FIRE ECOLOGY OF ANTELOPE BITTERBRUSH IN THE NORTHERN ROCKY MOUNTAINS

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ABSTRACT: Frequency of resprouting and number of newly established seedlings of antelope bitterbrush were sampled on sites burned by prescribed burns and wildfires 3 to 10 years previously to determine the effect of habitat type, growth form, and season of the burn on bitterbrush. Significant differences in resprouting response occurred among the growth forms, season of burning, and habitat type. Seedling establishment was also markedly influenced by growth form, season of burning, and habitat type. Results of this study document the short-term effects of fire on bitterbrush populations in the Northern Rocky Mountains.

INTRODUCTION

Antelope bitterbrush (*Purshia tridentata*) is widely distributed on vast areas of western North America. It is a major component in the diet of big game animals in many areas (Guinta and others 1973; Kufeld and others 1978) and may be used seasonally by domestic livestock (Cook 1954; Julander 1955). Because bitterbrush is important as a forage species, it is a major consideration when planning management practices on range vegetation.

Reviews of bitterbrush literature have been written by Basile (1967) and Clark and Britton (1979). Literature regarding the effects of fire has also been summarized in recent publications (Martin and Driver 1983; Rice 1983); however, the reported response of bitterbrush to fire varies considerably. Hormay (1943) and Billings (1952) stated that bitterbrush sprouted rarely and was nearly eradicated by fire in California and the Great Basin. Others have reported low sprouting potential for the species (Nord 1965; Daubenmire 1970; Sherman and Chilcote 1972). In eastern Idaho, the resprouting ability has varied from moderate (Blaisdell 1953) to high (Pechanec and others 1965).

The variation in resprouting is due to a number of factors. The growth form of bitterbrush ranges from low decumbent individuals to upright columnar forms (Nord 1965) and has been reported to be related to resprouting potential. Decumbent forms have been reported to resprout more readily than the columnar forms (Wright and others 1978; Clark and others 1982). The season of the fire may also affect the ability of plants to resprout. Most research indicates that sprouting is greatest on spring fires and least on summer burns. Sprouting response of bitterbrush burned in the fall is intermediate (Blaisdell and Mueggler 1956; Clark and others 1982; Murray 1983). The effect of season of burning may be confounded with several other factors. Soil moisture is often highest in the spring and lowest in the summer. Clark and others (1982), however, could not show a significant effect of soil moisture by artificially watering bitterbrush plants before burning. The carbohydrate recharge pattern may also be a factor. Carbohydrate levels are lowest in midsummer after seed set and do not recover until late summer (Menke and Trlica 1981). Late summer corresponds to the time when bitterbrush is most susceptible to fire.

Fire severity varies seasonally and may affect resprouting ability. In most regions, low-severity fires often occur during late winter and spring. Highest severity fires would likely occur during the summer period. Studies have shown an inverse relationship between resprouting and fire severity (Blaisdell 1950, 1953; Blaisdell and Mueggler 1956; Murray 1983). Driscoll (1963), however, found little correlation with fire severity and indicated that the soil surface texture was a more important factor in central Oregon.

Murray (1983) concluded that bitterbrush annual production on burned sagebrush grass ranges in eastern Idaho was less than on unburned areas after 30 years; however, bitterbrush studies in forested communities have found increased production after fire even though plant density may decrease (Edgerton and others 1975; Stuth and Winward 1976).

Seedlings are the primary mechanism involved in the development of a new stand of bitterbrush following fire (Daubenmire and Daubenmire 1968; West 1968), and seedling establishment has been as variable following fire as resprouting. Blaisdell (1950) reported that seedling establishment varied inversely with fire intensity (severity). Sherman and Chilcote (1972) stated that rodent caches were important sources of seed reproduction and that rodents preferred to cache seeds in areas where the duff and litter were removed. Driver and others (1980) reported better reproduction from seed in

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forested areas with the most severe fires. Some of this variation may depend on the microclimatic conditions of the site. In the more xeric sagebrush-grassland sites, adequate microsites for seedlings may be present following a low-severity fire. The remaining vegetation may be important to modify the microclimate; however, in more mesic forested sites, a more severe fire may open up the dense vegetation and provide suitable microsites for seedling establishment. Dealy (1970) and Hubbard (1956) found the release from competition by other plants a major factor in the establishment of bitterbrush seedlings. Ferguson and Medin (1983) found few bitterbrush seedlings on an area protected from livestock grazing and fire.

Production of bitterbrush seed varies annually, and good seed crops occur infrequently (Giunta and others 1978). Rodents are important in the dissemination and planting of seeds, and a high proportion of seedlings results from germination of seeds in unutilized rodent caches (Hormay 1943; Nord 1965; West 1968; Sherman and Chilcote 1972). Rodents transport seeds up to 1,000 ft (305 m) (Nord 1965) and are important in the movement of the relatively large bitterbrush seed away from parent plants. Rodents, however, may also reduce bitterbrush reproduction by consuming large quantities of the annual seed crop and by eating developing seedlings (Hubbard and McKeever 1961).

METHODS

This study was conducted in the Northern Rocky Mountains, primarily in Idaho and Montana. Within this region 56 prescribed burn and wildfire sites were located (fig. 1). These represent variation that occurs in habitat type, season of fire, growth form, and fire severity. Only burned sites between 3 and 10 years old were sampled. A minimum of 3 years was chosen because many plants that initially resprout following a fire die in succeeding years (Clark and others 1982). We believe that those individuals that lived for 3 years had a high probability of survival. The upper limit was chosen because our experience has shown that after 10 years the skeletons of the burned bitterbrush plants begin to decompose, thus making it difficult to establish the prefire density. Also, after 10 years, the sprouts become reproductively mature and begin to contribute to the seed source on the burn. Consequently, it would become increasingly difficult to determine the immediate postfire density of seedlings.

On each burn, one sample site was randomly selected from those where the prefire density of mature bitterbrush was estimated to exceed 200/acre (500/ha). Five 6.56- by 164-ft (2- by 50-m) belt transects were located by using a random numbers table. The density of dead, resprouting, and unburned plants on site at the time of the fire was recorded. Seedling density was also recorded for each transect. Additional data collected included habitat type, bitterbrush growth form, season of fire, elevation, slope, aspect, soil texture, and parent material. Where prefire density was less than 200 bitterbrush per acre, a plotless method

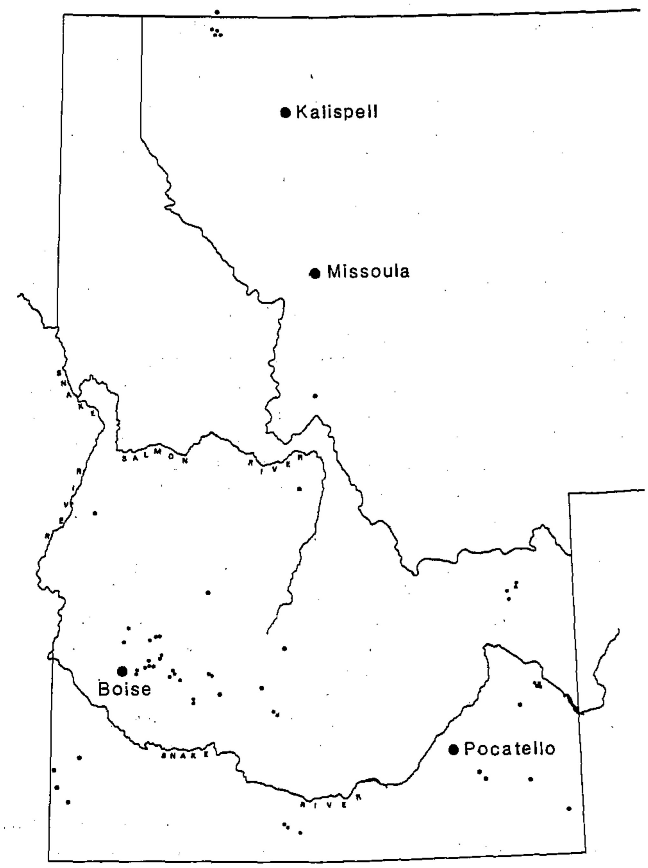

Figure 1.--Location of areas burned by prescribed burns or wildfires in the Northern Rocky Mountains which were sampled for bitterbrush resprouting frequency and establishment of seedlings.

was used to determine resprouting potential. Four random groups of 25 plants were located. Individuals were identified as dead or alive. Resprouting was estimated from this sample regardless of how much area was required to locate the 25 plants. An estimate of seedling density was not made on these sample sites.

The classification of habitat types follows Pfister and others (1977), Mueggler and Stewart (1980), Steele and others (1981), and Hironaka and others (1983), depending on the vegetation and area. A habitat type classification system for Utah juniper (*Juniperus osteosperma*) and western juniper (*J. occidentalis*) has not been developed for this region. These sample sites were classified only by the species of juniper present.

The other exception concerns a type of vegetation that has not been separately described. This vegetation has been included within the *Artemisia tridentata* ssp. *vaseyana-Symphoricarpos oreophilus/ Festuca idahoensis* habitat type by Hironaka and others (1983) and will be referred to as "mountain shrub" in this paper. It is slightly more mesic than the typical *A. tridentata* ssp. *vaseyana-S. oreophilus/F. idahoensis* vegetation. It is characterized by the presence of one or more of the following shrubs: Saskatoon serviceberry (*Amelanchier alnifolia*), snowbrush ceanothus (*Ceanothus velutinus*), bitter cherry (*Prunus emarginata*), quaking aspen (*Populus tremuloides*), and squaw currant (*Ribes cereum*). Our experience indicated that this vegetation responds differently to fire than that included in the drier end of the habitat type as described by Hironaka and others (1983); it was, therefore, separated.

Bitterbrush does not occur as distinctly different growth forms over the entire region. Variation within the species is continuous between populations which are decumbent and multiple stemmed to those which are upright (columnar) and single stemmed. The latter may exceed 9.6 ft (3 m) in height. Growth form variation was separated into three classes. The decumbent form included those low-growing multiple-stemmed individuals (less than 3.28 ft (1 m) tall) which commonly reproduce by layering. Subcolumnar individuals included those which did not layer, were usually between 2.5 and 4.9 ft (75 to 150 cm) tall, and multiple stemmed. The columnar form included plants that were usually greater than 3.28 ft (1 m) tall, did not layer, and had few to a single main stem. Mature, unburned plants in the general vicinity were used to make this distinction. When more than one form occurred on a site, the dominant form was recorded.

The season and year of the fire were obtained from land management agency records. Fires were located that had occurred in various seasons and habitat types in order to balance the design of the study as much as possible.

One-way analysis of variance (ANOVA) and Duncan's Multiple Range Test were used to test the data for significant differences. More complex ANOVA could not be used due to the unbalanced nature of the data.

RESULTS AND DISCUSSION

Habitat type-form-season of fire combination was found impossible to completely balance. The three forms of bitterbrush do not occur within every habitat type sampled. In general, there is an elevation-moisture gradient associated with form. The decumbent form is found at the higher elevations and on more mesic sites. The columnar form occurs primarily at the lower elevations and on more xeric sites. The subcolumnar form was intermediate in regard to both variables. In some instances pure stands of two different forms may be found close to each other, depending upon the site. Thus, large differences in elevations were not always necessary to cause a change in form.

In addition, different habitat types were not likely to be burned in all seasons due to differences in fuel conditions. The decumbent form occurs in communities that are not frequently burned by wildfires. Prescribed fire, however, is more likely to be utilized in these communities at the present time. With the columnar form, the reverse is true. They are likely to be burned by wildfire and only rarely burned with prescribed fires. Prescribed fires were usually ignited in the spring and fall, and wildfires occurred primarily in the summer and fall.

The habitat types were grouped into five major categories of conifer, mountain shrub, mountain big sagebrush, basin big sagebrush, and juniper (table 1). Bitterbrush responded similarly to fire in habitat types or communities within each group.

Resprouting

The decumbent form of bitterbrush resprouted more frequently than the other two forms (table 2), whereas the subcolumnar form resprouted on the average two times as frequently as the columnar form. The difference, however, was not significant. Columnar and subcolumnar forms resprout from a mass of dormant buds at ground level or from a callus of meristematic tissue above the ground level as described by Blaisdell and Mueggler (1956). The decumbent forms resprout from the central bud mass and from bud masses that form at the points where the branches layer. It was observed that when fire killed the above-ground connecting branches, the separate resprouting bud masses may no longer be interconnected. These individual bud masses may be over 3.28 ft (1 m) from the parent bud mass.

Resprouting frequencies of bitterbrush on sites burned in the spring- and fall-burned sites averaged 55 and 42 percent, respectively, but were not significantly different (table 3). Resprouting was less frequent on the summer-burned sites and averaged 21 percent. Summer fire may be more destructive to bitterbrush because burns occur during a period of lowest carbohydrate reserves (Menke and Trlica 1981), and summer is also when the most severe fires occur.

The highest resprouting potential of the five habitat groups was found to be in the mountain shrub and the conifer groups, with 60 and 49 percent of the plants surviving, respectively (table 4). The bitterbrush populations in these groups are composed primarily of decumbent plants. The mountain big sagebrush group is also dominated by the decumbent form, but resprouting was significantly lower than in the first two habitat groups. The habitat types in this group are slightly more xeric than those in the mountain shrub or conifer groups. Basin big sagebrush and juniper habitat groups had the lowest resprouting potential. These groups were dominated by columnar and subcolumnar forms of bitterbrush.

Seedling Establishment

Seedling establishment rates appeared to be most affected by moisture gradient (tables 2, 3, and 4). Postfire seedling densities were greater on the more mesic habitat types such as the conifer group. Seedling density was greatest on areas burned in

Table 1.--List of habitat types and other communities included within the analysis groups used in this study

Community or habitat type group	Habitat types and communities included within group	Reference
Conifer	*Pseudotsuga menziesii/ Symphoricarpos albus* ht	Pfister and others 1977
	Pseudotsuga menziesii/ Symphoricarpos oreophilus ht	Pfister and others 1977 Steele and others 1981
	Pinus ponderosa/Purshia tridentata ht	Pfister and others 1977 Steele and others 1981
Mountain shrub	*Artemisia tridentata* ssp. *vaseyana-Symphoricarpos oreophilus/Festuca idahoensis* (mesic phase) ht	Adapted from Hironaka and others 1983
Mountain big sagebrush	*Artemisia tridentata* ssp. *vaseyana-Symphoricarpos oreophilus/Festuca idahoensis* (dry phase) ht	Hironaka and others 1983
	Artemsia tridentata ssp. *vaseyana/Festuca idahoensis* ht	Hironaka and others 1983 Mueggler and Stewart 1980
Basin big sagebrush	*Artemisia tridentata* ssp. *vaseyana f. "xericensis"*[1] *Agropyron spicatum* ht	Hironaka and others 1983
	Artemisia tridentata ssp. *tridentata/Agropyron spicatum*	Hironaka and others 1983 Mueggler and Stewart 1980
Juniper	Includes all communities in which *Purshia tridentata* occurs with *Juniperus osteosperma* or *J. occidentalis*. At this date these habitat types have not been described for the region sampled.	

[1] Currently this taxon of *Artemisia* has not been officially established by taxonomists, but has been referred to by Winward and Tisdale (1977).

late winter or spring and least on areas burned in the summer (table 3). The rate of seedling establishment closely corresponds to resprouting potential. In general, the greater the ability to resprout, the greater the likelihood of seedling establishment. A notable exception is the conifer group. Although its average resprouting potential was slightly less than that of the mountain shrub, average seedling density was two times greater for the conifer group (table 4).

The lowest seedling density was found in the juniper group (table 4). We do not know why the rate is so low. Both the juniper and basin big sagebrush groups are usually dominated by the columnar form. Cheatgrass (*Bromus tectorum*), which competes with bitterbrush seedlings for soil moisture, was usually less prevalent within the juniper vegetation than in basin big sagebrush. Slow regeneration of bitterbrush on juniper sites probably involves more than plant competition. Precipitation in the

Table 2.--Percentage bitterbrush resprouting and seedling density 3 to 10 years after fire as affected by bitterbrush growth form in the Northern Rocky Mountains.

Growth form	Resprouting		Seedling density	
	Mean[1]	n[2]	Mean[1]	n[2]
	Percent		No./acre (No./ha)	
Decumbent	57a	28	189 (467)a	26
Subcolumnar	18b	12	87 (209)a	11
Columnar	7b	16	29 (71)a	9

[1]Values within a column followed by the same letter are not significantly different ($P \leq 0.05$) as determined by Duncan's Multiple Range Test.

[2]n is the sample size and varies within a growth form between resprouting and seedling density because density could not be sampled on all sites.

Table 3.--Percentage bitterbrush resprouting and seedling density 3 to 10 years after fire as affected by season of the fire

Fire season	Resprouting Mean[1]	n[2]	Seedling density Mean[1]	n[2]
	Percent		No./acre (No./ha)	
Late winter-spring	55a	10	266 (658)a	9
Fall	42a	19	136 (335)ab	16
Summer	21b	27	73 (181)b	21

[1]Values within a column followed by the same letter are not significantly different ($P \leq 0.05$) as determined by Duncan's Multiple Range Test.

[2] n is the sample size and varies within a season between resprouting and seedling density because density could not be sampled on all sites.

juniper types at least equals that of the basin big sagebrush group, so this probably is not a factor. Precipitation is low, however, in both types. The prefire density of bitterbrush was also approximately equal. It has been observed that seed production by bitterbrush on sites occupied by juniper is reduced as the juniper begins to dominate the site. This reduction would deplete seed reserves in the soil. This phenomenon has not been observed on sites occupied by sagebrush (Monsen 1984). Ferguson (1972) found soil moisture and surface temperature to be important in seedling establishment. In general, the juniper sites were more productive, cooler in summer, and not subject to as variable temperatures during the winter as the basin big sagebrush sites. It may be that large rodent populations remove seeds and girdle seedlings. The relationship of prefire and postfire rodent populations between the two groups is not known. Other research has shown that rodents have a significant impact on bitterbrush establishment from seed (Hubbard and McKeever 1961). On one burned site in this study, 25 seedlings were permanently marked with stakes. Close inspection of the burned area during the third year revealed that no seedlings had survived even through they were numerous the first 2 years after the fire. Browsing by rodents or rabbits was determined to have been the cause. This indicates the impact that rodents may have on bitterbrush regeneration.

Soil stability may be a factor in seedling establishment. Grazing by livestock after fire on unstable granitic soils near Horseshoe Bend, Idaho, had displaced substantial amounts of soil on the 56 percent slopes. The density of seedlings on this site was 145 per acre (360 per ha), which was the greatest of the sites dominated by the columnar form. The majority of seedlings were single plants, which indicated that they were not from rodent seed caches. This suggests that seed burial was a factor in seedling establishment.

Fall is believed to be the best time for prescribed burning if seedling establishment is a major consideration (Monsen and Christensen 1975). Fall burns occur after the current year's seed has fallen from the plants and the seed availability is maximized. This study, however, found two times as

Table 4.--Percent bitterbrush resprouting and seedling density 3 to 10 years after fire as affected by major habitat type groups or communities in the Northern Rocky Mountains

Community or habitat type group	Resprouting		Seedling density	
	Mean[1]	n[2]	Mean[1]	n[2]
	Percent		No./acre (No./ha)	
Mountain shrub	60a	12	107 (264)ab	11
Conifer	49a	15	260 (643)a	14
Mountain big sagebrush	28b	11	94 (231)ab	10
Basin big sagebrush	11bc	10	54 (133)b	6
Juniper	6c	8	6 (16)b	5

[1] Values within a column followed by the same letter are not significantly different ($P \leq 0.05$) as determined by Duncan's Multiple Range Test.

[2] n is the sample size and varies within a season between resprouting and seedling density because seedling density could not be sampled on all sites.

many seedlings on spring burns than fall burns, although the difference was not significant (table 3). It seems that fire severity and environmental conditions after the burn may be more important in seedling establishment than the number of seeds present.

Changes in Density Following Fire

When considering the short-term effects of fire on bitterbrush populations, overall changes in density may be more important than either mortality or seedling establishment. Changes in density are presented by habitat group in table 5. The smallest decrease in average density occurred in the conifer habitat group. Although the mountain shrub group had the greatest average number of resprouts (table 4), the higher seedling establishment in the conifer group more than compensated for this difference. The conifer group with density increases on 4 of 14 sites was also the only group in which density increased after fire. One site had 57 percent more bitterbrush plants after a fire than before it was burned.

The greatest decrease in bitterbrush density following fire occurred in the juniper group, which has low resprouting combined with low seedling establishment. The average decrease in this group was 91 percent. This poor response makes the management of bitterbrush difficult in the juniper communities because bitterbrush is poorly adapted to fire. It is probably fire dependent, however, in many of the communities in the Northern Rocky Mountains. It has been our observation that without fire or some other disturbance that removes the juniper, bitterbrush will eventually be replaced by the developing juniper stand. Similar results have been reported by Young and Evans (1981) for California.

Table 5.--Change in density of bitterbrush following fire by habitat type group or community averaged across season and growth form in the Northern Rocky Mountains

Community habitat type group	Change in density[1]	Standard deviation	Range Minimum	Range Maximum
	percent			
Conifer	-11	±36.9	- 62	+57
Mountain shrub	-30	±28.2	- 87	0
Mountain big sagebrush	-55	±30.6	-100	0
Basin big sagebrush	-68	±10.4	- 79	-54
Juniper	-91	±11.2	-100	-73

[1] Density change includes resprouting and seedling establishment 3 to 10 years after fire occurred minus mortality.

MANAGEMENT IMPLICATIONS

It is a common belief among land managers that prescribed burning has no role in the management of bitterbrush. This conclusion is based on the premise that bitterbrush is fire sensitive and needs protection. This study and others have shown that although variation in response to fire occurs due to growth form, habitat type, season of the fire, and other factors, some bitterbrush mortality should be expected in almost all situations. Seedling establishment also varies, but seldom compensates for the mortality in those areas where bitterbrush is not well adapted to fire in the short term (less than 10 years). Many prescribed fires in communities where bitterbrush is a component of the vegetation are currently conducted for objectives other than bitterbrush management. These objectives include sagebrush (*Artemisia* spp.) control, increased herbaceous production, or slash disposal. In these instances, prescribed burns may be conducted in a manner that minimizes the loss of bitterbrush or may be canceled because the bitterbrush losses are judged to be unacceptable. This and other research enable the manager to predict the short-term effects of fire on bitterbrush. The question then remains as to what, if any, is the role of prescribed burning in bitterbrush management.

In the Northern Rocky Mountain area, bitterbrush occurs as a component of many forested and nonforested habitat types. It may be present at the seral or climax stage or throughout the entire successional sequence. Even in those communities where it is a part of the climax vegetation, it may act as a pioneer species. Given a seed source, it is often one of the first species to reoccupy a disturbed site such as a roadcut (Nord 1965). Bitterbrush has also been shown to increase after other disturbances such as logging (Stuth and Winward 1976; Edgerton 1983) and fire (Sherman and Chilcote 1972; Driver and others 1980; Martin 1983). Consequently, it is important to realize the successional status of bitterbrush within the particular community and that these communities are dynamic, not static, even at the climax stage.

Our study and others have shown wide differences in the response of bitterbrush to fire; these differences depend upon several variables. These findings demonstrate that it may be ecologically sound to use fire in bitterbrush management. The level of fire use, however, varies with the situation.

The role of prescribed burning in the management of bitterbrush within the mesic forested communities, such as Douglas-fir (*Pseudotsuga menziesii*), is that of maintaining a subclimax community type. Peek and others (1978) found that bitterbrush was declining in a seral ponderosa pine (*Pinus ponderosa*) stand that had been protected from grazing and fire. The site was a Douglas-fir/snowberry (*Symphoricarpos albus*) habitat type. They stated that if the vegetation proceeded to the climax composition, bitterbrush would disappear from the community. This decline is now occurring within many bitterbrush stands in the Northern Rocky Mountain region.

Our data support the use of prescribed fire to regenerate bitterbrush in seral ponderosa pine stands. There are opportunities to either underburn or selectively log and burn in conifer types for bitterbrush improvement. Application of spring or fall prescribed fire would allow a rather high rate of resprouting of bitterbrush which are primarily decumbent. Establishment of many bitterbrush seedlings can be expected. This conclusion is similar to that drawn by Driver (1983) for ponderosa pine.

Bitterbrush is a climax component of the ponderosa pine/bitterbrush habitat type. Even in these communities, productivity and density will decline without periodic disturbance. Initially, bitterbrush increased on these areas as a result of fire protection (Leopold 1950; Weaver 1957; Johnson and Smathers 1974). With continued protection, however, many populations have become decadent. Sherman and Chilcote (1972) found that bitterbrush declined in density from 25 to 100 years following a fire. It has also been shown that productivity of individual plants greater than 70 years old declines (McConnell and Smith 1977). Fire suppression may reduce reproduction by reducing the available microsites for rodents to cache seeds since they prefer microsites with thin layers of litter (Sherman and Chilcote 1972). The establishment of bitterbrush seedlings on undisturbed sites is probably also regulated by competition. Any factor reducing competition enhances seedling survival. Litter accumulation also changes soil characteristics (Zinke 1962) which may influence seedling establishment.

The response of bitterbrush within the western juniper and pinyon-juniper communities is much different than the response in the more mesic forest types. In these communities, bitterbrush usually develops the columnar growth form, which is least adapted to fire. Our data indicated the lowest resprouting potential and number of established seedlings of bitterbrush in the juniper communities of those habitat types studied. It may seem logical then to restrict the use of fire in these communities in order to maintain the stands of bitterbrush; however, unless fire is permitted periodically into these areas the juniper will increase in density and invade adjacent sagebrush/grassland vegetation (Burkhardt and Tisdale 1976). Increasing dominance of juniper in a community decreases the understory shrub and herbaceous species. Consequently, with continued protection from fire the bitterbrush in these communities will be replaced by other species. Young and Evans (1981) found vigorous bitterbrush only in open stands of juniper. They suggested that these were probably areas that had previously burned and were being reinvaded by juniper. In dense juniper stands, the bitterbrush was dead or had very low vigor. It appears that even though bitterbrush is not well adapted to fire in these communities, it depends upon fire to maintain a lower successional stage than climax juniper.

Periodic fire will be necessary to maintain bitterbrush in juniper communities. The fire-free interval will need to be sufficiently long to allow the bitterbrush to redevelop. If the interval is too long, the reinvading juniper will eliminate the bitterbrush seed source. The development of a new bitterbrush stand will require more time because the seeds will have to be transported onto the burn from other areas. Dense juniper stands do not readily burn due to the lack of fine fuels; however, when they do burn the fires are usually severe. High-severity fires will also reduce the number of surviving plants. This situation is becoming common in many juniper communities at this time.

The role of prescribed fire in the management of bitterbrush in nonforested habitat types is less clear than that in the forested communities. Since these types are not occupied by trees, the decline in bitterbrush density and vigor is not as readily apparent even after long periods of fire absence. There is some evidence, however, that fire or other disturbance may be necessary to establish new bitterbrush plants in these communities. McConnell and Smith (1977) found that the productivity of bitterbrush was correlated to age regardless of browsing intensity. Annual production increased to a maximum at 60 to 70 years of age and then declined. In Idaho, it was found that deer browsing was not a significant factor in vegetation change over a 23-year period. Bitterbrush annual production and density decreased while canopy coverage increased (Ferguson and Medin 1983).

Bitterbrush associated with mountain big sagebrush is usually well adapted to fire. The bitterbrush present usually are of the decumbent form or, rarely, subcolumnar. Resprouting frequency averaged 45 percent in the nonforested communities where mountain big sagebrush was present. Prescribed fire is frequently used in these communities for sagebrush control. Coverage of mountain big sagebrush is among the greatest found in *Artemisia* types and may exceed 40 percent. Fire is an effective means to stimulate production of these communities. Initially, the herbaceous component is enhanced. Nearly all shrubs, including bitterbrush and mountain big sagebrush, establish more rapidly from resprouts or seed than many other sagebrush communities. Consequently, the productivity of the shrub component is also enhanced in the long term by periodic fire in many situations. Spring fires give the best results in this vegetation, but spring prescribed burning may be limited in some areas due to the climate. Most shrubs, including bitterbrush, also respond well to low-severity fall prescribed fires, however.

Bitterbrush in the basin big sagebrush and "species X" (*Artemisia vaseyana* f. "*xericensis*") (Winward and Tisdale 1977) communities are more seriously damaged by fire than those associated with mountain big sagebrush. They are usually columnar or subcolumnar forms which resprout poorly and do not readily establish from seed. Many of these communities are also heavily invaded by cheatgrass. This has altered the plant competition relationships, particularly at the bitterbrush seedling stage.

Cheatgrass, an exotic, has also altered the fire relationships in these areas by changing fuel distribution and amount. Since the invasion of cheatgrass, fires in these communities are likely more continuous than previously. The fire-free interval of fires in cheatgrass dominated areas is shorter. Cheatgrass responds favorably to fire, and fuels can return to sufficient levels to carry another fire within 1 to 2 years.

The role of fire in these communities before settlement is not known. It has been suggested that because the recovery of bitterbrush may take 30 years, the fire frequency would have been about 50 years for bitterbrush to exist (Wright and Bailey 1982). It has also been suggested that the fire interval was short and that many of the shrubs were not present in the densities we observe today (Gruell in preparation). This may have been the case with bitterbrush in the "species X" communities, which are often productive sites on moderate to steep slopes. They burn frequently today as a result of lightning and human-caused fires. Even though cheatgrass has increased the fire potential, it is probable that frequent Indian- and lightning-caused fires held bitterbrush to low levels in this community in presettlement times.

The current fire frequency combined with the poor adaptation of bitterbrush to fire in "species X" communities makes continued maintenance of bitterbrush difficult without artificial planting as suggested by Ferguson and Medin (1983). Another possibility is the development of a more fire-adapted cultivar of bitterbrush or the introduction of a resprouting browse species into these areas.

We conclude that although bitterbrush density usually decreases initially following fire, the continued productivity and dominance in a community of bitterbrush is disturbance-dependent. In many instances, continued protection from fire will result in low rates of reproduction and declining productivity. Proper application of prescribed fire may be used to maintain vigorous bitterbrush stands on a long-term basis. As managers we must not be so concerned with short-term effects that we lose sight of the future needs of the species and those animals that are dependent upon it.

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