Young University Science Bulletin, Biology Series. Vol. 4, No. 4. 16 p.

Cross, O. 1851. A report, in the form of a journal, to the quartermaster general, of the march of the regiment of mounted rifleman to Oregon, from May 10, to October 5, 1849. Senate Executive Document No. 1, 31st Congress, 2nd Session.

Dahl, B. E.; Tisdale, E. W. 1975. Environmental factors related to medusahead distribution. Journal of Range Management. 28: 463-468.

Ferris, W. A. 1983. Life in the Rocky Mountains: a diary of wanderings on the sources of the rivers Missouri, Columbia, and Colorado, 1833-1835. Denver, CO: Old West Publications Company. 444 p.

Fremont, J. C. 1988. The exploring expedition to the Rocky Mountains. Washington, DC: Smithsonian Institution Press. 319 p.

Gruell, G. E. 1983. Fire and vegetative trends in the northern Rockies: interpretations from 1871-1982 photographs. Gen. Tech. Rep. INT-158. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 117 p.

Gruell, G. E. 1985. Fire on the early western landscape: an annotated list of recorded wildfires in presettlement times. Northwest Science. 59: 97-107.

Gruell, G. E. 1986. Post-1900 mule deer irruptions in the Intermountain West. Gen. Tech. Rep. INT-206. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 37 p.

Gruell, G. E.; Bunting, S. C.; Neuenschwander, L. F. 1985. Influence of fire on curlleaf mountain-mahogany. In: Lotan, J. E.; Brown, J. K., eds. Fire's effect on wildlife habitat—symposium proceedings; 1984 March 21; Missoula, MT. Gen. Tech. Rep. INT-186. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 58-72.

Haines, A. L., ed. 1965. Osborne Russell's journal of a trapper. Lincoln, NE: University of Nebraska Press. 191 p.

Haines, F. D., ed. 1971. The Snake Country expedition of 1830-1831. John Work's field journal. Norman, OK: University of Oklahoma Press. 172 p.

Harris, G. A. 1967. Some competitive relationships between *Agropyron spicatum* and *Bromus tectorum*. Ecological Monographs. 37: 89-111.

Hill, W. E. 1987. The Oregon Trail—yesterday and today. Caldwell, ID: Caxton Printers. 179 p.

Hironaka, M. 1961. The relative rate of root development of cheatgrass and medusahead. Journal of Range Management. 14: 265-267.

Hironaka, M.; Fosberg, M. A.; Winward, A. H. 1983. Sagebrush-grass habitat types of southern Idaho. Bull. 35. Moscow, ID: University of Idaho, Forest, Wildlife and Range Experiment Station. 44 p.

Houston, D. B. 1973. Wildfires in northern Yellowstone National Park. Ecology. 54: 1111-1117.

Hull, A. C., Jr.; Hull, M. K. 1974. Presettlement vegetation of Cache Valley, Utah and Idaho. Journal of Range Management. 27: 27-29.

Hull, A. C., Jr.; Pechanec, J. F. 1947. Cheatgrass—a challenge to range research. Journal of Forestry. 45: 555-564.

Irving, W. 1986. The adventures of Captain Bonneville, USA in the Rocky Mountains and the far West. Norman, OK: University of Oklahoma Press. 421 p.

Johnson, K. L. 1986. Sagebrush over time: a photographic study of rangeland change. In: McArthur, E. D.; Welch, B. L., compilers. Proceedings—symposium on the biology of *Artemisia* and *Chrysothamnus*; 1984 July 9-13; Provo, UT. Gen. Tech. Rep. INT-200. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 223-252.

Mack, R. N. 1981. Invasion of *Bromus tectorum* L. into western North America: an ecological chronicle. Agro-Ecosystems. 7: 145-165.

Melgoza, G.; Nowak, R. S. 1991. Competition between cheatgrass and two native species after fire: implications from observations and measurements of root distribution. Journal of Range Management. 44: 27-33.

Melgoza, G.; Nowak, R. S.; Tausch, R. J. 1990. Soil water exploitation after fire: competition between *Bromus tectorum* (cheatgrass) and two native species. Oecologia. 83: 7-13.

Merriam, C. H. 1890. Results of a biological reconnaissance of south-central Idaho. Fauna No. 5. Washington, DC: U.S. Department of Agriculture, Division of Ornithology and Mammology.

Mullan, J. 1855. Report of a reconnaissance from the Bitter Root Valley to Ft. Hall, thence to the head of Hell Gate River, thence to the Bitter Root Valley. In: Explorations for a railroad route from the Mississippi River to the Pacific. House of Representatives. 22nd Congress, 2nd Session, Executive Document No. 91. Washington, DC: A.P.O. Nicholson: 322-349.

Ogden, P. S. 1910. Journal of Peter Skeene Ogden; Snake Expedition, 1827-1828. Oregon Historical Quarterly. 11: 361-379.

Pellant, M. 1990. The cheatgrass-wildfire cycle—are there any solutions? In: McArthur, E. D.; Romney, E. M.; Smith, S. D.; Tueller, P. T., compilers. Proceedings—symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5-7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 11-18.

Piemeisel, R. L. 1938. Changes in weedy plant cover on cleared sagebrush land and their probable causes. Tech. Bull. 654. Washington, DC: U.S. Department of Agriculture. 44 p.

Piemeisel, R. L. 1951. Causes affecting change and rate of change in a vegetation of annuals in Idaho. Ecology. 32: 53-72.

Spaulding, K. A., ed. 1953. On the Oregon Trail—Robert Stuart's journey of discovery. Norman, OK: University of Oklahoma Press. 192 p.

Tisdale, E. W.; Hironaka, M. 1981. The sagebrush-grass region: a review of the ecological literature. Bull. 33. Moscow, ID: University of Idaho, Forest, Wildlife and Range Experiment Station. 31 p.

Tisdale, E. W.; Hironaka, M.; Fosberg, M. A. 1969. The sagebrush region in Idaho: a problem in range resource management. Bull. 512. Moscow, ID: University of Idaho Agricultural Experiment Station. 15 p.

Torell, P. J.; Erickson, L. C.; Haas, R. H. 1961. The medusahead problem in Idaho. Weeds. 9: 124-131.

Turner, R. B.; Poulton, C. E.; Gould, W. L. 1963. Medusahead—a threat to Oregon rangeland. Spec. Rep. 149. Corvallis, OR: Agricultural Experiment Station, Oregon State University. 22 p.

Townsend, J. K. 1839. Narrative of a journey across the Rocky Mountains to the Columbia River. Lincoln, NE: University of Nebraska Press. 259 p.

Vale, T. R. 1975. Presettlement vegetation in the sagebrush-grass area of the Intermountain West. Journal of Range Management. 28: 32-36.

Van Vuren, D. 1987. Bison west of the Rocky Mountains: an alternative explanation. Northwest Science. 61: 65-69.

Whisenant, S. G. 1990. Changing fire frequencies on Idaho's Snake River Plains: ecological and management implications. In: McArthur, E. D.; Romney, E. M.; Smith, S. D.; Tueller, P. T., compilers. Proceedings—symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5-7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 4-10.

Wislizenus, F. A. 1912. A journey into the Rocky Mountains in the year 1839. Spokane, WA: Arthur H. Clark Company. 162 p.

Wright, H. A. 1971. Why squirreltail is more tolerant to burning than needle-and-thread. Journal of Range Management. 24: 277-284.

Wright, H. A.; Bailey, A. W. 1982. Fire ecology. New York: Wiley-Interscience. 501 p.

Wright, H. A.; Klemmedson, J. O. 1965. Effects of fire on bunchgrasses of the sagebrush-grass region of southern Idaho. Ecology. 51: 582-588.

Wright, H. A.; Neuenschwander, L. F.; Britton, C. M. 1979. The role and use of fire in sagebrush and pinyon juniper plant communities: a state-of-the-art review. Gen. Tech. Rep. INT-58. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 48 p.

Yensen, D. L. 1981. The 1900 invasion of alien plants into southern Idaho. Great Basin Naturalist. 41: 176-183.

Young, J. A.; Evans, R. A. 1978. Population dynamics after wildfires in sagebrush grasslands. Journal of Range Management. 31: 283-289.

Young, J. A.; Miller, R. F. 1985. Response of *Sitanion hystrix* (Nutt.) J.G. to prescribed burning. American Midland Naturalist. 113: 182-187.