Interior Columbia Basin Ecosystem Management Project Science Integration Team Terrestrial Staff Range Task Group

Scientific Contract Report

Preface

The following report was prepared by University scientists through cooperative agreement, project science staff, or contractors as part of the ongoing efforts of the Interior Columbia Basin Ecosystem Management Project, co-managed by the U.S. Forest Service and the Bureau of Land Management. It was prepared for the express purpose of compiling information, reviewing available literature, researching topics related to ecosystems within the Interior Columbia Basin, or exploring relationships among biophysical and economic/social resources.

This report has been reviewed by agency scientists as part of the ongoing ecosystem project. The report may be cited within the primary products produced by the project or it may have served its purposes by furthering our understanding of complex resource issues within the Basin. This report may become the basis for scientific journal articles or technical reports by the USDA Forest Service or USDI Bureau of Land Management. The attached report has not been through all the steps appropriate to final publishing as either a scientific journal article or a technical report.

IMPACT OF FIRE MANAGEMENT ON RANGELANDS OF THE INTERMOUNTAIN WEST

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INTRODUCTION

Many of the range communities of the Intermountain West are dominated by shrubsteppe species (Vale 1975), represented in part by the following: big sagebrush *(Artemisia tridentata),* rabbitbrush *(Chrysothamnus* spp.), antelope bitterbrush *(Purshia tridentata),* shadscale *(Atriplex* spp.), horsebrush *(Tetradymia* spp.), wheatgrass *(Agropyron spp.),* fescues *(Festuca* spp.), needlegrasses *(Stipa* spp.), ricegrass *(Oryzopsis* spp.), and squirreltail *(Sitanion)* (Humphrey 1974). Within higher elevation sites, juniper *(Juniperus* spp.) and singleleaf pinyon *(Pinus monophylla)* forests and mountain meadows occur. Prior to European settlement, periodic severe fires were common, and the grass, forb, and some shrub species, were well adapted to this disturbance regime (Burkhardt and Tisdale 1976). Most fires were caused by lighting. However, anthropogenic sources were important in some localities (Barrett 1981, Gruell 1985). Over much of this region, fire management practices, have impacted these communities by both direct and indirect means. The historic fire record provides an important understanding of the impacts of fire on successional changes, the vegetation patterns that were observed by the first Euro-American settlers, and a guideline for ecosystem management (Gruell 1985). A synopsis of the changes that have occurred within rangeland communities, and the type of fire management for that vegetation type, is presented in Table 1.

JUNIPER AND PINYON-JUNIPER WOODLANDS

Conifer woodlands within the Columbia and northern Great Basins may be separated into two broad types. The most extensive are those woodlands dominated by western juniper *(Juniperus occidentalis),* which occur in eastern and central Oregon, southwestern Idaho and northern Nevada. No pinyon occurs within this area, but stands may have substantial amounts of curl-leaf mountain mahogany *(Cercocarpus ledifolius)* or ponderosa pine *(Pinus ponderosa).* The upper Snake River Plain and adjacent northern Great Basin of Utah contain woodlands co-dominated by Utah juniper (J. *osteosperma)* and singleleaf pinyon. Understory species in both types are similar to those found in adjacent shrub steppe vegetation. The character of these woodlands may be thought of as having three general types: dense juniper or pinyon-juniper woodland, juniper savanna, juniper encroachment into sagebrush-steppe and dry meadow vegetation. The physiognomic character of a particular site was probably determined by a combination of soil and other environmental factors, successional stage, and fire history. The savanna and encroachment types were particularly dependant upon fire occurrence.

Post-fire successional changes in the pinyon-juniper zone were intricately associated with the effects of competition from grasses and shrubs, and drought (Burkhardt and Tisdale 1976). Generally, succession follows a change from perennial grasses to grass-shrubs, and finally to grass-shrub-trees (Barney and Frischknecht 1974). Climax juniper stands are characterized by a sparse understory, with a patchy distribution of shrubs and herbaceous species (Burkhardt and Tisdale 1969). Within pinyon and/or juniper forests, fires may have occurred every 10 - 30 years (Wright et al. 1979), primarily in the mid-to-late summer (Wright et al. 1979) after the grass and forb species had entered summer dormancy, and required specific moisture, temperature, and wind conditions were present (Burkhardt and Tisdale 1976). In areas where pinyon and juniper occur together, succession is generally dominated by juniper recruitment for the first 30 years, and then by an increase in pinyon recruitment as the forest matures (Tausch et al. 1981, Tausch and West 1988). Pinyon-juniper forests burn more readily as pinyon increases in the community through time, due to juniper being more fire resistant than pinyon (Leopold 1924 in Wright et al. 1979).

Prescribed fires in pinyon-juniper are usually conducted at relatively dry periods of the year which vary regionally. For most of the Columbia Basin the preferred time is late summer and early fall prior to the onset of fall precipitation (Bunting et al. 1987, Bunting 1984). These communities produce only small amounts of grasses and other fine fuels, often less than the 600-700 lbs/ac needed for successful fire spread (Wright et al. 1979). Flammability of juniper foliage is highly correlated to precipitation pattern and is not easily ignited when moist (Bunting et al. 1983). Pinyon and juniper trees less than 4 ft. tall are more readily killed but rapidly become difficult to kill as they grow larger (Jameson 1962, Dwyer and Pieper 1967, Wright et al. 1979). Post-burn succession following spring, summer, or fall controlled burn, depends on the season and type of burn plus the post-burn survival of mature plants and seeds present within the pre-burn community (Everett and Ward 1984). Because these factors vary widely, early seral community composition is highly variable.

Fire affects soil organic matter, nutrients, and organisms (Jorgensen and Hodges 1970, Ahlgren 1974, Raison 1979, Bissett and Parkinson 1980, DeBano 1991, Vasquez 1-993). Within pinyon-juniper communities, overland flow of potassium and phosphorus has been found to increase following debris burning (Buckhouse and Gifford 1976). Soil infiltration and sediment production has also been found to be affected by fire. Following a spring prescribed burn in eastern Nevada, burned coppices had decreased soil infiltration when the soil was at field capacity, and had increased sediment production (Roundy et al. 1978). The water repellency at the soil surface was also increased when most of the litter layer was reduced to ash in associated pinyon-juniper communities. They suggested that the soil morphology was not affected by the cool fire but the surface litter component had been reduced. Perhaps the reduction in litter coverage increased the raindrop impact and splash erosion potential of the site.

Fire suppression has impacted the population dynamics of the pinyon-juniper zone. Increases in pinyon and juniper densities have been noted in many regions of the Intermountain West, as well as encroachment into adjacent shrub-steppe communities (Burkhardt and Tisdale 1969, Blackburn and Tueller 1970, Burkhardt and Tisdale 1976, Tausch et al. 198 1). However, fire has not been the only factor to influence these communities. Tausch et al. (1981) report that increases in pinyon and juniper densities over the last 150 years are related to three factors. Removal of understory vegetation by livestock grazing resulted in greater pinyon and juniper establishment. Tree utilization by the mining industry removed the larger, mature trees, which temporarily reduced the density and may be still evident in some places today. In many areas, the mature stands have been replaced by dense young stands. Fires, which removed young trees, have been suppressed and more dense stands of pinyon and juniper have developed. A fourth factor to account for increased pinyon and juniper densities, is a response to increased atmospheric C02 (Johnson et al. 1990). There is some evidence that this may favor woody species through greater water-use efficiency at the expense of the herbaceous component (Polley et al. 1993, Miller and Wigand 1994). The combined effects of the above factors have produced a more homogeneous landscape dominated by woodland vegetation.

SHRUB-STEPPE

Determination of the historical fire frequency within shrub-steppe communities is difficult due to the almost complete combustion of some shrub species, unreliable annual ring counts, and their shorter life-spans as compared to trees. Approximate fire histories have been postulated, and are typically based on the fire history of the surrounding forest, ash layers in the soil, and the response of species to fire. The latter factor was utilized by Wright et al. (1979) to estimate the fire frequency within most shrub-steppe communities to be approximately 50 years, based on the response of horsebrush to fire. However, the shrubsteppe is comprised of many different communities, and fire frequency in these can be highly variable. Within the prairie-savanna surrounding Devils Tower National Monument in Wyoming, the mean fire interval was estimated to be 14-27 years (Fisher et al. 1987), while in northwestern Wyoming, Loope and Gruell (1973) estimated that fires occurred every 50-100 years. In Montana, Arno and Gruell (1988) estimated that the historic fire interval was probably less than 30 years within a shrub-grassland; in the shrub-steppe of southeastern

Idaho, a fire frequency of 10-15 years was proposed by Burkhardt and Tisdale (1976). Peters and Bunting (1994) estimated the mean fire interval for the more and sagebrush steppe on the Snake River Plain to be greater than 100 years. Many shadscale dominated communities produced so little fine fuel prior to cheatgrass Bromus tectorum) introduction that they rarely burned. Historic fire seasons within the shrub-steppe are represented by the timing of current wildfires, most occurring between July and September (Loope and Gruell 1973, Smolik and Rogers 1976, Young and Evans 1978, Antos et al. 1983, Acker 1992, Blank et al. 1994), with the middle to end of August being the period of most extreme fire conditions (Loope and Gruell 1973).

The early literature substantiates these differences in fire history between the different shrub steppe vegetation types (Gruell 1986, Peters and Bunting 1994). References to the grassland appearance of the vegetation were more frequent at higher elevations where precipitation and annual biomass production were greater (Townsend 1839, Stansbury 1852, Bradley 1873, Hayden 1873, Fremont 1887, Ferris 1940). Mean fire intervals in these areas are often estimated to be less than 50 years. Common fire occurrence would have resulted in a landscape where grass was more dominant. Comments on the abundance of sagebrush were common in the more and portions where fire was, and often still is, more limited in occurrence by low levels of grass and other fine fuels (Astor 1811, Stuart 1813, Fremont 1845, Ludlow 1876, Ferris 1940, Work 1830 in Haines 1971). Infrequent fire occurrence permitted mature extensive stands of sagebrush, shadscale, and other shrubs to dominate the landscape.

Prescribed fire has been found to be a useful management toot for decreasing the amount of sagebrush within much of the Intermountain West, as sagebrush, with the exception of threetip sagebrush (A. tripartita) and silver sagebrush (A. cana), does not resprout following fire (Blaisdell 1953, Neuenschwander 1980, Blaisdell et al. 1982). There has been a great deal of research on the response of shrub-steppe communities to both prescribed and wild fire (Blaisdell 1953, Harniss and Murray 1973, Young and Evans 1978, Bunting et al. 1987, Groves and Steenhof 1988, Yorks et al. 1992). Blaisdell (1953) and Harniss and Murray (1973) examined the effects of prescribed fire on heavily grazed sagebrush-bunchgrass communities in the Upper Snake River Plains of southern Idaho. Fifteen years after the bums, grasses had recovered to pre-burn production levels, forbs were found to have benefited, rabbitbrush and bitterbrush responded positively, while sagebrush levels were still low (Blaisdell 1953). Sagebrush production increased on the unburned areas, which continued to be grazed (Blaisdell 1953). On the unburned areas, densities of sagebrush experienced a 58% increase for the years between 1948 and 1966, while shrub density had an eight-fold increase on burned areas (Harniss and Murray 1973). Grass, shrub, and forb yields continued to increase over the 30 year period (Harniss and Murray 1973). During this same period, shrub and grass cover in unburned areas of southern Idaho were also increasing (Anderson and Holte 198 1) but at low rates.

Population dynamics following wildfires also provide a means of understanding how fire may be used to manage Intermountain rangelands. Young and Evans (1978) examined the population dynamics of species in sagebrush-grasslands within northern Nevada following mid-summer wildfires. Prior to burning, these communities were dominated by big sagebrush and Thurber needlegrass *(Stipa thurberiana)* and contained cheatgrass as an understory species. The year following the burns, cheatgrass density was very low, but by the third year it dominated the site and lessened the dynamics of other species (Young and Evans 1978). The productivity of cheatgrass on burned sites was greater than that on nonburned areas (Young and Evans 1978), a response that has been noted on other annual dominated ranges (Larson and Duncan 1982). No shrub seedlings established in the first year following fire, and after four years, sagebrush had only slight establishment (Young and Evans 1978). In our experience, the environmental conditions the first year following a fire are critical in determining the response of sagebrush and many other species. If conditions occur which are adequate for seedling survival, a cohort may become established and the species rapidly dominate the site. If no seedling establishment occurs from the soil seed bank, then the seeds must be transported in from adjacent stands and secondary succession may take a different pathway. The period until sagebrush dominates is then often extended.

Cheatgrass has been found to increase following fire in other range communities as well. Within shadscale and winterfat *(Ceratoides lanata)* associations, in the Snake River Birds of Prey Area in southwestern Idaho, a wildfire almost completely reduced the shadscale, and cheatgrass represented approximately a quarter of the cover one year following the bum (Groves and Steenhof 1988). The occurrence of highly flammable annual species within the Intermountain West has increased the fire frequency and altered the structure and distribution of native species (Pellant 1990). Fire within the shrub-steppe allows for the increase of annual species which are fire adapted (Brandt and Rickard 1994)

The effect of fire on soils within the shrub-steppe have been investigated by a few researchers. Changes is soil organic matter, nutrients, and moisture have been found to be initially affected by fire, but the impact has not been found to be long-term (Blaisdell 1953, Nimir and Payne 1978, Acker 1992, Blank et al. 1994). Short term effects of spring burning were most noticeable in the top surface layer of the soil (Nimir and Payne 1978, Blank et al. 1994). Following a spring burn in Montana, there were no changes in soil physical properties and little changes in soil chemistry properties (Nimir and Payne 1978). Over a three year period in southeastern Oregon, there were no significant differences in soil organic matter within 0- 10cm of soil between the burned and non-burned sites following a late summer wildfire (Acker 1992). Examination of the effect of late summer wildfires on extractable anions in an sagebrush-grass community in the eastern Sierra Nevada, indicated changes in soil nutrients within the 0-5cm. depth of undershrub soils immediately after the fire (Blank et al. 1994). The degree of changes in the soil depends on the intensity and duration of the bum (Blaisdell 1953, Nimir and Payne 1978, Blank et al. 1994).

There is a paucity of information on the effect of fire on soil micro-organisms. Due to species specific responses, and specific soil conditions at the time of the fire, it is important to refrain from generalization (Ahlgren 1974). Soil microfungi have been found to be related to soil organic matter, and the reduction of this layer by fire (Widden and Parkinson 1975, Lucarotti et al. 1978). Soil organisms are affected by many factors, the most important of which are: depth and intensity of fire, soil temperature, soil moisture, and soil chemistry (Ahlgren 1974).

Soil nematode biomass and density was investigated by Smolik and Rogers (1976). A very hot, mid-August wildfire completely removed the shrub cover on a site in southcentral Washington. The year following the fire, there were no discernible differences in nematode biomass and density between burned and non-burned areas (Smolik and Rogers 1976).

The climates of shrublands, grasslands, and pine forests within the northern Rocky Mountains and adjacent plains are similar, only differing in the length of summer drought (Weaver 1980). Fire has been an integral factor in the structuring of shrub-steppe communities (Loope and Gruell 1973, Humphrey 1974), especially at forest/grassland forest/shrubland ecotones. The efficacy of prescribed fire and the number of fire adapted species within shrub-steppe communities attest to this influence (Burkhardt and Tisdale 1976, Neuenschwander 1980). The removal of fire, or an increase in fire frequency, causes changes in community structure to occur. Much of the information on the effects of fire suppression comes from examination of ecotones between forest and shrub-steppe communities, and from the comparison of historic and current photographs.

Changes in forest/steppe ecotones may be attributed to fire suppression (Steinauer and Bragg 1987), and season of prescribed burning has been found to influence individual species survival rates (Wright and Klemmedson 1965, Bunting et al. 1985) and species composition (Biondini et al. 1989, Howe 1994). The greatest changes in species composition in North America have been documented for the mixed prairie where more diverse mixtures of cool and warm season species occur. The initiation of fire suppression has reduced the fire frequency in the last 90 years, and as a result, lodgepole pine (*P. contorta*), pondersoa pine, Douglas-fir *(Pseudotsuga menziesii),* and juniper have invaded the shrub-steppe, and the densities of sagebrush and other shrubs have increased (Loope and Gruell 1973, Burkhardt and Tisdale 1976, Arno and Gruell 1983, Arno and Gruell 1986). These changes in ecotone vegetation have been observed throughout the Intermountain West. Boundaries at Devils Tower National Monument, Wyoming, have changed such that the area dominated by forest has increased, the savanna has become more dense, and the grassland area has decreased since settlement by eastern immigrants in the early 1900's (Fisher et al. 1987). However, in the desert shrublands of western Utah ecotone boundaries and vegetation types were little changed after 56 years, although canopy cover had increased significantly, primarily for the perennial grasses, but also for the shrub species (sagebrush, rabbitbrush, and spiny hopsage *(Atriplex spinosa)).* (Yorks et al. 1992).

At forest-grassland ecotones in southwestern Montana, fire histories were examined by Amo and Gruell (1983). It was speculated that pre- 1900 grasslands had widely spaced sagebrush, or sagebrush confined to small clusters, and that fires were somewhat frequent thus removing any invading conifers from the shrub-steppe (Arno and Gruell 1983). Fire suppression began in these areas in 19 10, with no fires occurring on the study sites since 1918. Comparison of photographs, and field reconnaissance, showed an increase in sagebrush within the grasslands and conifer replacement of sagebrush at the forest-grassland edges within the last 100 years (Arno and Gruell 1983).

Juniper invasion into sagebrush/grass communities has also occurred in the Intermountain West (Burkhardt and Tisdale 1969, Blackburn and Tueller 1970, Burkhardt and Tisdale 1976). In black sagebrush *(A. nova)* communities in east-central Nevada, juniper was found to invade first, followed over time by singleleaf pinyon (Blackburn and Tueller 1970). Three factors were given for the increase in tree species within the black sagebrush communities: 1) overgrazing, which would reduce the effects of grass competition on tree seedlings; 2) fire suppression, which would remove young trees in the sagebrush/pinyon juniper ecotone; and 3) climatic variation, where non-drought years would favor juniper establishment (Blackburn and Tueller 1970). Others think that grass competition has little effect on juniper establishment. This has been documented for other junipers (Smith et al. 1975). Shrubs such as sagebrush may provide perching areas for birds carrying juniper seeds and safesites for juniper seedlings. As juniper trees become more pervasive with the shrubsteppe, soil development will be altered to reflect the influence of the juniper, which may facilitate further tree establishment (Barth 1980, Doescher et al. 1987).

Within the Owyhee Plateau of southeastern Idaho, juniper invasion into the sagebrush shrub-steppe has been occurring since the late 1800's (Burkhardt and Tisdale 1969, Burkhardt and Tisdale 1976). Sites which were being invaded by juniper, primarily from upslope communities, had an understory dominated by sagebrush-bunchgrass, which was more uniform, and much more floristically diverse (Burkhardt and Tisdale 1969). Active fire suppression, road development which provides a fire break, and increased grazing which removes the fine fuel source, have interacted to alter the historic fire frequency of 10-15 years, which would have eliminated the young, fire intolerant juniper and limited juniper to more fire protected habitats (Burkhardt and Tisdale 1976).

Not all community changes following fire suppression have resulted in a change of site potential. Cawker (1983) studied vegetation change in southern British Columbia using pollen analysis. They suggest that the increase in sagebrush populations is a recovery due to fire suppression within the grasslands. Pollen data indicate that sagebrush species were present in the area since the early Holocene, and that-the grasslands were not shrub free (Cawker 1983). During the early settlement period, shrub levels were low due to frequent fires. Shifts in the boundary between grasslands and shrub/grasslands, or juniper woodlands and shrub-grasslands may also be due to long term climatic changes (Cawker 1983, Mehringer and Wigand 1987).

GRASSLAND

Grasslands within the Intermountain West are limited in distribution. Maintenance of these grasslands are dependent on climate, fire, and soils (Koterba and Habeck 1971). Fire in these communities has been important in removing dry matter build-up and in removing invading shrub and tree species (Koterba and Habeck 1971, Vogl 1974). Without periodic fires, invasion by shrub and tree species is common in the more mesic grassland sites. (Koterba and Habeck 1971). The occurrence, or lack of fire occurrence, has little effect on tree density in the more and canyon grassland vegetation (Tisdale 1979).

Studies in these grasslands following fire are few. For a period of twelve years, Dauberimire (1975) compared vegetation changes in an *Agropyron spicatum/Poa sandbergii* association in southeastern Washington, following a summer wildfire. Although cover of bluebunch wheatgrass was similar for the burned/unburned sites, bluegrass cover was greater on the burned site, while frequency was fairly similar. Cheatgrass cover and frequency was lower on the burned sites after year twelve (Daubenmire 1975). Similarly, a wildfire within a fescue dominated grassland outside of Missoula, Montana caused an initial decrease in grass species and an increase in forb species, but by three years following the burn, grass species had approached control levels (Antos et al. 1983).

The introduction of annual grasses such as cheatgrass has increased the time period when the grasslands are readily flammable. As a consequence, perennial grasslands with large amounts of annual grasses present sustain larger, more frequent and more continuous fires than those without annual grasses. As a result, species such as big sagebrush which cannot tolerate frequent fires are declining in annual dominate ecosystems (Pellant 1990).

MEADOWS

Information on the fire history of montane meadows is sparse, but fire occurrence was most likely less than that of the surrounding forest (DeBenedetti and Parsons 1979). Fire has been suggested as a major factor in meadow maintenance and creation (Kuramoto and Bliss 1970, DeBenedetti and Parsons 1979, 1984, Parsons 198 1). Meadow communities responded positively to fire, by sustaining little damage to existing plants, and rapidly moving towards non-burned community composition and structure (Parsons 19 8 1, DeBenedetti and Parsons 1984). However little research has been done on the ecological impact of prescribed fire in these areas (Ratliff 1985).

A major concern has been the invasion of mountain meadows by conifers (Franklin et al. 197 1, Vale 198 1, Butler 1986, Jakubos and Romme 1993). Conifer establishment in meadows increased in the Cascade Mountains of Oregon and Washington in the 1930's (Franklin et al. 1971, Butler 1986). In these areas, there is little to no evidence of fire, and grazing has not occurred on many of the sites. Vale (1981) suggested that a cooler climate, grazing, and fire suppression were important in conifer establishment in Oregon, but that climate had the least influence. However, changes in weather appear to be the driving force behind conifer invasion into montane meadows, as conifer establishment occurred in many meadows throughout the Cascades (Franklin et al. 197 1, Vale 198 1), in Wyoming (Jakubos and Romme 1993), and in Idaho (Butler 1984) during a warming period between 1920 and 1940, and since the late 1800's in Wyoming (Jakubos and Romme 1993). This warming period resulted in a long growing season which decreased the snow cover in the meadows allowing for seedling establishment (Franklin et al. 1971, Butler 1984, Jakubos and Romme 1993).

ANNUAL GRASSLANDS

In areas where native vegetation has been invaded by exotic species, the successional response of the communities can be drastically altered. Cheatgrass is a winter annual species which is capable of dominating abandoned farms (Piemeisel 195 1), overgrazed ranges (Mack 198 1), as well as occurring within climax communities (Daubenmire 1942). Since its introduction in the late 1800's (Mack 198 1), it has become ubiquitous throughout the Intermountain West, and Dauberimire (1942) considered it a naturalized alien. Another winter annual grass with similar characteristics is medusahead *(Taeniatherum caputmedusae)*, which occupies a smaller range of habitats as compared to cheatgrass (Dahl and Tisdale 1974). Cheatgrass and medusahead produce a small particle-sized fuel source, and can be continuous due to lodging or from a uniform cover (Turner et al. 1963). Medusahead also contains high amounts of silica which slows decomposition (Bovey et al. 196 1), and old stalks will form a dense, highly flammable mat (Turner et al. 1963). These annual grasses are well suited for a short fire cycle, and the fire return interval can be from 3 - 6 years (Peters and Bunting 1994). With this short fire return interval, even resprouting shrubs will be removed from the communities. Also, the establishment of perennial seedlings will be limited due to competition from the annual seedlings (Peters and Bunting 1994), and over time the community will be dominated by annual species. The warmer portions of the sagebrush-grass and juniper woodlands are the most affected by changes in the fire interval as a result of annual grasses. Shrub communities dominated by shadscale, saltbush, or winterfat may also be affected, particularly during above average precipitation years when the additional fine fuels resulting from higher production by the annuals are capable of carrying fire and destroying the fire-intolerant shrubs. Site dominance by the annuals with shorter fire return intervals result.

RIPARIAN

Very little information is available on the fire history of riparian areas within the Intermountain West. From accounts of community composition, the fire frequency in these areas should have been similar to, or slightly greater than, the surrounding communities. Because riparian vegetation has greater fuel loading and more continuous fuel distribution than the surrounding vegetation in and and semi-arid areas. they tend to act as corridors which aid the spread of fire on the landscape. Daubenmire (1942) divided the vegetation within southeastern Washington into 3 major zones: *Artemisia-Agropyron, Agropyron-Poa,* and *Festuca-Agropyron.* The *Artemisia-Agropyron* zone is the driest and occurs closest to the Cascade Mountains, and its riparian areas were dominated by sagebrush and bitterbrush. The riparian areas in the *Agropyron-Poa* zone were -found to be dominated by willows *(Salix),* birch *(Betula),* dogwood *(Cornus),* and currant *(Ribes).* Riparian areas of the *Festuca-Agropyron* zone were dominated by hawthorn *(Crataegus),* birch, alder *(Alnus),* and serviceberry *(Amelanchier).* The composition of the *Artemisia-Agropyron* zone was probably most affected by fire since the dominants are moderately sensitive to fire. The dominants of the other zones resprout readily and consequently recover more rapidly following fire.

SUMMARY

Throughout the Intermountain West, human activity such as fire management, intensive agriculture, introduction of exotic species, and grazing of domestic livestock has directly or indirectly changed the development and dynamics of rangeland vegetation. These activities have resulted in several widespread vegetation changes which can be attributed to alteration of former fire occurrence. In some instances, the human impacts have been exacerbated by climatic fluctuations during the last century (Mehringer and Wigand 1987, Pielou 1991, Miller and Wigand 1994). Changes resulting from decreased fire occurrence include: 1) encroachment of conifers into non-forested vegetation at the forest-steppe ecotones, 2) increased tree density in former savanna-like stands of juniper and ponderosa pine, and 3) increased big sagebrush and other shrub density and/or coverage. Increased fire occurrence resulting from introduction of annual grasses has resulted in lower densities of sagebrush, bitterbrush, bluebunch wheatgrass, Thurber needlegrass, fescues, and many other species with a concurrent increase in exotic annual species dominated communities. The combined effect of both increased or decreased fire occurrence has resulted in greater homogeneity of many landscapes. The influences of human activity on fire occurrence cannot be completely reversed through the use of prescribed fire, which would impart additional changes (Baker 1992). However, the judicious use of fire management planning, which includes both prescribed and natural fire, can be used to address some of these changes.

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Table 1. Fire and fire management outcome for different vegetation types within the Intermountain West and associated areas. Prescribed fires are indicated by Rx in the "Fire?" column.

LOCATION	**HABITAT**	**DOMINANT SPECIES**	**FIRE?**	**MANAGEMENT OUTCOME**	**CITATION**
Sheeprock Mts., UT	Pinyon - Juniper	*Pinus monophylla* *Juniperus osteosperma*	Yes	Succession in pinyon and juniper woodlands followed a general scheme of annuals to perennial grasses (5 years), to grasses and shrubs (3 5 years), to shrubs and juniper (70 years), and juniper - pinyon (+100 years).	Barney and Frischknecht 1974
Needle Range, UT	Pinyon - Juniper	*Pinus monophylla* *Juniperus osteosperma*	Yes	Juniper established at a higher rate following fire than did pinyon. By 60 years post-fire, pinyon establishment was greater than juniper.	Tausch and West 1988
White River Mts., NV	Pinyon - Juniper	*Pinus monophylla* *Juniperus osteosperma*	Yes, RX	Prescribed fire impacted the pinyon- juniper woodlands differently, depending on season of burn, pre-burn community composition.	Everett and Ward 1984
Great Basin, ID, NV, UT	Pinyon - Juniper	*Pinus monophylla* *Juniperus osteosperma*	No	Within pinyon-juniper woodlands, pinyon density was found to be increasing faster than juniper density. It was suggested that livestock grazing, tree utilization, and fire suppression may have interacted to influence the differences in density.	Tausch et al. 1981
Upper Snake River Plains, ID	Sagebrush - grass	*Artemisia tridentata* *Agropyron dasystachyum* Stipa Comata Poa spp. Carex spp.	Yes, Rx	After 15 years, shrub cover was greatly reduced, while on the unburned areas had increased. Grass production was as much as or greater than on unburned areas. Forb production was also increased.	Blaisdell 1953
				30 years following the prescribed burns, sagebrush had regained a dominant position in the communities, but had not reached the unburned level. Grass and forb yield declined as sagebrush increased.	Harniss and Murray 1973

LOCATION	HABITAT	DOMINANT SPECIES	FIRE?	MANAGEMENT OUTCOME	CITATION
Northwest Yellowstone Nat. Park, WY	Sagebrush - grass	*Artemisia tridentata* *Festuca idahoensis*	No	Lodgepole pine invading sagebrush communities . Invasion is thought to be the result of climatic change.	Patten 1963 Patten 1969
Jackson Hole Area, northwestern *WY*	Sagebrush - grass	*Artemisia tridentata* *Artemesia arbuscula* *Purshia tridentata* *Chrysothamnus* spp. Various grass species	No	Due to active fire suppression in the Jackson Hole area since the 1890's, lodgepole pine has invaded sagebrush communities, and sagebrush and other shrubs have increased. It is believed that recurrent fire kept shrub levels lower, and prevented conifer invasion.	Loope and Gruell 1973
Owyhee Mts. ID	Sagebrush - grass	*Artemisia tridentata* *Artemisia arbuscula* *Agropyron spicatum* *Festuca idahoensis*	No	Active fire suppression is believed to have allowed the invasion of juniper into the *Artemisia* dominated communities. Ancillary to fire suppression is grazing by domestic livestock and climatic changes.	Burkhardt and Tisdale 1976
Idaho National Engineering Laboratory, southeastern ID	Sagebrush - grass	*Artemisia tridentata* *Chrysothamnus viscidiflorus* *Leptodactylon pungens* *Gutierrezia sarothrae* *Sitanion nystrix* *Agropyron dasytachyum* *Oryzopsis hymenoides* *Stipa comata*	No	Over a disturbance- free period of 25 years, shrub and grass species increased in cover, but began a decline after 20 years.	Anderson and Holte 1981
Galena Gulch, MT	Sagebrush - grass	*Artemisia tridentata* *Festuca idahoensis* *Festuca scabrella*	No	The historic fire frequency favored the species of the shrub-grassland. With fire suppression, invasion of *Pseudotsuga menziesii* and *Pinus contorta* into the shrub grasslands has occurred.	Arno and Gruell 1986

LOCATION	HABITAT	DOMINANT SPECIES	FIRE?	MANAGEMENT OUTCOME	CITATION
Gallatin Nat. For. MT	Sagebrush - grass	*Artemisia tridentata* *Artemisia cana* *Danthonia unispicata* *Bromus marginatus*	Yes, Rx	A spring prescribed bum resulted in decreases in sagebrush and smooth brome *(Bromus marginatus);* an increase occurred for danthonia *(Danthonia unispicata)*.	Nimir and Payne 1978
Southwestern MT	Sagebrush - grass - forest ecotone	*Artemisia tridentata* *Agropyron spicatum* *Festuca idahoensis*	No	Suppression of fires is believed to be responsible for the encroachment of conifers into the sagebrush grasslands, and also the increase in density of sagebrush in these areas.	Arno and Gruell 1983
East-central NV	Sagebrush - grass	*Artemisia nova*	No	Invasion by pinyon pine and juniper into black sagebrush communities has been occurring since 1869. Overgrazing, fire suppression, and change in climate have been proposed as factors in the invasion process.	Blackburn and Tueller 1970.
Northwestern NV	Sagebrush - grass	*Artemisia tridentata* *Stipa thurberiana* *Bromus tectorum*	Yes	The first year following the wildfires, both perennial and annual species were reduced. By the second year post fire, the areas became dominated by cheatgrass, which prevented seedling establishment of native species.	Young and Evans 1978
Southern British Columbia	Sagebrush - grass	*Artemisia tridentata* *Agropyron spicatum*	No	It is believed that recurrent fire maintained sagebrush at low densities prior to settlement by immigrants. With fire suppression, sagebrush densities have increased.	Cawker 1983
Hanford Nuclear Res., WA	Bitterbrush - cheatgrass	*Purshia tridentata* *Bromus tectorum*	Yes	The first year following wildfire, cheatgrass production was very low. By the fifth year post-fire, production was similar on burned and unburned sites. Bitterbrush was removed from the site, and there was no evidence of re establishment.	Rickard and Sauer 1982

LOCATION	HABITAT	DOMINANT SPECIES	FIRE?	MANAGEMENT OUTCOME	CITATION
Devils Tower Nat. Monument, WY	Savanna-prairie	Shrub and grass species	No	The fire history of this area indicates an historical fire return period (FRP) of 14 years. Currently, the area has a much longer FRP, which has resulted in the invasion of the savanna and prairie communities by ponderosa pine.	Fisher et al. 1987
Glacier Nat. Park, MT	Grassland	*Agropyron spicatum* *Festuca idahoensis* *Festuca scabrella* *Danthonia intermedia*	No	These grasslands are thought to have developed and be maintained through the interactions of climate, soils, and fire. Fire suppression in the park, since 1910, has resulted in the invasion of lodgepole pine into the grasslands.	Koterba and Habeck 1971
Southeastern WA	Grassland	*Agropyron spicatum* *Poa secunda*	Yes	Fire resulted in a change in balance between the two dominant grass species, with *Poa* becoming the dominant. Preburn levels were attained after 12 years.	Daubenmire 1975
		Chrysothamnus nauseosus *Bromus tectorum*		Cheatgrass levels attained preburn level by the second year. Rabbitbrush was completely eliminated, in part due to heavy insect herbivory prior to the fire.	
Mt. Sentinel, *MT*	Grassland	*Festuca scabrella* *Festuca idahoensis* *Agropyron spicatum*	Yes	Active fire suppression allowed the encroachment of ponderosa pine and Douglas fir into the more mesic areas *of* the grassland. Three years following a wildfire, cover of most species was similar in both burned and unburned areas, fescue was slightly lower on burned areas.	Antos et al. 1983

LOCATION	HABITAT	DOMINANT SPECIES	FIRE?	MANAGEMENT OUTCOME	CITATION
Cascades of OR and WA	Subalpine meadow	*Phyllodoce empetriformis* *Vaccinium deliciosum*	No	High conifer invasion	Franklin et al. 1971
		Valeriana sitchensis		Low conifer invasion	
		Festuca viridula		Low conifer invasion	
		Polentilla flabellifolia		High conifer invasion	
				Change in climate, resulting in a longer snow-free period, is suggested as the driving force of the invasions.	
Calispell Peak, northeast WA	Subalpine meadow	*Artemisia tridentata* *Agropyron spicatum* *Abies lasiocarpa*	No	Trees occur in swales with deeper soils and low stone content Sagebrush/grass occurs on mounds with deeper soils and low stone content Grasses occur in intermound areas with shallow , stoney soils.	Roche and Busacca 1987
Cascades, central and southern OR	Montane meadow	*Rubus parviflorus / Pteridum aquilinum* *Bromus carinatus / Rudbeckia occidentalis*	No	Invasion of meadows by various conifer species depending on the surrounding forest. Fires were believed to be the dominant force in maintaining. the meadows	Vale 1981
Southern. Sierra Nevada, CA	Subalpine meadow	*Carex scopulorum* *Carex rostrata* *Deschampsia caespitosa*	Yes	First year post-fire, area dominated by forbs, some lodgepole pine invading the meadow were killed; after 4years, returning towards pre-fire community, tree encroachment slowed.	DeBenedetti and Parsons 1979 Parsons 1981 DeBenedetti and Parsons 1984

LOCATION	HABITAT	DOMINANT SPECIES	FIRE?	MANAGEMENT OUTCOME	CITATION
Lemhi Mts., ID	Subalpine meadows	*Festuca ovina* *Festuca idahoensis* *Poa secunda* *Artemisia* spp.	No	Most conifer invasion occurred between 1895-1915 and again between 1920-1940. Several factors are suggested as driving the invasions: climate change, fire history, and grazing pressures.	Butler 1986
Yellowstone Nat. Park, WY	Subalpine meadows: dry and mesic	Dry: *Artemisia tridentata* *Artemisia cana* *Carex spp.* *Muhlenbergia spp.* *Achillea millefolium* Mesic: *Carex spp.* *Antennaria carymbosa* *Potentilla gracilis* *Deschampsia caespitosa* *Phleum alpinum*	No	Conifer encroachment is suggested to be due to climatic variability in the dry meadows, and due to episodic seed production and microhabitat changes in mesic meadows.	Jakubos and Romme 1993

Review of " IMPACT OF FIRE MANAGEMENT ON RANGELANDS OF THE INTERMOUNTAIN WEST by S.C. Bunting and E. F. Peters
Order Number 40-OEOO-5-5190

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General Comments

The report reads well, but seems somewhat unbalanced in its treatment of different types, and does a poor job of including description of innate variations in fire treatments that may be critical in determining observed effects. For instance, it is commonly agreed that season of burn is highly influential in determining mortality of many intermountain range species, as well as post-fire dynamics. However, since season of burn directly impacts both plant phenology and fire behavior (due to fuel moisture content) these variables are confounded. Although I am in entire agreement with the general conclusions drawn in the report's summary, there is a great deal of variability that is to be expected within these overall expected trends. Thus, when determining site specific management actions, it behooves the manager to develop an understanding of all the site-related factors that might impinge on actual treatment outcomes. It is therefore highly desirable to include reference material for all fire related studies in all intermountain range types to give the manager a good understanding of what has been demonstrated, and what remains speculation. For instance, the report gives scant information in regard to fire effects on bitterbrush, which from a wildlife standpoint is of critical concern. The literature contains a number of references regarding this species capacity to resprout, yet the report fails to mention them (see Britton and Clark 1985, and Olson et al 1982). Similarly, direct effects of fire on woody species are incontrovertibly dictated by (at least partially) fire behavior, and very little mention of variation in this feature of fire is given.

In the very least, I believe that this report would serve its purpose to a greater extent by including those referenced studies in its compendium appendix. I further believe that the table would be of greater use if it were more detailed both in regard description of site characteristics, and observed affects. For instance, direct effects on stand structure are outlined, but nowhere in the text are key mechanisms of plant persistence described. I have documented (as have others, e.g., Patton et al 1988) fire induced flowering and seedling establishment of perennial bunchgrasses in the immediate years following wildfire. In conjunction with overstory removal of woody species, this has managerial importance for those trying to restore perennial grass abundance. Similarly, these mechanisms are given short attention, and possibly require further elaboration. but at least the manager is aware of this mechanism and can take measure of it.

In summary, I feel that the report is a good beginning for understanding the manner in which fire has and can in the future effect intermountain rangelands. Other than minor editorial comments on syntax, and the like, its main shortcoming is in its relatively broad approach to a highly variable and somewhat unpredictable subject. The included references will begin to fill in these gaps, as will continuing research in fire on western rangelands.

Review of. "Impact of Fire Management..." by Bunting and Peters

Specific Comments, Additions, and Recommendations

The following is a line-by-line critique of the report. Please refer to the enclosed line-numbered draft of the report for cross-reference to these comments.

Page 1

Line 11: Omit "within higher elevation sites as western juniper" (JUOC) and singleleaf pinyon (PIMO) as well as additional woody species such as curly-leaf mountainmohogany (CELE) and ponderosa pine (PIPO) all occur as components in the intermountain west ecosystems. That is, there should be some mention of additional woody species present (although not frequently or widely abundant components associated with intermountain shrub steppe. Particularly in regard to long-term successional impacts of past, present and future succession in the ecosystems, longlived woody species capable of increasing in abundance and altering system attributes and function, deserve special attention. Further, with the possible exception of PIMO, all can be present at the lower ranges of elevation found in the intermountain region (i.e., approx. 700 m). I suggest beginning the sentence with: Other important woody species include... and have a new sentence to discuss mountain meadows and their relationship to elevation, soil geomorphology etc.

Line 13: "severe" needs defining, as in stand replacing, or initiating high rates or mortality or topkill. Follow up with a sentence relating variation in fire characteristics with direct fire effects and subsequent secondary succession.

Line 14: in reference include summary paper by Wright et al. 1979, which addresses effects on all components of these systems.

Line 15: 1 believe that this is presumptive, if not it needs a reference. To my knowledge, most of the shrub steppe is incapable of giving significant evidence of actual fire history, let alone source of ignition, for the pre-settlement period. Away around this dilemma, and in turn diluting the dogmatic tone of the sentence would be to say based on current lightning frequency it could be surmised that most..."

Line 16: Include ref. Shinn, 1977.

Line 18: after "historic fire record" include " including both wild and prescribed fire events", reveals...

Line 21: I do not understand what is meant by "type of fire management for that type". I believe what is meant is what type of fire that was used in that reference, i.e., column 4 in the table.

Review of: "Impact of Fire Management..." by Bunting and Peters

Page 2
Line 11: Apparently the authors mean instead of a comma following savanna either parenthesis or dashes surrounding their description of savanna as juniper encroachment.

Line 13: replace was with "is largely". Lots of shifting tense throughout. I believe that since this is a discussion about current status, present tense is most appropriate.

Line 17: include "fire behavior" or "fire characteristics" after associated...

Line 19: Include ref: Martin and Johnson 1979.

Line 23: Last word " and) should be "when".

Page 3
Line 6: Replace "more fire resistant" with "less conducive to fire spread" i.e., mistaking issues relating to fire effects with those pertaining to flammability and fire spread.

Line 15: Include refs Martin and Johnson 1979 and Sapsis 1990.

Also include new sentence: however, mortality of large juniper have be reported when prescribe burned under extreme fire weather and from wildfires (Martin and Johnson 1979).

Line 16: After season of burn, include "fire behavior".

Line 18: Incl. ref : Humphrey 1984.

Page 4
Line 6: I suggest another word besides "cool". I believe what is meant is "low consumption".

Line 12: Include Olson et al 1982, Martin and Johnson 1979, Humphrey 1984.

Line 20: An additional impact of livestock grazing has been the dramatic reduction in fine fuels necessary for successful fire spread (Wright 1974).

Page 5
Line 1: Insert: There has also been speculation that changes in regional climate have influenced the areas that can potentially be established by these species, due to changing elevation levels of freezing (Lee Edelman, pers. comm.).

Line 9: Citation should be Harniss and Murray 1973, not Wright et al . 1979.

Line 16: Insert: Similarly, Houston (1973) estimated point fire frequencies between 39 and 70 years, with associated composite fire frequencies (i.e., area-based fire occurrence) at approximately 20-25 years.

Line 20: Insert: In contrast, fire frequency in pine/shrub/grass associations at lava Beds National Park revealed average intervals of 8-21 years (Olson and Martin 1982).

Page 6

Line 3: Previous sentence reflects only wildfire occurrence. Deliberate fires by Native Americans, as well as modern prescribed fires, can be conducted over a wider range of months, likely extending back to late Spring (May-June) (Sapsis 1991).

Line 21: and many other refs not cited (e.g., Wright and Klemmedson 1965, Kuntz 1982, Champlin 1983)

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Detailed discussion of Young and Evans work is OK, but many other studies exist, both in regard to understory composition changes (e.g. Wright and Klemmendson 1965) as well as woody plant dynamics. For a comprehensive review up the 1970's see Wright et al 1979. More recent work was reviewed by Sapsis (1990 and in preparation).

Line 20: In contrast, areas with significant intact stands of perennial grasses and only moderate cheatgrass composition, both spring and fall prescribed fire has been found to cause increases in bunchgrass cover concomitant with decreases in cheatgrass abundance (Sapsis 1990).

Line23: In contrast, Sapsis (1990) found sagebrush reproduction the first year following a fall prescribed fire in eastern Oregon.

Page 8

Line 4: The mechanism by which propagules enter the post-fire environment obviously has implications in regard to burn size, shape, and surrounding physiognomy (Mueggler 1956).

Line 22: May want to contact Boone Kauffman re: ongoing work on N mineralization work conducted in eastern Oregon sagebrush steppe following Rx fires (late summer as I remember).

This is work done by Ken Till at John Day Fossil Beds N.M. so you may also want to contact him directly. It is my understanding that the thesis is in the final stages of preparation

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Line 4: Although I am aware of no direct experimentation, it is clear that successional changes associated with woody plant development, such as increasing dominance of western juniper, have significant impact on soil moisture availability, and may be the dominant mechanisms of competitive displacement of understory grasses and forbs witnessed for long fire free intervals.

Line 12: 1 caution against the word "hot" unless temperature was measured. Measures of fireline intensity, flame length, fuel consumption, residence time, heat per-unit area and the like are all much better descriptors of fire behavior. Heat flux into the soil has been studied extensively, but not in these range types (see Bentley and Fenner 1958) 1 would replace hot with severe, as is evident from the effects on shrub cover stated in the latter part of the sentence.

Page 10
Line 5: add Sapsis (1990) and Sapsis and Kauffman (in prep)

Line 20: add Successional trajectories have also been hypothesized to be a result of plant attributes ala Noble and Slatyer, where time since fire in conjunction with pre-fire composition, and subsequent mechanisms of survival and regeneration, and establishment act to drive the systems post-fire composition and structure (Humphrey, 1984)..

Page 11
Line 5: Similar changes have been photographically recorded in eastern Oregon (J.B. Kauffman, pers. comm.).

Line 14: add 4) and the effect of grazing on limiting fuel structure so as to preclude successful fire spread under otherwise non-limiting conditions (Sapsis 1990 and Sapsis and Kauffman 1991).

Line 5: add In Northeast California, Martin (1978) found wide variation in juniper survival after prescribed burning, with tree size and fire weather and behavior being the most clearly defined parameters driving mortality. Backfires conducted under moderate temperatures resulted in mortality of only the smallest tress (<4 ft.), while headfires under slightly hotter and drier conditions were capable of killing trees up to 8 ft., and a headfire under very hot and dry conditions 80 degrees F, 10% relative humidity) killed all trees under 15 ft. with survival of larger classes averaging 37% (Martin 1978). Sapsis (1990) found similar relationships between burning conditions/fire behavior and woody plant mortality. Spring burning resulted in moderate flame lengths averaging 1.7 meters, which resulted in 83% mortality of basin big sagebrush and 88% of all juniper under 8 feet tall. In contrast, a higher intensity fall prescribed fire (mean flame length 4.1 m) killed all sagebrush and juniper under 8 feet tall, with mortality of larger sized juniper averaging 45%.

Page 12
Line 17: Makes no sense to me. What other types are not limited? Is the message that they occupy very little land area? And by grasslands, do we mean pure stands of only grass? A better general reference to a review of grassland structure and function, with particular note to fire effects and successional implications is Daubenmire 1968.

Line 23: I challenge the data (if any) on which this was based, but have read the publication.

Review of: "Impact of Fire Management..." by Bunting and Peters

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Line 9: add In eastern Oregon, mean basal area of bluebunch wheatgrass increased by 40% compared to both pre-burn and control (unburned) plants following prescribed burning in September (Sapsis 1990 and Sapsis and Kauffman in prep) This same treatment resulted in increases in Idaho fescue to 30% greater than pre-treatment levels and 60% greater than control plants, which declined steadily over the three years. Spring burning at the same site resulted in moderate reductions in bluebunch wheatgrass mean plant size, while stimulating significant increases for Idaho fescue.

May also want to talk about grass mortality studies (Wright and KIemmedson 1965, Conrad and Poulton 1966, Wright 1971, Uresk et at 1980, Sapsis 1990, etc.).

Line 18: the referenced study is from the southern Sierra Nevada in California, and represents a significantly different climate than much of the higher elevation areas of the intermountain region where meadows are likely to be found (particularly in regard to lightning activity and summer precipitation patterns).

Line 22: Does not read clearly; i.e., what is meant by non-burned. More descriptive discussion in regard to successional influence is needed such as effects on invading conifers, water table maintenance, etc.

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Line 8: icl. Pachanek and Hull 1945 reference. Although fire related reductions in viable plants may be in excess of 98%, sufficient numbers of propagules survive to assure continued persistence where present, giving the impression that direct control of cheatgrass is not likely (Sapsis 1990).

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Line 12: add Thus, the best means of predicting successional change in riparian communities is to superimpose likely fire. frequency and behavior estimates with current understanding of autecological response based on species present.

Line 19: replace "former fire occurrence" with pre-settlement fire regime.

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(note to editor: Appendix references Patten 1963 and 1969 do not appear in the Literature Cited.).